Dimension Stone Design Manual
2022

NATURAL STONE INSTITUTE

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www.naturalstoneinstitute.org

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For an online version of the Dimension Stone Design Manual 2022,
please go to www.naturalstoneinstitute.org
and select Resource Library under the Resources tab

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FOREWORD

How did man discover the beauty hidden in stone? The curiosity of an unknown genius may have been sparked by markings on exposed ledges. Smoothing the surface and cleaning the stone to get a closer look may have revealed color, veins, and graining. Rubbing the stone with sand may have polished it. To work with stone is to work with the basic rhythms of the Earth.

By the time the pyramids were built, man had become highly skilled in the use of stone to shape and place it according to his needs. Many of the stone works of ancient man have survived with little visible sign of change, except for earthquakes, wars, natural disasters, and more recently, the pollution of civilization.

The need for building materials in which beauty and permanence are prerequisites is greater today than ever before. To meet this increasing need, the dimension stone industry, through its international trade association, the Natural Stone Institute, provides products that satisfy contemporary design concepts while retaining all the outstanding qualities for which the industry has always been respected.

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NATURAL STONE INSTITUTE

ABOUT NATURAL STONE INSTITUTE

The Natural Stone Institute is a trade association representing every aspect of the natural stone industry. The current membership exceeds 2,000 members in over 50 countries. The association offers a wide array of technical and training resources, professional development opportunities, regulatory advocacy, and networking events. Two prominent publications—the *Dimension Stone Design Manual* and *Building Stone Magazine*—raise awareness within the natural stone industry and in the design community for best practices and uses of natural stone.

The association serves as the authoritative source for safety and technical standards and information regarding the use of natural stone. It operates an industry accreditation program and two prestigious awards programs, as well as a continuing education program for architects and designers.

The Natural Stone Institute was formed in 2018 as a merger of the Marble Institute of America and the Building Stone Institute. The Building Stone Institute was formed in 1894 as the International Cut Stone Contractors and Quarrymen's Association; the name was changed to the Building Stone Institute in 1955. Established in 1903 as the National Association of Marble Dealers, the Marble Institute of America officially formed in 1944, when the association merged with the National Association of Marble Producers. In 1962, the National Association of Marble Builders merged with MIA.

DIMENSION STONE DESIGN MANUAL

The purpose of the *Dimension Stone Design Manual* is to present reliable performance data and design information in one volume to facilitate use of dimension stone in architectural designs. The dimension stone industry provides quality products that meet the design and construction requirements of the buildings of today, as well as tomorrow.

The *Dimension Stone Design Manual* presents current practice in the industry. The information also represents industry recommendations and experience published in previous forms as the former *American Standard Specifications for Interior and Exterior Marble,* the *Marble Engineering Handbook*, and *Dimension Stone Design Manual I, I-R, II, III, IV, V, VI, VII* (these publications are out of print). Some detail plates from older MIA publications are reproduced because they still illustrate current practice.

ACKNOWLEDGEMENTS

The Natural Stone Institute was able to compile the information in this edition only with the willing cooperation and assistance of many Members, Committees of Members, editors, other individuals and organizations, and NSI staff. We are grateful for their combined commitment to NSI and the dimension stone industry.

LIMITATIONS ON USE AND DISCLAIMER

As with any building material and technique:

1. Many variations, including but not limited to design, climate, topography, building and zoning codes, materials, labor cost, and quality, markedly affect the safety, cost, utility, and appearance of the applications shown in this Manual. Accordingly, the variations contained in the Manual are not being recommended or endorsed by NSI.

2. Nothing in this Manual should be used without independent approval by a qualified architect, professional engineer, contractor, or other technically qualified person who should also specify dimension stone and installation methods and systems, with specific location of expansion and control joints on drawings, and use of standards, such as those of the American National Standards Institute (ANSI) and ASTM International, to develop specifications.

3. ACCORDINGLY, NATURAL STONE INSTITUTE DISCLAIMS ANY GUARANTEE OR WARRANTY, WHETHER EXPRESS OR IMPLIED, FOR MERCHANT-ABILITY, FITNESS FOR A PARTICULAR PURPOSE, OR ANY OTHER PURPOSE, OR FOR SAFETY FOR ANYTHING DESCRIBED OR ILLUSTRATED HEREIN, AND ASSUMES NO RESPONSIBILITY FOR ERRORS AND OMISSIONS.

4. References to ANSI or ASTM standards are merely suggested and are not mandatory and are NOT an NSI express or implied endorsement or warranty of the adequacy or completeness of those standards for safety or any other purpose.

This manual represents general practices found to be successful in natural stone applications. Regional practices may vary from those described in this manual. Given the variable involved in working with natural stone products, deviation from these practices does not necessarily result in failure, nor does adherence to these practices necessarily result in success. Thorough review of project details should be completed by a competent industry professional prior to construction. The methods prescribed herein do not supersede those in applicable construction specifications and building codes. No warranty or guarantee is made by NSI.

ORGANIZATION WEBSITES

American Concrete Institute (ACI)
www.concrete.org

American Geosciences Institute (AGI)
www.agi-usa.org

American Institute of Architects (AIA)
www.aia.org

American National Standards Institute (ANSI)
www.ansi.org

American Society of Civil Engineers (ASCE)
www.asce.org

American Institute of Steel Construction (AISC)
www.aisc.org

American Iron and Steel Institute (AISI)
www.steel.org

APA The Engineered Wood Association
www.apawood.org

Association of Marble Producers from Verona
www.asmave.it

ASTM International
www.astm.org

Construction Specifications Institute (CSI)
www.csinet.org

European Commission for Standardization (CEN)
www.cenorm.be

Indiana Limestone Institute of America, Inc. (ILI)
www.iliai.com

International Masonry Institute (IMI)
www.imiweb.org

Masonry Institute of America (MIA)
www.masonryinstitute.org

National Association of Architectural Metal Manufacturers (NAAMM)
www.naamm.org

National Building Granite Quarries Association, Inc. (NBGQA)
www.nbgqa.com

National Tile Contractors Association (NTCA)
www.tile-assn.com

Natural Stone Council
www.genuinestone.com

Natural Stone Institute
www.naturalstoneinstitute.org

NSF International
www.nsf.org

Precast/Prestressed Concrete Institute (PCI)
www.pci.org

The International Stone Event (StonExpo)
www.tisewest.com

Terrazzo Tile and Marble Association of Canada
www.ttmac.com

Tile Council of North America (TCNA)
www.tcnatile.com

United States Green Build Council (USGBC)
www.usgbc.org

GREEN BUILDING

Introduction - History of Green Building

History of Green Building – Historical Buildings

Green building is defined by the Office of the Federal Environmental Executive as "the practice of: 1) increasing the efficiency with which buildings and their sites use energy, water, and materials, and 2) reducing building impacts on human health and the environment, through better siting, design, construction, operation, maintenance, and removal throughout the complete life cycle."[1] While the green building movement has gained momentum in the last decade, the origin can be traced back to the late nineteenth century.

According to David Gissen, curator of architecture and design for the National Building Museum in Washington, DC, structures such as London's Crystal Palace and Milan's Galleria Vittorio Emanuele II used methods that decreased the impact of the structure on the environment. Systems such as roof ventilators and underground air-cooling chambers were used to regulate indoor air temperature.[2] In the early twentieth century, several skyscrapers, such as the Flatiron Building and the *New York Times* Building in New York, utilized deep-set windows and the Carson Pirie Scott department store in Chicago had retractable awnings. Both of these techniques were effective in controlling interior temperature while lessening the buildings' impact on the environment.[3]

From the 1930s through the 1960s, the forward-thinking cooling methods mentioned above gave way to some new building technologies that would change inner-city building construction dramatically. The invention of air conditioning, reflective glass, and structural steel popularized the enclosed glass and steel buildings that dominate the American city today. These buildings were able to be heated and cooled with massive HVAC systems that consumed huge amounts of cheap and readily available fossil fuels.[4] The massive consumption of energy required to inhabit these buildings made their viability tenable and entirely dependent upon energy availability and cost.

History of Green Building – The Infancy

Around the time that the "glass box" style high rise had become the icon of the American city (circa 1970), a forward-thinking group of architects, environmentalists, and ecologists[5] were inspired by the growing environmental movement and the higher fuel costs that were prevalent during the 1970s.[6] The genesis of these two scenarios ultimately resulted in the modern green building movement.

The first Earth Day, celebrated in April 1970, gave some credence to this new building concept, but the OPEC oil embargo of 1973 gave the burgeoning environmental movement, and subsequently the green building effort the kick start it needed. With gas lines stretching for blocks, some Americans began to question the conventional wisdom of being so reliant upon fossil fuels for our energy.[7]

As a result of the oil embargo, among other energy concerns, the American Institute of Architects (AIA) formed a Committee on Energy that was broken into two camps. "One group looked toward passive, such as reflective roofing materials and environmentally beneficial siting of buildings, to achieve energy savings, while the

[1] Office of the Federal Environmental Executive, "The Federal Commitment to Green Building: Experiences and Expectations," 18 September 2003.

[2] Building Design and Construction, "White Paper on Sustainability", page 4, November 2006

[3] Building Design and Construction, "White Paper on Sustainability", page 4, November 2006

[4] Building Design and Construction, "White Paper on Sustainability", page 4, November 2006

[5] Building Design and Construction, "White Paper on Sustainability", page 4, November 2006

[6] http://www.nyc.gov/html/nycwasteless/html/in_business/green_building.shtml

[7] Building Design and Construction, "White Paper on Sustainability", page 4, November 2006

other concentrated more on technological solutions, such as the use of triple-glazed windows."[8]

As energy concerns subsided, momentum for green building and the environment, in general, slowed down, but a dedicated core group of architects continued to push their green building concept forward. A couple of notable buildings constructed during the 1970s that utilized concepts of green design are: The Willis Faber and Dumas Headquarters in England, which utilized a grass roof, day-lighted atrium, and mirrored windows, and the Gregory Bateson Building in California, which used energy-sensitive photovoltaic (solar cells)[9], under-floor rock-store cooling systems, and area climate-control devices.[10]

Through the late 1970s, throughout the 1980s, and into the early 1990s, much research was commissioned on energy efficient processes. This research resulted in more effective solar panels, pre-fabricated efficient wall systems, water-reclamation systems, modular construction units, and direct usage of light through windows in order to decrease daytime energy consumption.[11]

History of Green Building – The Greening of the White House

When Bill Clinton was elected President in 1992, the green build/sustainability communities began to toss around the idea of "Greening the White House" as a way to put their ideas on the radar screens of everyday American society. Twenty-three years after the initial Earth Day, President Bill Clinton announced a plan to make the White House the "model for efficiency and waste reduction."[12]

The "Greening of the White House" program was designed to improve "energy efficiency and environmental performance of the White House complex by identifying opportunities to reduce waste, lower energy use, and make an appropriate use of renewable resources, all while improving the indoor air quality and building comfort."[13] In March 1996, it was reported that through the first two years of the "Greening" project, more than $150,000 per year in energy and water costs, landscaping expenses, and expenditures associated with solid waste were saved. Since 1996, $300,000 has been saved annually due to additional projects. In all, 845 metric tons per year of carbon emissions were eliminated during Clinton's presidency.[14]

Some of the methods utilized to "green" the White House were as follows:

1. Building Envelope – decreasing energy lost through the roof, windows, walls, etc.
2. Lighting – utilizing energy-saving light bulbs and maximizing use of natural light.
3. Plug Loads – Energy-saving office equipment was installed. Refrigerators and coolers were replaced with more energy-efficient models.
4. Waste – a comprehensive recycling program was initiated.
5. Vehicles – leased many vehicles that utilized cleaner-burning fuels.
6. Landscaping – reducing unnecessary water and pesticide usage.[15]

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[8] Building Design and Construction, "White Paper on Sustainability", page 4, November 2006
[9] "Photovoltaic Fundamentals", www.fsec.ucf.edu/pvt/pvbasics
[10] Building Design and Construction, "White Paper on Sustainability", page 4, November 2006
[11] Building Design and Construction, "White Paper on Sustainability", page 4, November 2006
[12] Building Design and Construction, "White Paper on Sustainability", page 5, November 2006
[13] "The Greening of the White House", http://clinton3.nara.gov/Initiatives/Climate/greeningsummary.html
[14] The Greening of the White House", http://clinton3.nara.gov/Initiatives/Climate/greeningsummary.html
[15] The Greening of the White House", http://clinton3.nara.gov/Initiatives/Climate/greeningsummary.html

History of Green Building – Where Are We Now?

With the overwhelming success of the "Greening of the White House", other government institutions have since been given a green makeover. The Pentagon, the Presidio, and the U.S. Department of Energy, among others, have gone green.[16]

The concepts of green building and, on a larger scale, sustainability are ideas that we hear all of the time. These two concepts, however, are rarely properly understood.

"Sustainability is a *systemic* concept, relating to the continuity of economic, social, institutional and environmental aspects of human society, as well as the non-human environment. It is intended to be a means of configuring civilization and human activity so that society, its members and its economies are able to meet their needs and express their greatest potential in the present, while preserving biodiversity and natural ecosystems, and planning and acting for the ability to maintain these ideals for a very long time. Sustainability affects every level of organization, from the local neighborhood to the entire planet".[17] In short, the concept of sustainability refers to thinking holistically about how everything you do affects everything around you. It is an attempt to minimize each person's impact on the world.

Today, green building is one of the fastest growing building and design concepts. Every month, new magazines are popping up that report on this growing trend. Architects, designers, and homeowners are becoming infatuated with the cost-saving possibilities, energy-saving emphasis, modern look, and the symbiotic relationship with nature that green buildings possess.

The United States Green Build Council (USGBC) is the foremost leader and educator within the world of green building today. They are the sanctioning body for Leadership in Energy and Environmental Design (LEED), the program with which points are awarded to various design applications within a building ultimately resulting in LEED certification for the building.

USGBC (The United States Green Build Council) & LEED (Leadership in Energy and Environmental Design)

USGBC

The USGBC was created to promote the design and construction of buildings that are environmentally responsible, profitable, and healthy places to live and work. They are focused on integrating building industry sectors and leading a market transformation towards greener construction. The organization consists of various trade associations, architects, designers, and individuals all interested in the greening of the construction business.[18]

Between 1990 and 1995, the USGBC worked feverishly with the American Society of Testing and Materials in order to create a rating system for sustainability. ASTM's rigorous consensus-based process moved much too slowly for the USGBC, and in 1995, it was determined that they would create their own rating system to exist under the USGBC banner. A committee was formed to study other green building programs currently in existence, and after three years, LEED 1.0 unveiled.[19] By 2003, LEED was refined to its current form that is the talk of the construction and design communities.

LEED

In short, LEED is a system for designing, constructing, and certifying green buildings. Buildings are classified as Certified, Silver, Gold, or Platinum, depending upon the number of

[16] Building Design and Construction, "White Paper on Sustainability", page 5, November 2006
[17] http://en.wikipedia.org/wiki/Sustainability

[18] "An Introduction to the USGBC and LEED Green Building Rating System", www.usgbc.org
[19] Building Design and Construction, "White Paper on Sustainability", page 7, November 2006

points they acquire within six building components[20]:

1. Sustainable Sites
2. Water Efficiency
3. Energy and Atmosphere
4. Materials and Resources
5. Indoor Environmental Quality
6. Innovation and Design Process

Within each of these categories, there are a specific number of credits available via many subcategories. LEED ratings are rapidly becoming boasting points for property owners, with property values of LEED-certified buildings skyrocketing.

LEED has been assisted in its success by the early adoption of many government agencies. Today, however, it is mostly a market-driven engine, with the number of LEED registered projects growing each year.

Characteristics of LEED Building

Site Design and Planning

- Site a building within proximity of commuter rail or bus lines to reduce pollution and any land-development impacts associated with increased automobile usage.
- Establish building specifications that maintain the current level of storm-water runoff or decrease the amount of imperviousness already existing on site.
- Develop a site with a minimum density of 60,000 square feet per acre. Channeling development to urban areas with existing infrastructure protects green spaces and preserves natural habitats and resources.

Material and Product Selection

- Use building materials and products that contain post-consumer recycled content.
- Support the regional economy by using materials and products manufactured regionally.
- Encourage environmentally responsible forestry through the use of wood or wood-based material that meets Forest Stewardship Council's Principles and Criteria for wood building components.
- Utilize rapidly renewable materials, such as bamboo flooring, wool carpets, strawboard, cotton ball insulation (made from denim scrap), genuine linoleum flooring, or poplar oriented-strand board (OSB). Using rapid renewables helps reduce the use and depletion of finite raw materials.

Construction and Demolition Waste Management

- Develop and implement a waste management plan that diverts a substantial amount of construction, demolition, and land-clearing debris from landfills to recycling or salvage facilities.
- Reuse a percentage of salvage or refurbished materials from construction, demolition, or land clearing as new building material. For more information on the benefits of salvaging materials from existing sites, go to www.deconstruction.com.

Energy and Atmosphere

- Generate building electricity on site from renewable resources like geothermal, solar, or biogas sources.
- Eliminate the use of chlorofluorocarbons (CFCs) in new heating, ventilation, air-conditioning, and refrigeration (HVAC & R) systems. Eliminating the use of CFCs reduces ozone depletion.
- Contract with a green power provider to purchase building electricity generated from renewable resources, such as solar, wind,

[20] Building Design and Construction, "White Paper on Sustainability", page 7, November 2006

geothermal, biomass, or low-impact hydro sources.

- Optimize energy performance.

Water Management

- Install water-efficient or low-flow equipment and appliances in kitchens and bathrooms to reduce water consumption.
- Use water-efficient irrigation, captured rain, or site-recycled water for onsite landscaping.
- Utilize innovative wastewater technologies, such as treating wastewater on site or significantly decreasing the amount of potable water used for sewage conveyance.

Indoor Environment

- Design the HVAC system and building envelope to provide for the optimal delivery and mixing of fresh air. Effective air exchange supports the safety, comfort, and well-being of building occupants.
- Reduce the number of indoor air contaminants by selecting paints and coatings, adhesives, carpets, and composite woods that emit low Volatile Organic Compounds (VOCs) or none at all. Examples of low-VOC emitting products are carpets made of wool, carpets made of recycled plastic bottles, and low-VOC paint.
- Establish segregated areas for chemical-using operations (such as copy/printing rooms and housekeeping); these areas should have separate outside exhaust and no air recirculation.
- Maximize day lighting and view opportunities. Day lighting and increased view opportunities can save energy costs and enhance worker productivity. [21]

Stone in Green Building

What is Stone's Current Perception?

With the growing influence of green building, it is imperative that the natural stone industry does everything it can to position its product as being green friendly. Despite what many of us in the industry may think (natural stone is about as green as something can get), that perception is at odds with the prevailing thought among the architecture and design communities. Many of these misconceptions arise from the inaccurate idea that mining natural stone is somehow on par with strip mining, an environmentally devastating practice.

One facet of LEED certification in which natural stone stands out is in product origin. A major tenet within the green community is that of supporting local products and business. LEED points are available for products whose origin or manufacturing is within 500 miles of the building site. Regionally manufactured and extracted materials reduce environmental impact by lowering emission of greenhouse gases during transportation while supporting local economies. Fortunately for the stone industry, there is a quarry site within 500 miles of nearly everywhere in the United States and Canada.

Future Areas of Emphasis

There are some areas where natural stone should be an obvious choice for green builders, but where further research is needed to prove the hypothesis:

- The enduring life cycle of natural stone makes it a great green build option. Because stone has proven that over the centuries it holds up to weathering and time better than any other building material, one would think that less energy would be consumed by the initial fabrication and installation than in manufacturing and replacing another product.
- The ease of care and maintenance involved with maintaining natural stone applications

[21] http://www.nyc.gov/html/nycwasteless/html/in_business/green_building.shtml

should be very attractive to those in the green community. Harsh chemicals are not needed to either clean or finish stone.

- The recyclability of natural stone is unequaled. Nearly 100% of stone from old projects and scrap stone are recyclable.

These components of natural stone use need to be studied and reported on adequately before the natural stone industry can go to the USGBC and request LEED certification points.

Quarrying

In the past 15 to 20 years, the business of quarrying has been vastly cleaned up from an environmental perspective. Domestic quarries today are required to comply with a strict code of practice and are monitored by OSHA, U.S. Department of the Interior, EPA, the Department of Resources and Economic Development, and the Mine Safety and Health Administration, among others. This message needs to be spread throughout the entire construction industry: Quarrying is not what it was 20 years ago, and certainly not what it was 50 or 100 years ago.

Quarry reclamation projects have added to the ability of quarries to limit their long-term impact on the environment. Today, many old quarries are being turned into golf courses, lakes, recreation areas, and state parks. A list of quarry reclamation projects appears at the end of this chapter as examples of how old quarry sites can be successfully utilized for the public good.

As technology moves forward, the greening of quarrying will continue and this will, in turn, continue to further enhance natural stone's position within the green community.

The Committee of Sustainability

In order to properly position natural stone, to research elements of building with natural stone that would qualify for LEED points, and to market the use of natural stone as a green product, the Natural Stone Council has commissioned a Committee on Sustainability. The NSC Committee on Sustainability (NSI is a member) will take the lead for the industry in ensuring that stone becomes a viable green building option. A couple of early initiatives for the committee are establishing a set of green best practices for quarrying and fabrication. The committee is also pursuing the commissioning of studies to research Life Cycle Assessment, Life Cycle Cost, Water Use Reduction, Construction Waste Management, and Material Reuse for the Natural Stone Industry. While the initiatives being undertaken by the Committee on Sustainability are aggressive, they are greatly needed in order to ensure that stone becomes a viable option for green building.

Additional GREEN References

Quarry Reclamation Site List

Quarry Park and Nature Preserve
County of Stearns, MN
https://co.stearns.mn.us/Recreation/CountyParks/QuarryParkandNaturePreserve

Halibut Point State Park
Gloucester, MA
https://www.mass.gov/locations/halibut-point-state-park

The Quarry Golf Club
San Antonio, TX
https://quarrygolf.com/home/historic-cementville/

Oak Quarry Golf Club
Riverside, CA
www.oakquarry.com/about

Crystal Springs Quarry Golf Club
Maryland Heights, MO
https://www.quarrygc.com/

Old Quarry Nature Center
Danbury, CT
https://www.danbury-ct.gov/government/departments/parks/

Quarry Lakes Regional Recreational Area
Fremont, CA
www.ebparks.org/parks/quarry.htm

Quarry Oaks Golf Club
Ashland, NE
www.quarryoaks.com/

Bomoseen State Park
Fair Haven, VT
www.vtstateparks.com/htm/bomoseen.cfm

Natural Bridge State Park
North Adams, MA
www.mass.gov/dcr/parks/western/nbdg.htm

Canoe Creek State Park
Hollidaysburg, PA
www.dcnr.state.pa.us/STATEPARKS/PARKS/canoecreek.aspx#history

Banning State Park
Sandstone, MN
www.dnr.state.mn.us/state_parks/banning/index.html

Sleeping Giant State Park
Hamden, CT
www.sgpa.org/

Knightdale Environmental Education Park
Knightdale, NC
www.hsmm.com/UPLOADS/BD/News/20050427_013046/Art_Knightdale_Lnd%20Wtr_10%2004%20(final).pdf

Emerald Lake State Park
East Dorset, VT
www.vtstateparks.com/htm/emerhist.cfm

Elephant Rocks State Park
Belleview, MO
www.mostateparks.com/elephantrock.htm

Suggested Contract Warranty Provision/ Disclaimer

The following warranty is provided as a guide only to Natural Stone Institute Members who desire to or are required to provide warranties in connection with contracts with their customers ("Owner"). However, the Member is cautioned that such language and the legal obligations arising therefrom *must* be reviewed and approved by the individual Member's legal counsel prior to usage on a case-by-case basis. NSI is not providing legal advice to Members, nor may a Member rely on these provisions as being in compliance with relevant federal, state or local statutes, ordinances or codes.

Warranty

1. [Name of Company] ("Company") warrants to the Owner on project in which Company installs dimension stone for one year from the date of the completion of installation, that the dimension stone shall be free from defects in material and workmanship IF, BUT ONLY IF:

    a) The dimension stone, its specifications, and installation are set forth in a written contract signed by Company and Owner;
    b) The Owner does not hinder Company from installing dimension stone and other materials and performing services in conformity with the contract; and
    c) Such dimension stone installation was not exposed to conditions more severe or otherwise exceeding those set forth in the contract specification.

2. Company's obligation under this warranty is limited to replacing or repairing, free of charge, F.O.B. point of fabrication, any defective dimensional stone, IF, BUT ONLY IF:

    a) Owner notifies Company by certified mail, return receipt requested, of such breach of warranty, within ninety (90) days after the discovery thereof, otherwise such claim is waived. (However, without limitation on the foregoing, any alleged defect discovered more than one year after installation is excluded from warranty.)
    b) No attempted alteration or repair of the dimension stone or its installation has been made without Company's written consent;
    c) The dimension stone is inspected by Owner or representative on arrival at the project site for visible defects, and complaints relating thereto are filed in writing immediately with Company before installation; and
    d) The dimension stone or installation thereof is not subjected to misuse, negligence, accident, or use contrary to Company's written instructions.

3. Company does not warranty dimension stone or its installation to any safety, building, or other code of any state, municipality or other jurisdiction unless the terms of such code are specifically incorporated into Company's written contract with Owner. Except for this warranty by Company, Owner assumes all risk and liability for the use of such dimension stone, whether alone or in combination with other building materials.

4. THIS WARRANTY IS EXPRESSLY IN LIEU OF ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. COMPANY SHALL NOT BE LIABLE UNDER THIS WARRANTY FOR ANY OTHER LOSS OR DAMAGE INCLUDING WITHOUT LIMITATION, CONSEQUENTIAL DAMAGE, SAFETY PROBLEMS, OR PERSONAL INJURY RESULTING DIRECTLY OR INDIRECTLY FROM THE PURCHASE, OTHER ACQUISITION, USE, OR LOSS OF THE DIMENSION STONE, EXCEPT AS EXPRESSLY SET FORTH HEREIN.

5. No statement by Company's employee or agent directly or indirectly admitting liability under this warranty shall be binding against Company unless: a) made in writing; b) made by a representative of Company authorized to do so.

SUGGESTED RESIDENTIAL CONTRACT (INSTALLATION OF DIMENSION STONE)

The following residential contract is provided as a guide only to Natural Stone Institute Members. However, the Member is cautioned that such language and the legal obligations arising therefrom *must* be reviewed and approved by the individual Member's legal counsel prior to usage on a case-by-case basis. NSI is not providing legal advice to Members, nor may a Member rely on these provisions as being in compliance with relevant federal, state or local statutes, ordinances, or codes (for example, Home Sales Solicitation Act in Ohio).

Residential Contract

This RESIDENTIAL CONTRACT to provide and install dimension stone, entered into between ______________________ ("Purchaser") residing at ______________________ ("Residence") and ______________________ ("Seller") with principal office at ________________, with effective date of the ___ day of _______, 20__.

1. **Services**. Subject to the terms and provisions herein, Seller agrees to provide to Purchaser the following services (check applicable boxes):
   - ☐ Fabricating and installing kitchen countertops
   - ☐ Supplying and installing stone paving
   - ☐ Supplying and installing stone bath work
   - ☐ Supplying and installing other stonework:

     ____

     (describe)
2. **Contract price**. The total contract price, as installed, is $____________________.

3. **Schedule of payments**. The contract price shall be paid as follows:
   - A. $______ on signing this contract.
   - B. $______ on completion of field measuring.
   - C. $______ on commencement of fabrication.
   - D. $______ on completion of fabrication.
   - E. $______ on completion of installation.
4. **Sample approval**. Fabrication of stone will not commence until the Purchaser has approved in writing below the stone samples or slabs to be furnished by the Seller. Seller shall not be bound by samples furnished by the Purchaser (from third parties) unless indicated below:
   - ☐ Samples provided by Seller, approved by Purchaser. ____ (Purchaser's Initials)
   - ☐ Seller acknowledges review of Purchaser's samples and acceptance. ____ (Seller's Initials)

5. **Commencement; Completion**. The work shall commence on or about __________ and will be completed on or about __________, provided, however, Seller shall not be responsible for delays in commencement or completion caused by events beyond the Seller's reasonable control.

6. **Ownership of work**. No legal interest in the stonework shall pass to Purchaser until full price has been paid, regardless of the location of the stonework, and whether it has been installed or not installed in the residence.

7. **Standards and Guidelines**. Installation of the stonework by the Seller shall be in strict accordance with the Natural Stone Institute's Dimension Stone Design Manual, as updated from time to time. No deviation from the standards, guidelines, or other work specifications set forth in said Manual shall be permitted.

8. **Assignment**. This agreement is personal to the parties and may not be assigned without the written consent of the non-assigned party.

PURCHASER: ________________________

Print Name: ________________________

Date Signed: ________________________

PURCHASER: ________________________

Print Name: ________________________

Date Signed: ________________________

SELLER: ________________________

Print Name: ________________________

Date Signed: ________________________

NSI CODE OF ETHICS

Members of the Natural Stone Institute, upon acceptance as Members in good standing, agree to abide by the following Code of Ethics:

Members of the Natural Stone Institute believe and affirm that:

The fabrication and installation of dimension-cut natural stone should meet NSI and other industry standards as articulated in the NSI *Dimension Stone Design Manual* and other technical publications, along with courteous and professional customer service. To achieve these goals, we pledge adherence to the following principles and policies:

- Our primary objective is a satisfied and happy customer, be it a homeowner, a building owner, or a design professional.
- We will maintain and conduct business in accordance with fair and honorable standards of competition.
- Honesty, integrity, quality, and professionalism guide our firm's business philosophy.
- High standards of health, safety, and product quality will be incorporated into every installation.
- We shall deal fairly with customers, as well as with our employees, our subcontractors, and our suppliers.
- We encourage research to develop new materials, techniques, tools, and equipment, as well as improved methods of stone fabrication and installation.
- We pledge to assist in the education and product knowledge of our firm's clients and customers (builders, kitchen and bath dealers, architects, designers, and homeowners) before, during, and after installation.
- We shall strive to promote a spirit of cooperation within the industry.

We assume these responsibilities freely and solemnly, mindful that they are continuing conditions to and part of our obligation as Members of the Natural Stone Institute.

NOTE: A copy of the NSI Code of Ethics is presented to each Member upon acceptance into membership. The document is suitable for framing and display in the Member's office or showroom.

NSI MEMBERSHIP

Membership in the Natural Stone Institute provides you with outstanding advocacy, networking, marketing & publicity, information & education, and professionalism and stone craftsmanship — benefits that continue to make NSI one of the fastest-growing trade associations in the world. Members are also encouraged to take advantage of a whole array of value-added services that can easily pay for your membership costs and add money to your bottom line.

With NSI and its member-friendly, cost-saving services you can save money on collections, credit card transactions, office supplies, lead referrals, shipping, and utility costs.

NSI Member Benefits Include:

NSI Freight Discount Program
Save money on your shipping costs by using the services of FedEx®, YRC, and UPS Freight.

NSI Credit Card Processing Program
NSI members in the U.S. receive tremendous savings on Visa, MasterCard, & debit card processing. Online account management, 24 hour a day customer service, plus exclusive discounts on point-of-sale solutions and additional products and services are all accessible with no monthly minimum fee.

Free Technical Guidance
NSI serves as the industry's leading clearinghouse of information about natural stone and can respond to technical and other questions from Members as well as those in the construction, architectural, and design communities. Consultation on specific questions is also available at no charge to Members from NSI's Technical Director.

NSI Bookstore Discounts
NSI Members save up to 50% on technical publications and consumer brochures.

Industry Promotion
NSI actively works to educate design professionals, homeowners, and others about the advantages of natural stone to increase demand within the commercial and consumer markets.

NSI Receivables Management Solutions
NSI Members can receive a variety of customized outsourcing services to meet their collection needs from VeriCore. Preferred rates are offered on all collection accounts, outsourcing, complimentary demand letters and many other services to help improve your bottom-line.

***The Cutting Edge* Newsletter**
This monthly newsletter provides valuable industry and association news, new member listings, member activity updates, and Technical Q&A column.

NSI Membership Directory
Print and online versions of the directory give you quick access to fellow producers/quarriers, fabricators, installers, distributors, and contractors with whom you can do business.

Discounted StonExpo Registration
NSI Regular Members receive reduced-rate admission to StonExpo, the premier trade show of the natural stone industry, held concurrently with the NSI Annual Meeting.

Office Supplies and Print Services Program
The NSI and OfficeMax introduce the new OfficeMax Partner Advantage℠ program. This members-only program will allow you to take advantage of special promotions and other one-of-a-kind benefits.

Internet Exposure
NSI operates a web site that can drive new business your way: www.naturalstoneinstitute.org is designed for natural stone professionals, architects and members of the design community. Direct links to your web site draw interested parties to your business.

And more! For a complete listing of NSI member benefits, go to www.naturalstoneinstitute.org or call the Membership Department at 440.250.9222.

NOTES:

NATURAL STONE INSTITUTE

SAMPLE SPECIFICATION LANGUAGE FOR DESIGN PROFESSIONALS

Natural Stone Institute

The Natural Stone Institute was formed in 2018 as a merger of the Marble Institute of America (MIA) and the Building Stone Institute. The Building Stone Institute was formed in 1894 as the International Cut Stone Contractors and Quarrymen's Association; the name was changed to the Building Stone Institute in 1955. Established in 1903 as the National Association of Marble Dealers, the Marble Institute of America officially formed in 1944, when the association merged with the National Association of Marble Producers. In 1962, the National Association of Marble Builders merged with MIA.

The Natural Stone Institute serves as the authoritative source of information on standards of natural stone workmanship and practice and the suitable application of dimension stone products. Membership in the association is worldwide and includes natural stone producers, exporters/importers, distributors/wholesalers, fabricators, finishers, installers, and industry suppliers – all committed to the highest standards of workmanship and ethics.

Sample specification language is provided for 1) The ***Dimension Stone Design Manual*** (DSDM); 2) Natural Stone Institute Accredited Contractors and Fabricators; and 3) Natural Stone Institute Member Companies.

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1) The ***Dimension Stone Design Manual*** (DSDM) is the stone industry's single-source reference for dimensional stone design and construction facts and details. Contents include sections on granite, marble, limestone, serpentine, soapstone, travertine, quartz-based stone and slate with product descriptions and technical data; general installation guidelines; guidelines and typical detailing for horizontal surfaces, vertical surfaces, wet areas, furniture and countertops; restoration and maintenance of exterior and interior stone installations; and a glossary of terms relating to dimension stone.

Sample Specification Language to Reference the Natural Stone Institute's DSDM
For [variety of] dimension stone, comply with recommendations in Natural Stone Institute's *Dimension Stone Design Manual* (DSDM) 2022.

2) **Natural Stone Institute Accreditation** for natural stone fabricators and commercial contractors recognizes those companies meeting the industry's highest standards for business activities, product knowledge, fabrication and installation. To earn Natural Stone Institute Accreditation, a company must complete an intensive, rigorous process that includes documentation of its business and employment practices, letters of recommendation, a written examination and site visits to the facility and completed jobs.

Sample Specification Language for Natural Stone Institute Accredited Natural Stone Fabricators:
Fabricator Qualifications: Preference shall be given to a Natural Stone Institute Accredited Natural Stone Fabricator. Natural Stone Institute Accredited Natural Stone Fabricators are those companies meeting the industry's highest standards for business activities, product knowledge, fabrication and installation. Bidding company must supply their official Natural Stone Institute Accreditation number as proof of accreditation.

Sample Specification Language for Natural Stone Institute Accredited Commercial Contractors:

Installer Qualifications: Preference shall be given to a Natural Stone Institute Accredited firm experienced in installing engineered dimension stone cladding systems. Company must be a Natural Stone Institute Accredited Commercial B Contractor (low rise) or a Natural Stone Institute Accredited Commercial A Contractor (high rise) of current good standing with the Natural Stone Institute. Bidding company must supply their official Natural Stone Institute Accreditation number as proof of accreditation.

Installer's responsibilities include sourcing of qualified fabricator of dimension stone cladding and providing professional engineering services per project requirements. Engineering Responsibility includes comprehensive design of stone attachment systems by an experienced, licensed professional in accordance with practices outlined by the Natural Stone Institute *Dimension Stone Design Manual* and compliant with applicable codes. Comprehensive shop drawings with attachment details shall accompany engineering analysis.

3) **Natural Stone Institute members** include marble, granite, limestone, sandstone and other natural stone producers and quarries, fabricators, installers, distributors and contractors around the world. Natural Stone Institute Members, upon acceptance as members in good standing, agree to abide by a Code of Ethics.

Sample Specification Language for Fabricator/Installer Qualifications (Residential or Commercial Projects)

Fabricator/Installer Qualifications: A Natural Stone Institute (Natural Stone Institute) member firm experienced in fabrication/installation of dimension stone as indicated for this project and whose work has a record of successful in-service performance.

For more information:

Natural Stone Institute
380 E. Lorain Street
Oberlin, OH 44074
USA
PH: 440-250-9222
FAX: 440-774-9222
www.naturalstoneinstitute.org

THE GEOLOGY OF STONE

1.0 INTRODUCTION

1.1 Earth is geologically classified as a "stony planet," as it is entirely stone (rock) of various mineral compositions and forms, excluding its water and atmosphere.

1.2 Earth scientists prefer the term "rock,"[1] while the commercial stone industry, prefers the term "stone".[2] Both words are correct in their respective frame of reference, and for practical purposes, interchangeable. Every type of rock or stone is composed of one or more minerals. For those who work with dimension stone, it is important to know these minerals—there are about 25 common minerals—that make up the bulk of all dimension stone commonly used. These 25 minerals are easy to learn to recognize, and this basic knowledge in turn helps to identify the many varieties of natural stone.

1.3 Identifying the minerals in a particular type of stone is important because the properties and behavior of stone are the sum total of the properties and behavior of the minerals found in the stone. Knowing something about the mode of formation or "genesis" of a stone further aids predicting the behavior of a stone. Thus, performance questions can be knowledgeably approached, such as how a particular stone might behave in a given application. Stone industry professionals need this information to reduce waste and avoid costly mistakes.

[1] *The Glossary of Geology,* 4th edition, 1997, Robert L. Bates and Julia A. Jackson, eds., American Geological Institute (AGI), defines rock as "a mixture of one or more minerals."

[2] *The Glossary of Geology* (ibid) defines *stone* as: "A general term for rock that is used in construction, either crushed for use as aggregate or cut into shaped blocks as dimension stone."

2.0 STONE CATEGORIES

2.1 Three general rock or stone categories are recognized according to their mode of origin. This is a genetic classification, and it not only states how and under what general conditions a stone was formed, but also implies a general compositional range. The basic stone groups are:

2.1.1 Igneous rock is formed by solidification (cooling) or, in some cases, by solid-state transformation[3] of molten or semi-molten material in the Earth's upper mantle or crust into crystalline rock generally consisting of silicates (compounds with SiO_4) and some dark-colored accessory minerals such as iron oxides or other iron- and magnesium-bearing silicate minerals. Example: granite.

2.1.2 Sedimentary rock can be:

2.1.2.1 Detrital sedimentary stone, which is the naturally cemented accumulation of solid granular materials or particles derived from both mechanical and chemical weathering of any existing rock. Examples include limestone, shale, sandstone, and conglomerate.

2.1.2.2 Chemical sedimentary stones, the precipitates of chemicals like salt that are the dissolved weathering products of any existing rocks. Chemical weathering yields some soluble salts, and examples of the resulting stones include onyx ($CaCO_3$), limestone ($CaCO_3$), dolomite ($CaMg(CO_3)_2$), alabaster ($CaSO_4$), some types of travertine ($CaCO_3 + SiO_2$) and common table salt (NaCl). Onyx is actually precipitated in caverns and travertine is a precipitate deposited

[3] A *solid-state transformation* is an atomic or molecular-level process by which a compound changes from one crystalline solid to another new crystalline solid–without going through an intervening liquid and/or gaseous state. This process occurs under conditions of very high pressure, temperature, and chemistry through time at depths in the crust of several to tens of kilometers.

around freshwater springs in shallow marine (salty) water. Alabaster is usually a slightly metamorphosed anhydrite or calcium sulfate.

2.1.2.3 Many other chemical precipitates are of no use as dimension stone due to solubility and softness, but may be much more valuable as chemical feedstock, table salt, or fertilizer.

2.1.3 Metamorphic[4] rock is formed from any pre-existing rock type in the Earth's crust under variable conditions of high pressures, high temperature, chemistry, and time. The process produces mechanically deformed stone and chemically alters the mineral assemblages of the parent stone. The new mineral suite may be a different or the same chemical composition as the parent, but as newly formed crystals. Examples of metamorphic stones include marble, slate, schist, and gneiss.

2.1.3.1 Earth scientists have assigned hundreds of names for rocks in each of the genetic groups, and for minerals or stones resulting from different processes of formation and slightly different chemical makeup. The many technical names are confusing; the few names given in this chapter will suffice for most commercial purposes. When legal questions arise, it may be appropriate to consult a professional earth scientist about stone types and nomenclature of a particular stone.

3.0 STONE FORMATION

3.1 Igneous Stone (Oceanic and Continental Stone). The Earth's crust is composed of two general types of stone: oceanic and continental. Each has distinct characteristics, mineral and chemical compositions, colors, specific gravities, and behaviors. Most, but not all, commercial stone is quarried from continental rock. Earth's **lithosphere**, or rocky crust, is the cool and rigid outermost rock layer, which varies from about 3 to 25 miles (5-40 km) thick.

3.2 The underlying mantle is about 1,800 miles (2,900 km) thick and can be is envisioned as two parts: a weak **upper mantle** of about 400 miles (640 km) of rock, mostly uniform in composition and capable of flow, i.e., not quite molten. Below it, the **lower mantle** is a denser, "mushy" or partially molten material somewhat different in composition from the upper mantle.

3.3 Deep in its center, Earth has a solid, iron-rich **inner core** about 760 miles (1,200 km) thick, and a molten metallic **outer core** about 1,420 miles (2,200 km) thick.[5] As the inner core is under tremendous pressure, it is hard to conceive what its "molten" physical state is really like.

3.4 Ocean basins cover approximately 70% of Earth's surface and are underlaid by oceanic-type crust, while a thicker continental-type crust, being lighter in weight, floats on older, denser, oceanic crust. Continents comprise the remaining 30% of Earth's surface.

3.5 The chart on the following page contrasts characteristics of the two major kinds of rock in the lithosphere (see next page):

[4] *Metamorphic* is a word derived from Greek that literally means *to change in form*.

[5] Since deep Earth materials cannot be physically examined, the above information is known through geophysical studies of earthquakes and vibrations from atomic bomb tests.

Oceanic Stone	**Continental Stone**
Dark in color	Light in color
Comp: High Iron (Fe), Magnesium (Mg), Calcium (Ca)	High silica (SiO_2, ≈70%), Potassium (K), Sodium (Na) and Aluminum (Al)
Low: SiO_2 (<50%), K, Na & Al	Low: Fe, Mg, Ca
Heavy: Specific gravity ≈2.9	Not heavy: Specific Gravity ≈2.6+
Melting temperatures: High (1000-1500° C.)	Low: ≈800°+ C.
Viscosity of Lava: Very runny – flows like water	Very stiff – like honey in winter
Kind of eruption: Quiet like Hawaii	Explosive like Mt. St. Helens
Scientific name of lava type: Basaltic	Granitic
Scientific code word: Mafic[6]	Felsic[7]

3.6 In each case, it is the elemental content of the major minerals that make the sharply different characteristics shown in the chart. The generalizations of composition in the chart hold for most cases. Although the differences in specific gravity or density of the two classifications of stone appear to vary little, that apparently small difference is enough for oceanic rock to float on denser layers underneath. Like blocks of wood in ponds, the world's continents are floating on heavier, darker crust below.

3.7 Nature, however, is by no means quite so accommodating as to always exactly fit this twofold classification. The compositional differences of these stone classifications represent the end members of a continuous element spectrum of high Fe, Mg, Ca and low Si, K, Na, etc., to low Fe, Mg, Ca and high Si, K and Na.

3.8 **Andesite**, named after the Andes Mountains of South America, is a lava stone with an intermediate composition at about the middle of the element spectrum. It is gray and has a medium specific gravity. Andesite flows well or poorly depending on its silica content, and may contain all of the following elements in its variable composition: Si, Fe, Mg, Na, Ca, K and Al. It is known simply as an "intermediate" or "Andean-type" stone.

3.9 **Plate Tectonics.** According to the theory of plate tectonics, the lithosphere of the Earth is divided into large crustal plates that have continuously separated or collided with each other over millions of years, always moving and forming new and destroying old crustal material in the process. Almost all of the ocean floor is basaltic or volcanic rock created by plate movement called "sea-floor spreading," initiated from mid-oceanic ridges. These linear ridges or rifts are the spreading centers between undersea crustal plates that allow molten rock to emerge from the mantle through volcanic action. Conversely, when plates collide, the far edge of one oceanic floor plate is thrust under the edge of the adjacent plate in a process called *subduction*. Subducted material is reincorporated into the Earth's upper mantle.

3.9.1 The life-span of oceanic floor is typically no more than 180 million years from formation at spreading centers to disappearance of subduction. This is a relatively short time compared with some continental stone that is 3.9 billion years old. Thus, the sea floor is similar to a conveyor belt moving from zero to 180 million years old, then disappearing. However, because of its comparatively young age, oceanic stone lacks the abundant variety of

[6] *Mafic* is a word made up from the first letters of its characterizing components. In this case, *ma-* from *ma*gnesium plus *–fic* from *f*err*ic,* which means "of iron content."

[7] *Felsic* is derived from *fel*dspar and *si*lica, from the high quartz content.

types, colors, and textures found in the much older continental stone.

3.9.2 The lower crust and upper mantle of Earth are composed of rocks remarkably similar in composition, closely related to basaltic lava: dark-colored, heavy, with silicate minerals having high amounts of Fe, Mg, and Ca-rich silicates and lesser amounts of silica in the form of quartz (SiO_2). The natural process of crustal formation through nearly 4.5 billion years has chemically differentiated these dark, heavy stones into the lighter-colored and lighter specific gravity stones of the continents.

3.9.3 Other stone formation processes that are a part of or affect plate tectonics include continental movement and collision, mountain formation, earthquakes, chemical weathering of stone, the freeze/thaw cycle, landslides, and climatic events, such as violent storms, torrential rain, and floods.

3.9.4 These and other natural processes continuously operate to form new stone and to chemically differentiate existing stone materials through time, yielding a spectrum of colors and unique designs in an abundance that satisfies an increasingly demanding market.

3.10 Igneous Stone. Igneous stone is cooled and solidified from material melted by heat from decay of radioactive minerals in the Earth's crust (lithosphere), and by frictional heat caused by crustal movements. The release of these powerful forms of thermal energy can produce explosive volcanism like the type seen in mountain ranges such as the Cascades in the northwestern United States. Mount St. Helens in Washington is an example of this geologic process.

3.10.1 Other volcanic areas known as "hot spots" are formed from molten rock emerging on the ocean's floor through stationary spots or plumes or vents in the underlying upper mantle and crust. The basaltic volcanic islands of Hawaii were born in this manner. Subsea volcanic activity is continually creating new oceanic floor and volcanic islands.

3.10.2 However, not all igneous stone is volcanic. All genuine granites[8] are solidified slowly from a melt miles deep in the crust, well encapsulated and thus well insulated by surrounding solid rock. This is significant to the quality of granite dimension stone because slow cooling yields the larger crystals that give many commercial granites their distinctive textural character and beauty.

3.11 Clastic Sedimentary Stone. The formation of clastic sedimentary stone is relatively uncomplicated compared to the complex chemistry and natural processes associated with either igneous or metamorphic stone.

3.12 Clasts are fragments or grains of any existing stone, produced by one or more processes, such as freezing and thawing, earthquakes, and other events of weathering, both mechanical and chemical. Clasts are also called "detritus;" thus, clastic sedimentary stone is sometimes referred to as detrital sedimentary stone.

3.13 Sizes of clasts range from boulders to cobbles, pebbles, sand grains, silt, and clay-sized particles. They are moved by gravity, wind, and water, and are further abraded or rounded and dissolved in the process, and sorted and carried vast distances. The rivers of the world are the prime movers of sediment while sorting them by size, weight, and shape, grinding or abrading the particles to very fine sand, silt, and finally, clay-sized grains carried in suspension to the oceans and deposited on continental margins. As deposits thicken, compaction occurs and the natural process of chemical cementation takes place through time to produce clastic sedimentary stone.

[8] Some types of stone defined by ASTM International as "granite" are not true, geological granites.

3.13.1 Chemical alteration is a continual process acting on stone, from the moment of solidification, exposure and weathering, to its transportation, deposition, compaction, burial, and cementation throughout the time that piece of stone exists. Chemical change during burial continues. Change continues after quarrying, fabrication, and installation on a structure, and faster if water is present. But if stone is kept dry, chemical action slows up to a minimal level.

3.14 Clast Sizes. Clasts are graded according to size, and the resulting stone after compaction and cementation is classified as follows:

3.14.1 Particle Name[9]: **Boulders**
Size Range: >256 mm
Rock Name: Boulder Conglomerate
Stone Abbreviation: Cgl.

3.14.2 Particle Name: **Cobbles**
Size Range: 64 to 256 mm
Rock Name: Cobble Conglomerate
Stone Abbreviation: Cgl.

3.14.3 Particle Name: **Pebble**
Size Range: 2 to 64 mm
Rock Name: Pebble Conglomerate
Stone Abbreviation: Cgl.

3.14.4 Particle Name: **Sand**
Size Range: 1/16 to 2 mm
Rock Name: Sandstone[10]
Stone Abbreviation: Sst.

3.14.5 Particle Name: **Silt**
Size Range: 1/256 to 1/16 mm
Rock Name: Siltstone
Stone Abbreviation: Sltst.

3.14.6 Particle Name: **Clay**
Size Range: <1/256 mm
Rock Name: Mudstone and Shale
Stone Abbreviation: Sh.

3.15 Sandstones and Conglomerates. Sedimentary stones most important to the dimension stone industry are sandstones and some of the smaller-grained conglomerates. Siltstone, shale, and the very large-grained conglomerates are of less commercial importance except for landscaping and occasional artistic constructions. Siltstone, where well-cemented and readily available, was utilized as a fieldstone for buildings or other structural work in earlier centuries.

3.16 Sand Grain Composition. Sand grains are graded very fine, fine, medium, coarse, and very coarse. They may be further characterized as well-rounded, almost spherical, to very angular. Angular grains tend to interlock well, and when cemented, are desirable in sandstone, just as angular sand is desirable for the same reason in masonry. Sandstones buried over tens to thousands of feet become compacted, and the flow, often miniscule, of chemical-charged aqueous fluids proceed to cement the grains with one or more of cementing minerals. Chemical activity does not cease, but continues to cement or de-cement the stone, or change the stone by introduction and sometimes substitution of one mineral for another of both grains and cement.

3.17 Cementing Minerals. The common cementing minerals of clastic sedimentary stone in order of hardness and desirability are the following:

3.17.1 Silica: Either hydrous or crystalline, both types are hard and relatively insoluble.

[9] Particle names are simply names for a defined grain size. They do not suggest the mineralogical content unless a mineral name precedes the particle name as a modifier.

[10] Although sand-sized grains can be from any rock fragment and one or more of several minerals, sandstone is generally regarded as "quartz" sandstone. Quartz is among the longest-lasting minerals in the environment, resisting chemical degradation and abrasion.

3.17.2 Carbonate: Even though calcite is soluble in dilute acids like rain, it is a good cement, and much clastic sedimentary stone is cemented with calcite and/or a mixture of calcite and silica cements. Other carbonates may be less soluble, but these are rare as cements.

3.17.3 Iron Oxides: These are fairly common as clastic cements, but tend to be softer and bleed ugly stain. Although some excellent sandstones are red to red-brown from some iron cement and stained quartz grains, the better brownstones may have silica cements, making them truly excellent, highly colored stones.

3.17.4 Clay Minerals: These are generally considered a rather poor cementing medium. Even though clay cemented stone may appear well-cemented, the clay cement is soft, weak, easily crushed, and readily removed by water.

3.17.5 Other mineral cements may be found from time to time, but are rare.

3.17.6 All of the cementing minerals mentioned in this section, plus some other rare mineral cements, can combine in various mixtures that will bond stone satisfactorily.

3.18 Chemical Sedimentary Stone. This class of sedimentary stone precipitates from chemically dense bodies of water such as the Great Salt Lake, the Dead Sea, and other closed marine basins lacking outlets. Salt-laden water flows in and evaporation constantly increases the salt content until precipitation takes place. Common building stones that are chemical precipitates include travertines ($CaCO_3$), onyx ($CaCO_3$), alabaster ($CaSO_4$), and cherts such as flint, jasper, and agate. Chert is a sedimentary deposit of hydrous silica ($SiO_2 \cdot nH_2O$). The popular dimension stones **travertine** and **onyx** are chemical precipitates of mostly limestone or calcium carbonate ($CaCO_3$) deposited around ground springs, in caves, or springs in bodies of saline water, although some travertine is actually fossiliferous limestone, which is not strictly a chemical sedimentary stone (see the Travertine chapter).

3.18.1 Salt, anhydrite, and gypsum form in other marine settings such as the Red Sea, which has very wide tidal flats in a hot climate that promotes evaporation and precipitation. Even the Mediterranean Sea was a closed basin millions of years ago in which thick evaporates formed similar to those now found in the Dead Sea.

3.19 Metamorphic Stone. Many of the most colorful, highly figured, and beautiful dimension stones are the result of metamorphic processes. The popularity of these spectacular stones has encouraged the exploration for the new types of stone that frequently appear in the market. Metamorphic processes are capable of producing stone in a color palette and textural complexity that rivals that of igneous and sedimentary processes.

3.19.1 Metamorphic stone makes up a large part of all continents, is exposed on all continents, and is found deep beneath the relatively flat areas of continents thickly covered by sedimentary rocks, such as the U.S. Midwest. It makes up the core areas of continents. For example, the ancient, complex metamorphics of the Canadian Shield in northern Canada comprise the core of the North American continent. The root areas of many mountain chains such as the Himalayas, Rockies, and Urals are the same type of strongly metamorphosed rock that underlies the central Midwest from Ohio to Illinois.

3.19.2 Metamorphic stones are among the most interesting of Earth's products, for they are the only direct evidence of major catastrophic events in the history of the Earth's crust. Some of this stone is up to 3.8 billion years old, and has changed in its long existence from igneous to sedimentary to metamorphic.

3.19.3 Any deeply buried, existing stone–igneous, sedimentary or metamorphic–may be subjected to forces that cause profound mechanical, textural, and ultimately, chemical changes in the mineral content. Metamorphosed stone may or may not resemble its parent stone. Metamorphism is caused by regional-scale crustal movements and mountain-building forces, or by local crustal disturbance, at temperatures about 200ºC to near-melting, ≈700-800ºC, and pressures from around 450,000 pounds per square inch (psi) to several million psi in the presence of chemically charged aqueous fluids through time.

3.19.4 Metamorphic rock produced from widely variable conditions yields three distinct grades of metamorphism, from low-grade through medium- to high-grade metamorphic rock, each characterized by specific stone colors, textures, and mineral content. Stone of all metamorphic grades can be found as beautiful dimension stone of many types, including slate, quartzite, marble, and serpentine.

4.0 THE ROCK CYCLE

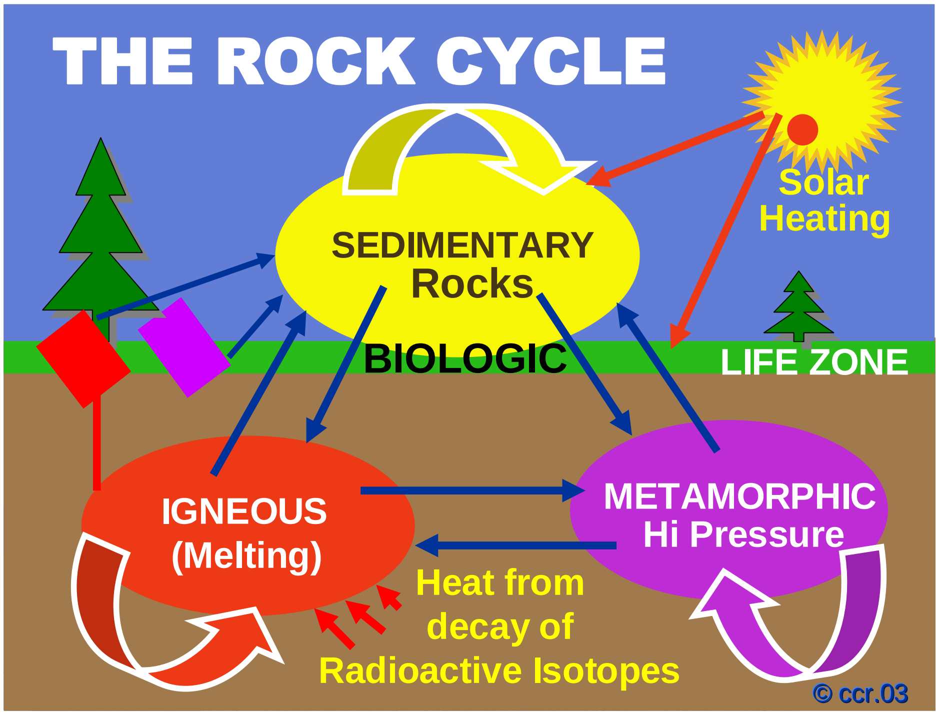
4.1 Basic processes and relationships inherent in the geological concept known as "the rock cycle" help to understand the variety and complexity of stone.

4.2 As shown in the rock cycle illustration on the following page, the curved arrows at each stone type indicate that a new igneous, metamorphic, or sedimentary stone can be developed from an existing stone by a repetition of melting and metamorphism, or by the weathering, transportation, deposition, compaction, and cementation processes.

4.3 The straight arrows from one stone type to another show that any of the three basic types of stone can be produced from an existing stone of one of the other types.

4.4 Two great energy sources drive the rock cycle: the sun, and the heat from the Earth's interior generated from the decay of radioactive materials. The sun heats the Earth's gaseous atmosphere, driving the weather patterns that cause weathering and erosion of any exposed or nearly exposed rock —the beginning of the sedimentary cycle. Biological activity on the Earth's surface, and to some depth beneath it, also interacts with the chemical processes affecting stone.

4.5 The rock cycle has been going on continuously for much of the Earth's 4.5 billion years. Some zircon grains (zirconium silicate, $ZrSiO_4$) from an Australian sandstone have been through the rock cycle five times, covering more than 3.9 billion years. Continuous cycling through the multiple processes, mechanical and chemical, serves to chemically and mineralogically differentiate stone; thus, the rock cycle allows continental stone to develop into the wide range of colors and varieties of beautiful dimension stone that have been used by mankind throughout history.



The geological concept of the rock cycle illustrates that new igneous, metamorphic, or sedimentary stone can form from existing stone of another type through the repetition of natural processes.

NOTES:

Each Material chapter has a section that further details geological information about that specific stone.

STANDARDS AND SPECIFICATIONS FOR STONE PRODUCTS

1.0 ORGANIZATIONS

1.1 ASTM International

100 Barr Harbor Drive
West Conshohocken, PA 19428-2959 U.S.A.
Telephone: 610.832.9585
Fax: 610.832.9555
www.astm.org
European Office:
Telephone: 146.243.7933
Fax: 146.243.3678

1.2 American National Standards Institute (ANSI)

25 West 43rd Street, 4th Floor
New York, NY 10036 U.S.A.
Telephone: 212.642.4900
Fax: 212.398.0023
www.ansi.org

1.3 NSF International

P.O. Box 130140
789 N. Dixboro Road
Ann Arbor, MI 48113-0140 U.S.A.
Telephone: 734.769.8010
Fax: 734.769.0109
www.nsf.org
European Office:
Kleine Kloosterstraat 6
1932 Zaventem
Belgium
Telephone: 32.2.771.36.54
Fax: 32.2.763.00.13

1.4 European Commission for Standardization (CEN)

36 rue de Stassart
B-1050 Brussels
Belgium
Telephone: 32.2.550.08.11
Fax: 32.2.550.08.19
www.cenorm.be

2.0 WHY ASTM STANDARDS AND OTHER LIKE STANDARDS ARE IMPORTANT

2.1 In today's building environment, the emphasis is on safe, permanent, low maintenance products, of which stone leads the list in the minds of architects, designers, and consumers worldwide.

2.2 Without a consistent, realistic set of standards and testing procedures for stone products, the stone industry as a whole would be in disarray. The standards that have been developed and set in place for these products are important tools to help protect end users, individual companies, and the industry from negative effects related to product failures. Materials standards help to prevent the use of stone products for unsuitable applications. For instance, without the minimum standards for Abrasion Resistance of Stone Subjected to Foot Traffic (ASTM C241), it would be more likely that very soft, easily damaged materials would be installed in commercial applications. This may cause the owner to incur additional cost for repair and maintenance, and negatively affect the reputation of the stone industry as a whole.

2.3 These standards also serve as benchmarks for quality limits of products. If a stone with a below-minimum flexural strength is used for a lintel, then it may be more likely to fail, thus causing damage and possible injury. Interior or exterior flooring or paving with an inadequate slip resistance level will more likely cause slipping accidents in public or private projects.

3.0 HOW AND WHEN THESE STANDARDS APPLY

3.1 As stone industry professionals, it is our task to apply the correct standards to materials at appropriate times in order to keep the stone industry strong and to remain a reliable source of quality products.

3.2 Most architectural specifications require that stone meet certain specified ASTM or other testing standards before it will be accepted for use. Some products on the market today have not been tested for quality standards that are required for certain projects. The required testing should be reviewed and, if test results are not available for the stone product, then testing should be performed by the quarry or representative company as required. Some quarries and their representatives do not embrace this idea because their products can be marketed to homeowners and residential projects without the need to perform testing. It is up to our industry to know how to identify these products and make sure to request the required material data needed.

3.3 Testing of stone can be performed by other companies in the event that required test data are not available. Independent labs can perform the appropriate tests and provide the information in a well organized, professional report.

3.4 It is important to know when a certain test is not required for a product. For example, a test for Slip Resistance would not be necessary for stone used in a vertical application, which will never receive foot traffic. Some examples are not as easily established. For instance, what are the needs for testing a stone to be used for interior flooring in a commercial application where the stone is installed over a raised floor deck subject to deflection, and will be subject to traffic from pedestrians and cleaning carts weighing 1,000 pounds? It may be required that the stone of choice meets standards related to Slip Resistance, Abrasion Resistance, Absorption, Compressive Strength, and Bending Strength. These are all physical requirements of the stone product during everyday use.

3.5 Be aware of the requirements of performance that will be placed on the stone at the time of installation, and in the future. If a stone has proven not to perform for a particular use, then avoid marketing it for that use. If testing is not available, require that it be done or avoid the product's use.

4.0 ASTM INTERNATIONAL

4.1 The American Society for Testing and Materials International (ASTM), founded in 1898, is a not-for-profit organization that provides a global forum for the development and publication of voluntary consensus standards for materials, products, systems, and services. Over 30,000 individuals from 100 nations are the members of ASTM International, who are producers, users, consumers, and general interest parties such as government representatives and academicians.

4.2 Committees are established that focus on and have jurisdiction over standards for different designations, such as Dimension Stone (Committee C18) or Cement (Committee C01). These committees are made up of several subcommittees which are tasked to develop and discuss individual segments within the committee's jurisdiction. For example, one subcommittee may deal with the development of standards dealing with Test Methods of Dimension Stone, and another with Anchorage Components and Systems for Natural Stone. These committees meet on a regular basis to discuss and present information for each new or existing standard.

4.3 The entire membership of ASTM International votes on whether a standard is suitably developed and researched before it is forwarded for final approval. Negative votes cast during the balloting process are fully resolved before forwarding.

4.4 Companies, agencies, and individuals use ASTM standards. Buyers and sellers of materials, products, and services include these standards in contracts; engineers, scientists, architects, and designers use them in their work; government agencies reference them in codes and regulations; and many others refer to them for performance information.

4.5 ASTM International is recognized globally and continues to review and develop new standards needed in a wide range of materials.

5.0 ANSI

5.1 The American National Standards Institute (ANSI), founded in 1918 by five engineering societies and three government agencies, is a private, not-for-profit organization that administers and coordinates U.S. voluntary standards and conformity assessment activities. The Institute represents the interests of its nearly 1,000 company, organization, government agency, institutional, and international members through its office in New York City and its headquarters in Washington, D.C.

5.2 ANSI currently provides a forum for over 270 ANSI-accredited standards developers representing approximately 200 distinct organizations in the private and public sectors. These groups work cooperatively to develop voluntary national consensus standards and American National Standards (ANS).

5.3 The ANSI standardization process provides and promotes standards that withstand scrutiny, yet protect the rights and interests of all participants. This process helps quicken the market acceptance of products, while advising how to improve the safety of those products to protect consumers.

5.4 U.S. standards are promoted internationally by ANSI. The organization also advocates U.S. policy and technical positions in international and regional standards organizations, as well as supporting the acceptance of international standards as U.S. standards where they meet the needs of the user community.

5.5 The Institute is active internationally with the International Organization for Standardization (ISO), and, via the U.S. National Committee (USNC), the International Electrotechnical Commission (IEC). In many instances, U.S. standards are taken forward to ISO and IEC through ANSI or the USNC, where they are adopted in whole or in part as international standards.

6.0 NSF INTERNATIONAL

6.1 NSF International, formerly the National Sanitation Foundation, is a not-for-profit, non-governmental organization that provides standards, certification, education, and risk management services in the fields of public health safety and the environment. NSF was founded in 1944 in response to a need for a single set of food equipment sanitation standards that manufacturers and operators could accept and regulators could adopt into code. NSF has 21 standards for all types of products and materials used in food service. The standards contain requirements for materials, design, construction, and performance of food service equipment to ensure that it is safe and can be kept sanitary. Today, NSF Food Equipment Standards are globally recognized, and certification to the standards is required by regulators, specified by end users, and marketed by manufacturers.

6.2 NSF Material Requirements – Standard 51. An important component of the NSF Food Equipment Standards is the material requirements. While each standard can have its own unique material requirements, all food equipment standards reference NSF/ANSI Standard 51-2002, Food Equipment Materials. The material require-ments help to ensure that only nontoxic and cleanable materials are used. Material suppliers have utilized NSF Certification to Standard 51 as an effective method for marketing their products to food equipment manufacturers. Manufacturers who purchase NSF-certified materials have one less item of concern when getting their own equipment certified.

6.3 Applying Standard 51 to Natural Stone. When reviewing granite, marble, and other natural stones to the requirements of Standard 51, there are essentially two issues that can determine its acceptance: smoothness and toxicity.

6.4 Smoothness. The standard defines "smooth" as free of surface imperfections that are detectable by visual or tactile inspection. This includes pits, cracks, and crevices. This concern for smooth surfaces applies not only to the natural surface, but also the treatments used to make a surface smooth. Application of a coating is sometimes considered a way of addressing smoothness; however, coatings have a tendency to chip or flake over time, thus creating their own difficult-to-clean surface. As a result, there is a prohibition on the use of coatings for surfaces subjected to cutting and chopping actions, such as countertops and cutting boards. It is important to note that this prohibition would not necessarily apply to all surface treatments the natural stone industry might use. Sealers that are buffed off to the point where they only remain to fill surface imperfections are not considered a "coating" for the purposes of NSF standards, and could potentially be used on countertops and cutting boards.

6.5 Toxicity. Standard 51 requires that materials meet FDA regulations for their intended end use, as specified in the Code of Federal Regulations, Title 21 (21 CFR). Applying Standard 51 toxicity requirements to the stone is fairly easy. Because natural stone does not fall under the scope of 21 CFR, we simply conduct extraction testing to verify that the material does not contain any regulated heavy metals. When sealers are used, NSF must have verification from the sealant manufacturer that it meets 21 CFR. An alternative is that the sealant manufacturer can obtain an NSF certification.

Copies of each standard can be obtained online or by fax from the source.

7.0 ASTM SPECIFICATIONS AND STANDARDS

7.1 Material Specifications

7.1.1 ASTM C503, Standard Specification for Marble Dimension Stone

7.1.2 ASTM C568, Standard Specification for Limestone Dimension Stone

7.1.3 ASTM C615, Standard Specification for Granite Dimension Stone

7.1.4 ASTM C616, Standard Specification for Quartz-Based Dimension Stone

7.1.5 ASTM C629, Standard Specification for Slate Dimension Stone

7.1.6 ASTM C1526, Standard Specification for Serpentine Dimension Stone

7.1.7 ASTM C1527, Standard Specification for Travertine Dimension Stone

7.2 Test Standards

7.2.1 ASTM C97, Standard Test Method for Absorption and Bulk Specific Gravity of Dimension Stone

7.2.2 ASTM C99, Standard Test Method for Modulus of Rupture of Dimension Stone

7.2.3 ASTM C120, Standard Test Method of Flexure Testing of Slate (Modulus of Rupture, Modulus of Elasticity)

7.2.4 ASTM C121, Standard Test Method for Water Absorption of Slate

7.2.5 ASTM C170, Standard Test Method for Compressive Strength of Dimension Stone

7.2.6 ASTM C217, Standard Test Method for Weather Resistance of Slate

7.2.7 ASTM C241, Standard Test Method for Abrasion Resistance of Stone Subjected to Foot Traffic

7.2.8 ASTM C880, Standard Test Method for Flexural Strength of Dimension Stone

7.2.9 ASTM C1201, Standard Test Method for Structural Performance of Exterior Dimension Stone Cladding Systems by Uniform Static Air Pressure Difference

7.2.10 ASTM C1352, Standard Test Method for Flexural Modulus of Elasticity of Dimension Stone

7.2.11 ASTM C1353, Standard Test Method for Abrasion Resistance of Dimension Stone Subjected to Foot Traffic Using a Rotary Platform Abraser

7.2.12 ASTM C1354, Standard Test Method for Strength of Individual Stone Anchorages in Dimension Stone

7.3 Other Application Standards

7.3.1 ASTM Manual Series: MNL 21. Modern Stone Cladding: Design and Installation of Exterior Dimension Stone Systems. 1995.

7.3.2 ASTM A666, Standard Specification for Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar

7.3.3 ASTM B221, Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes

7.3.4 ASTM C36/C36M, Standard Specification for Gypsum Wallboard (Withdrawn 2005). Replaced by C1396/C1396M.

7.3.5 ASTM C91, Standard Specification for Masonry Cement

7.3.6 ASTM C119, Standard Terminology Relating to Dimension Stone

7.3.7 ASTM C144, Standard Specification for Aggregate for Masonry Mortar

7.3.8 ASTM C150, Standard Specification for Portland Cement

7.3.9 ASTM C207, Standard Specification for Hydrated Lime for Masonry Purposes

7.3.10 ASTM C270, Standard Specification for Mortar for Unit Masonry

7.3.11 ASTM C482, Standard Test Method for Bond Strength of Ceramic Tile to Portland Cement Paste

7.3.12 ASTM C630/C630M, Standard Specification for Water-Resistant Gypsum Backer Board (Withdrawn 2005). Replaced by C1396/C1396M.

7.3.13 ASTM C920, Standard Specification for Elastomeric Joint Sealants

7.3.14 ASTM C1242, Standard Guide for Selection, Design, and Installation of Exterior Dimension Stone Anchors and Anchoring Systems

7.3.15 ASTM C1515, Standard Guide for Cleaning of Exterior Dimension Stone, Vertical and Horizontal Surfaces, New or Existing

7.3.16 ASTM C1528, Standard Guide for Selection of Dimension Stone for Exterior Use

7.3.17 ASTM C1721, Standard Guide for Petrographic Examination of Dimension Stone

7.3.18 ASTM C1722, Standard Guide for Repair and Restoration of Dimension Stone

7.3.19 ASTM E72, Standard Test Methods of Conducting Strength Test of Panels for Building Construction

7.3.20 ASTM E119, Standard Test Methods for Fire Test for Building Construction

7.3.21 ASTM E575, Standard Practice for Reporting Data from Structural Tests of Building Constructions, Elements, Connections, and Assemblies

7.4 ANSI Specifications and Standards

7.4.1 ANSI A10.20, Safety Requirements for Ceramic Tile, Terrazzo and Marble Work

7.4.2 ANSI A108, Standards for Installation of Ceramic Tile

7.4.3 ANSI A118, Specifications for Mortars and Grouts

7.4.4 ANSI A326.3, Method for Measuring Dynamic Coefficient of Friction of Hard Surface Flooring Materials.

7.5 NSF/ANSI Specifications and Standards

7.5.1 NSF/ANSI Standard 51, Food Equipment Materials

7.6 CEN Specifications and Standards

7.6.1 CEN specifications and standards are in the process of being compiled. This information will be available at a later date.
All standards and specifications are revised or updated periodically. The current status of any standard or specification can be confirmed by contacting the proper authority.

DIMENSION STONE SELECTION

1.0 INTRODUCTION

1.1 Stone Selection Options. Architects and builders throughout the ages have chosen stone for its permanence and beauty. Where selection was once limited mainly to what was locally available, today's stone marketplace is virtually worldwide. With the broad and growing array of options, the stone selection process has become more complex under the weight of multiple considerations.

1.2 Stone Is A Product Of Nature. Dimension stone has its own unique qualities that not only distinguish it from man-made materials, but also should be considered in selecting it for a particular project. Stone is not manufactured; it is a product of nature. Blocks are removed from the quarry, slabs are cut from these blocks, and the slabs are further fabricated into the final stone to be installed. Each block is different; each slab is different. Skillful blending or matching of the dimension stone blocks, veneer panels, tops, etc., results in a beautiful blending of nature's variety and man's design. In contrast to the uniformity of materials produced by machine or assembly line, dimension stone's naturally varied appearance has wonderful character. "Uniformity of material," when applied to natural stone, is a term of relative value that needs to be understood when making a selection.

1.3 Exterior vs. Interior Installations. The factors to be weighed in selection may not be equally applicable to exterior and interior installations. The following discussion is therefore divided, as appropriate, between exterior and interior uses if the factors do not readily apply to both.

1.4 Selection Influencers. While any number of stipulations may direct selection of a particular stone for a specific application, there are several significant influencing factors. Among them are aesthetics, color, strength, durability, design, texture, finish, size, thickness, availability, stone testing, stone sampling, and cost. The effects any of these factors may have on another can influence the final choice. But aesthetic considerations nearly always drive the selection process.

2.0 AESTHETICS & APPEARANCE

2.1 Factors beyond Appearance. A palette of colors and a variety of textures provide ready options in the aesthetic choices among dimension stones. Yet, as the following pages suggest, it is advisable to examine and apply other factors that may recommend alternatives to a selection based purely upon aesthetic appeal, particularly on exterior applications. A stone that is most desirable in appearance, for example, may lack needed strength or durability for a particular application.

2.2 Exterior Cautions. The cautions regarding exterior applications are of far less concern when considering interior installations. Aesthetics can be allowed much freer rein for stone that is not subjected to the elements.

2.3 Variegated or veined materials, especially marbles, that offer interesting colors and patterns and that are by their nature "faulted" and not generally suitable for exterior use are often highly valued for their decorative qualities in interior installations.

2.4 Translucence occurs in some white or very lightly colored marbles and onyxes having a crystal structure that will transmit light to varying degrees depending upon stone thickness and finish. Translucence can be an aesthetically intriguing decorative attribute.

2.5 Sample Variations. Assuming that all critical factors support the desired choice in a given application, expectations as to final appearance must be realistic. Unless a choice is made and marked on an actual slab, variation from a submitted sample is a fact and should not come as a surprise.

2.6 Fleuri Cut Stones. Many dimension stones today are being cross cut or fleuri cut. This is true in travertines and some granites, for example. Many times, the reason this is done is to avoid a directional vein and achieve a more "cloudlike" effect. In any case, the Specifier and the Stone Supplier should know if this is done and investigate the test data, as it may change from normal, conventional means. See illustration at the close of chapter 7.

2.7 Filling Might Be Required. Another issue is where cross cut (fleuri cut) stones are used. As in the case of travertine, a limestone, it may require filling with cement or epoxy, which may or may not hold up under heavy traffic conditions, and the fills may come out.

2.8 Choosing a Finish. Choosing the manner in which stone will be finished is an integral part of the selection process. Finish can be anything from saw cut to high polish. A high polish will bring out the color of the stone to its fullest, because it will optimally reflect the light. Conversely, a textured finish will always appear lighter. A combination of finishes can add interest to a chosen stone. New finishes are appearing on the market yearly, so check and investigate all finishes available with your Stone Supplier.

2.9 Finishes commonly available are:

2.9.1 Polished: Mirror gloss, with sharp reflections.

2.9.2 Honed: Dull sheen, without reflections, achieved by abrasive heads. The degree of honing depends on the stone, but may vary from light to heavy.

2.9.3 Fine Rubbed: Smooth and free from scratches; no sheen.

2.9.3.1 Flamed or Thermal: Plane surface with flame finish applied at high temperature by mechanically controlled means to ensure uniformity; changes the color of the stone.

2.9.3.2 Water-jet Flamed Finish: Gives a more uniform, textured finish and allows more of the natural color to show.

2.9.3.3 Sandblasted: Coarse plane surface produced by blasting an abrasive, allowing a fine-textured finish; may lighten the color.

2.9.3.4 Bush-hammered: Coarsely textured surface produced by hammering, and may vary according to the metallic head used, from fine point to very coarse, and may leave high, lighter-colored markings.

2.9.3.5 Natural Cleft: A cleavage face formed when the stone is split into any thickness.

2.9.3.6 Picked, Hand-hewn Rock Face: Using a chisel or other metallic object that gives deeper indentations and cleavage to the stone.

2.9.3.7 Sawn: Usually refers to slabs coming from a gang saw, with blades that are applied to the block of stone using water and fine grit.

2.9.3.8 Gauged: Done by a machine, usually with circular abrasives to grind the material to a specific thickness.

2.9.3.9 Planed: Usually refers to slate, where a metallic scraper peels a layer of stone, making the stone flat and smoother.

2.9.3.10 Acid Washed: Usually applied to a sawn finish to lower the degree of sawn marks showing, yet maintain a natural textured finish.

2.9.3.11 Tumbled: Method of putting tiles in a mixing container with sand and rotating them, allowing the edges and corners of the tiles to chip.

NOTE: Many new finishes are being applied to stone as the market demand increases and new uses for stone are being conceived. In some productions, combinations of finishes on the same stone are being made. Check with the Supplier to verify the finish and how it was made in order to specify properly.

3.0 DESIGNING WITH DIMENSION STONE

3.1 Design Considerations are nearly equal among the factors of aesthetics, strength and durability. This is particularly true of interior applications. The imagination of Designers is boundless, and it is the Fabricator or Supplier who must counsel the design professionals as to what is feasible and what is not. Stone is not a plastic material. It is rigid and breakable when handled in fabrication.

3.2 Yield. Before making final selection of a stone, particularly on a larger project, take wastage into account to make certain there will be enough material to complete the project. An often-forgotten fact is that the material from a quarry today may be different from what was available six months ago. Further, there may be more than one quarry of the material. The criteria of the Producer to select stone also vary from quarry to quarry.

3.3 Modular Stone Tiles. For ease and economy, modular stone tiles offer a good alternative to stone panels for walls and level floors. Thin stone tiles, varying in thickness from 1 cm to 1.5 cm, are available in modular sizes of 12" x 12" (300 mm x 300 mm), 16" x 16" (400 mm x 400 mm), 18" x 18" (450 mm x 450 mm), and other sizes, up to a maximum of 24" x 24" (600 mm x 600 mm). The proper tile thickness for the installation will depend upon the stone type selected and the modular size of the tile specified.

3.4 Mixing Tiles. The final look of mixed tiles may fall short of appearance expectations, especially if the stone is variegated and veined. The Installer should mix tiles from different boxes during the installation to achieve a more even, visually pleasing result in the finished surface.

3.5 Matched-vein Patterns. In contrast to modular tiles, panels cut from the slab usually will give the best results aesthetically. There are different ways that veined dimension stones or other stones can be matched to form a pattern, and stones must be of types that lend themselves to specific pattern arrangement. Patterned and matched panels require that the material be selected and thus, often increases the cost of the stone. See diagrams at the close of chapter 7 for a detailed description of vein patterns.

3.6 Mixing Types of Materials. Designs calling for a mixture of stones with different physical properties, while aesthetically interesting, can give rise to problems of wear and of maintenance, mainly on floor areas. Re-polishing will pose problems, should that need arise. The Specifier should be aware that mixing types of stones means there will be different abrasion resistance levels as well as different densities of stones that must be considered in the long-term maintenance of the stone and its wearability.

4.0 EXTERIOR APPLICATIONS

4.1 Strength. A most important concern when selecting stone is strength. This is particularly true in cases of exterior stone cladding for buildings over two stories high. Strength in those situations should be the determining factor in the final selection of the stone.

4.2 Exterior Stone Stresses. Exterior stones must be able to withstand the stresses that will be imposed upon them, such as the following:

4.2.1 Gravity load, which must be borne by the anchorage system.

4.2.2 Windload, which exerts both positive and negative pressure on the panels and is typically higher at building corners and other areas of discontinuity.

4.2.3 Water vapor, which must be released to prevent condensation and efflorescence problems.

4.2.4 Freeze/thaw cycles, which can cause stone to crack and joints to fail.

4.2.5 Structural contraction, which occurs during the curing stage of the concrete.

4.2.6 Creep, or permanent structural distortion, which takes place progressively over the years until the structure has settled.

4.2.7 Elastic distortion, which is caused by movement produced by load charges on the structure.

4.2.8 Thermal expansion and contraction, which affects stone and other structural elements

4.2.9 Absorption or porosity of the stone is a factor, as it will affect the durability and life of the stone, as well as its appearance.

Note: The durability of the installation method for walls is determined by the substrate it is being applied to and the anchoring method being used. Consult an engineer to evaluate all installation issues.

4.3 Test Data. Where structural capability is critical, test data for compressive strength, flexural strength, modulus of elasticity, and sheer strength should be studied. Where weather is a factor, absorption, porosity, and permeability studies should be made. Freeze/thaw compressive strength testing should also be carried out. For walls, the type of anchoring, and performing an anchorage pull-out test, are important.

4.4 High-traffic Floor Areas. For high-traffic floor areas, abrasive hardness testing should be a requisite. The absorption or porosity is important, as well as the density of the stone. The finish applied to the stone will be a factor in the slip resistance specified for the area.

4.5 Durability. For durability, exterior stone should be free from structural defects and varying characteristics of vein structure, scaling planes, hairline cracks, earthly parts, and cavities. Panel dimensions should be controlled in size for optimal results.

4.6 Granites have been historically favored for exterior use. Their composition makes them both resistant and stable, and surfaces will hold a high polish longer. As a rule, weaker stones require greater and more costly reinforcement.

4.7 In dry and temperate climates, softer stones like limestones can also be used successfully in thicknesses appropriate to the job. However, exteriors of gray or black limestones with a bituminous or carbon composition should be avoided because the action of atmospheric agents will rapidly cause the surface to deteriorate. Other stones considered inappropriate are the ophicalcites and the breccia in general, as well as all stone containing pyrites, which may produce rust spots when exposed to air and moisture.

5.0 INTERIOR APPLICATIONS

5.1 Selection Criteria. The fact that interior stone is sheltered from the action of the elements makes all types of stone, from the hardest granite to the softest limestone, suitable for application. Criteria for the selection of interior stone for both commercial and residential projects tend to be similar. Selection considerations focus on whether the application will be on vertical or horizontal planes.

5.2 Interior Vertical Surfaces. Nearly any stone may be chosen for interior cladding of commercial buildings. Practical considerations for highly used areas, however, lead to stones that are dense, resistant, and easily maintained. These prove to be the best choice when aiming for a long-term investment.

5.3 Water Resistance. The action of water in areas such as fountains and showers is a factor to be reckoned with. Stones must be able to withstand frequent or continuous water projections, and in the case of showers, the presence of hot steam. Again, the best results are obtained with a dense, resistant stone, such as a granite, or a compact stone with a low absorption coefficient. The action of water on polished marble or limestone might cause surface dulling, spalling, warpage, or deterioration of stone over time.

5.4 Interior Horizontal Surfaces. Traffic is obviously a major consideration in selecting floor stone, whether for heavy, medium, or light duty. In heavy-traffic situations, floors need to withstand vehicles or carts, stiletto heels, mud and sand, salting compounds, spilled high-acidity liquids, and other pollutants and indignities.

5.5 Heavy-volume traffic and abuse require stone of maximum resistance–granite, quartzite, or highly compact marble, depending on the degree of punishment it must take. Testing for hardness as measured by ASTM C241 or C1353 and discussed elsewhere in this manual can help in the selection process.

5.6 For medium-volume traffic, stones can be somewhat softer. Many dimension stones will perform well, if properly maintained. There are good methods and maintenance products available to preserve the stone's appearance. Generally, it is recommended that a dimension stone floor receive a honed rather than a highly polished finish in commercial applications. Etching, scratching, and traffic paths will be far less obvious on a honed surface, thus making for easier maintenance.

5.7 In light-volume traffic and residential areas, where problems of etching, scratching, and staining are minimal, it is quite acceptable to make a selection based mainly on aesthetics and choose a highly polished floor if desired. In all cases, proper maintenance must be done.

5.8 Countertops. Stones for kitchen and lavatory tops should be chosen with regard to functionality. Foods and their handling will affect long-term appearance as acids and grease come in contact with the surface. Not all stones are resistant to staining; therefore, selection should be carefully considered. In all cases and regardless of the type of stone, spills should be wiped up immediately and cutting knives not used directly on the surfaces. There are also nontoxic sealers (necessary in food preparation areas) that can improve the performance of a stone to a great degree.

5.9 Lavatory Tops. As a rule, lavatory tops in residential bathrooms can be chosen according to taste, since the surface receives little abuse other than pollutants that might be contained in cosmetics.

5.10 MIA Statement of Position on Sealing Natural Stone Countertops. Most granite countertops do not need to be sealed. Before 1995 there were very few quality penetrating sealers on the market and there were very few cases of staining. Both prior to and after the availability of penetrating sealers, no cases of food poisoning, radon, or food preparation issues associated with treated or untreated granites have been reported. If a homeowner cleans their countertops after each meal, they will rarely, if ever, have staining or cleanability issues with granite. All this being said, many granite countertops receive additional benefit from being sealed. That benefit is the further reduction of moisture migration into an already moisture resistant surface.

Should natural stone counters be sealed? In many cases it makes sense to seal marble and granite countertops with a quality sealer. The product should have a life expectancy of ten to fifteen years and be of an oliophobic (resistant to water and oil based stains) nature. Once properly sealed, the stone will be more resistant against everyday dirt and spills.

In today's natural stone industry, many species of granite receive a resin treatment at the factory where the blocks of granite are cut into slabs and then polished. The treatment is used to fill microfissures, indentations and other minor characteristics that are found in many natural stones. The reason for the resin treatment is to address what most consumers consider as imperfections, but in reality are "birth marks." The consuming public gravitates to perfection, defined as no "birth marks," and so the marble and granite industry tries to fulfill the desire. Both resined as well as unresined slabs will outlast most of our lifetimes. Granite should, and in most cases will, be the last countertop surface a person will buy, providing a strong return on investment. The bottom line: Sealing resin treated countertops may increase the resistance of the already resistant nature of stone (adopted 11/8/06).

6.0 TESTING FOR PHYSICAL PROPERTIES

6.1 ASTM Tests. Stone is tested under a rigorous set of standards developed by the ASTM International, the world's largest voluntary standards development organization.

6.2 Purpose of Tests. The tests apply standard methods to uniformly evaluate stone characteristics and performance. ASTM standards are the recommended guidelines for installation in the stone industry. See Chapter 2 for more information about this organization and a list of ASTM specifications and standards.

6.3 Original Test Data. The Specifier has the right to request from the Supplier original test data on the stone to be used and verify the age of the test and its validity. In some cases historical data is sufficient on small jobs, but on larger jobs historical test data should only be taken as indicative, and new tests should be run on the specific stone from the specific quarry to be used.

7.0 SAMPLING

7.1 Stone Samples and Mockups. Preparation and supply of dimension stone samples and mockups are often expensive and time-consuming, but an essential part of stone projects. Samples and mockups help ensure that materials meet contract requirements.

7.2 Promotional samples are for color consideration only, but must be representative of the color and finish being proposed for use. They should be supplied in small sizes, such as 3" x 4" (75 mm x 100 mm), 4" x 6" (100 mm x 150 mm), or 6" x 6" (150 mm x 150 mm).

7.3 Project samples should be 1' x 1' (300 mm x 300 mm) in size or larger. Care must be taken to select samples that accurately reflect the shades, markings, and anticipated ranges of color, texture, finish, veining, filling, and other characteristics of the variety of stones specified.

7.4 Large Projects. For very large projects, multiple samples are needed in order to show the range of variations. These are normally assembled by selecting from the blocks that best meet the requirements at that point in time. Sometimes visits to the quarries become a necessary step in the selection process. Selecting slabs to be cut for the project is necessary to see the overall variation of the stone and finish to be used. In all cases, availability of the material should be secured.

7.5 Number of Samples. The number of sample submissions required on a specific project depends primarily on the amount and particular use of the stone required. However, there should never be fewer than two sets of samples submitted. Control samples should be kept by the Architect, Contractor, and

Producer for verification of the selection approved.

7.6 For stone that will be matched, prepare at least two sets of four matched samples each, showing proposed veining, flows, movements, texture, and range in each set.

7.7 Support Documentation. Depending on the stone selected and quantity required, a mock-up containing a full range of colors may be needed to further define the texture and characteristics of the stone. The Specifier or Buyer should request all samples and submission of stone be accompanied by the following in writing:

7.7.1 Actual name of stone and name of stone as applied by the Quarrier, as well as alternate names of stones in the marketplace, if any are known.

7.7.2 Country or state of origin.

7.7.3 Quarrier, if known.

7.7.4 ASTM test data or European equivalent for first evaluation purposes.

7.7.5 Age of sample, if known.

7.7.6 References of where this stone has been used near where the job may be located.

7.7.7 Photos of slabs showing more range of the material and other finishes available. Define whether there is more than one quarry and bed level of quarry where this stone is located.

7.8 This information will assure the Specifier of writing a specification that will control that the material being specified will indeed be the stone to be used on the job.

Note: As an example, specifying White Carrara (a generic name with over 30 quarries, and each quarry having possibly 4 selections) is meaningless if all the other information is not supplied.

7.9 Viewing Samples. When natural stone samples are viewed for approval, the viewer should be no closer than 6 ft. (2 m) from the sample surface and viewing from an angle normal to the surface. Natural light is preferred, striking the samples at an angle normal to the surface.

8.0 COST

8.1 Pricing Stone for the Job. A key factor in determining which stone to use will be the price. Today, thanks to the development of new technologies, stone is plentiful and competitively priced. There are many alternatives in stone selection, with a range of prices to fit any budget. The Specifier should ask for a budget price when initially considering a stone for the stone only. In the final consideration and determination, the Specifier should know the real cost of the stone based on the design and its installation costs to see if the stone fits into the budget of the job.

8.2 Size of stone is also important. Not all stones are available either in the size being designed or to get the best yield from the blocks or boulders. Price will be determined many times by the size and waste factor of the blocks in relation to the finished project.

8.3 Stone Thickness. In the past, buildings were erected using blocks or thick slabs. Now, cladding systems make it possible to use panels only ¾" or 1¼" thick, and with a notable reduction in the cost of stone. The thickness of the stone will be determined by engineering and the anchoring system for the specific stone.

8.4 Modular thin stone tile, a product of modern technology cut to a thickness of only 1 cm, is suitable for many applications and is competitive in price. These panels and tiles compare very favorably with other natural and manufactured products available for construction, and have the added advantage of conferring character and durability to the structure.

8.5 Multiple Factors Affect Price. Many factors determine the price of a particular stone. Availability, ease of extraction, market demand, quality, and transportation are a few of the variables that will affect the price. This is an advantage when cost is important, for there is always the possibility to select alternatives offering essentially the same desired characteristics. Availability is important to check to determine whether the stone is still quarried, is available in the quantity required, and in the time frame of installation of the project. Sometimes the more limited the availability, the higher the cost. If the stone is only available from one company, the Producer can demand a very high price and the Specifier should be made aware of this.

8.6 Other factors affecting the cost on large projects may include:

8.6.1 Quantity allowed for storage or attic material.

8.6.2 Extra material needed in the event of damages, improperly fabricated material, or other reasons replacement material might be needed.

8.6.3 Determination of who will pay taxes may be an issue and should be clarified.

8.6.4 Availability of a storage facility at the jobsite that is of adequate size to properly and securely store material until job is complete.

8.6.5 Consult with your local MIA Member to review these and other costs that factor into the overall project budget.

9.0 MAINTENANCE

9.1 General. Maintenance of the stone after it is installed is commonly forgotten. The Specifier should be aware of the maintenance required to maintain the color and finish of the stone for years to come. Ask the Stone Supplier and Salesperson for maintenance suggestions or requirements. Investigate with authoritative maintenance companies what they recommend for a specific stone and the cost factors involved in maintaining the stone. The more knowledgeable the Specifier and End Buyer are about stone maintenance, the longer and happier all parties will be in giving the Owner a quality finished job that will last for years to come.

9.2 Sealers. If sealers are to be used, have the stone tested to ensure in writing the sealer's performance for the stone and application of the stone intended. New surface and penetrating sealers are becoming available on the market every year.

9.3 Maintenance and Cost. The maintenance issues for a specific stone and the cost attributed to it can vary from one type to another, and may impact the decision to use that stone in a particular application.

STONE TESTING

1.0 INTRODUCTION

1.1 General. Testing evaluates the suitability of a specific stone for a particular application. The strength of the stone is tested to determine its resistance to crushing and bending. The density, or specific gravity, is tested to design a support system capable of carrying the weight of the stone. The amount of water the stone will absorb (absorption rate) will help determine the resistance of the stone to staining and freezing. The stone's wear resistance and slip resistance are crucial in flooring applications.

1.2 ASTM tests, many of which are conducted within engineering parameters, do not include petrographic and other geologic tests useful to evaluating stone behavior through time in adverse environmental settings. If and when a failure occurs, questions about what went wrong and why are asked; however, test data reviewed frequently may not reveal information useful to answer these questions. Stone behavior is directly related to the behavior of the mineral or minerals that make up the stone. Knowing something about physical and chemical characteristics of the common minerals found in stone can be very useful in understanding its behavior.

1.3 Petrography is the science of description and classification of rocks. A petrographic analysis can be arranged through most construction material laboratories. A comprehensive petrographic analysis will often suffice to answer many behavioral questions. Other, more sophisticated analyses performed in well-equipped chemical laboratories to determine exact chemical and trace element content can also be useful.

1.3.1 Perhaps the most common and time-tested petrologic studies use thin sections of stone. These are prepared by polishing small samples very flat, gluing them to glass microscope slides [1" x 3" (25 mm x 75 mm) to 2" x 3" (50 mm x 75 mm)], and slicing the stone thin with an ultraprecision, thin-blade diamond saw. The stone slice on a slide is then precision-ground to a precise thickness of about 20 to 30 microns. At that thickness most minerals, regardless of color, are translucent and can be studied under a microscope. In this way minerals can be identified, the crystal or fragment boundaries can be evaluated, and incipient microfractures can be seen, as can any chemical degradation that may weaken stone, permit water entry, or allow unanticipated breakup.

1.3.2 Exact identification of the minerals by thin section is a subjective, experience-based skill and is largely being replaced by exact methods of chemical analysis. Having both the thin section and chemical analysis is the preferred procedure, as the physical features can be seen documented on known mineral crystals or grains.

1.4 X-ray diffraction (XRD) analysis is one of the tried-and-true analytical techniques used for decades in petrology and remains the preferred technique in certain situations. However, more modern analytical techniques have evolved that are far more precise, analyze far more compounds and elements, and are rapidly replacing XRD for most routine purposes.

1.5 Lithogeochemistry, the chemical analysis of stone, relies on many new procedures too numerous to attempt explanation here. The following are just a few notable lithogeochemical analysis procedures:

1.5.1 Instrumental Neutron Activation Analysis (INAA)

1.5.2 Atomic Absorption Spectroscopy (AA)

1.5.3 Inductively Coupled Plasma Emission Spectroscopy (ICP-OES)

1.5.4 X-ray Fluorescence Spectroscopy (XFS)

1.5.5 Inductively Coupled Plasma Emission Mass Spectrometry (ICP-MS)

1.5.6 A few grams of a stone can be qualitatively and quantitatively analyzed accurately for bulk stone chemical content plus more than 53 trace elements–some to fractional parts per billion.

1.5.7 Although the ASTM Committee on Stone, C-18, has yet to include petrologic tests in their repertoire, lithogeochemistry is already quality-standardized by the International Organization for Standardization (ISO). ISO/IEC Guide 25 is an accreditation that many laboratories have because of the importance of these studies in the global mineral-extraction industries.

2.0 ASTM STANDARD TEST METHODS AND SPECIFICATIONS

2.1 ASTM International, formerly known as the American Society for Testing and Materials, has developed several standard test methods to evaluate stone characteristics so that stones can be compared on a uniform basis. The Marble Institute of America recommends ASTM methods and standards for dimension stone as guidelines for specification and installation. ASTM International is the world's largest voluntary standards development organization. Note that stone testing according to European methods and conditions may use different procedures that give different results than do ASTM methods for the same stone. This is particularly true of tests for abrasion (wear). The ASTM Standard Test Methods are listed in Chapter 2.

2.2 Current Standards. ASTM standards are revised from time to time. A revised version is indicated with a hyphen followed by a two-digit number after the basic designation of the standard, e.g., ASTM C119-20, showing that it was revised in 2020. An additional number in parentheses, e.g., ASTM C1527-11(2018), indicates that the 2011 edition was formally reaffirmed without change in 2018. The latest edition should be used. Copies of ASTM standards can be obtained from ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959 U.S.A. Telephone 610.832.9585. Copies can also be ordered through ASTM's web site and downloaded electronically. The Internet address is www.astm.org.

2.3 ASTM Standard Specifications. In addition to the standard test methods, ASTM has developed a series of standard specifications prescribing the minimum performance of each kind of stone when tested in accordance with the standard test methods. The ASTM Standards and Specifications are listed in Chapter 2.

2.3.1 These specifications are the standard methods for determining the characteristics of building stone needed for proper design for a particular application. They should be performed with care and the results used with an understanding of their intent and limitations. An independent testing laboratory properly equipped and capable of performing the tests should perform all tests. Stone Producers or Distributors, Associations, and other Promotional Organizations may publish typical test values. While these values can serve as a guide, current tests should be conducted on the actual stone to be used for a particular project.

2.4 Review for Suitability. ASTM test results for various stones are guidelines and information on the stone characteristics. In many cases, an Engineer should be employed to review the results of the test data and compare with actual installation methods to determine if the stone is suitable for the application in the specified thickness suggested, and if not, what changes should be employed to make the stone work as intended for the job in question. Evaluation and/or testing of compatibility of grouts, sealers, setting methods, and anchoring must be performed along with the stone.

3.0 OVERVIEW OF STANDARD TEST METHODS

3.1 Stone Uniformity. Stone is a product of nature, and as such, it varies. The properties of stone from one part of a quarry may not be truly representative of the same stone from a different part of the quarry. Some Architects specify strength-testing specimens from each quarry block to verify sufficient uniformity for the application. At the very least, current test results should be used because they are more apt to reflect the stone currently being quarried.

3.2 Wet/Dry Testing. For most tests, the stone specimens are tested dry. However, since the strength may vary when the stone is wet, the strength tests (i.e. compressive strength, flexural strength, modulus of rupture) are sometimes performed using wet stone specimens. For the dry condition, the stone specimens are dried in an oven at 60°C ±2°C (140°F ±4°F) for at least 48 hours or until the weight does not change with additional drying. For the wet condition, the stone specimens are soaked in water at 22°C ±2°C (72°F ±4°F) for 48 hours, wiped, and immediately tested. For general "catalog type" information, the stone is usually tested in a dry condition. The Specifying Authority may specify additional wet testing for a particular project to ensure that the stone will have adequate strength for the application.

3.3 Testing Parallel/Perpendicular with the Rift. The strength of stone also varies with the relation of the load or force to the direction of the "rift" of the stone. The rift is the plane of easiest splitting of the stone. Consider that a block of stone is like a deck of cards with rift direction corresponding to the plane of the cards. The cards are like the layers of the stone. The stone will be weaker if the applied loads tend to make the cards (layers) slide against each other than if the load is applied to squeeze the cards against each other. The variation in strength is likely to be greater in a stone with a more pronounced rift, like a sedimentary stone such as slate, than in a stone with a less definite rift, such as some igneous stones. The variation also depends on how strongly the layers are cemented or adhered to each other. To determine the variation, strength tests are conducted with the load parallel and perpendicular to the rift. For general information only one direction is tested, but the Specifying Authority may specify testing in both directions to ensure that the stone strength is adequate for the application. When specimens are submitted for such testing, it is important that the rift be clearly marked. The strength tests can be conducted by four conditions, wet or dry, and with the load parallel or perpendicular to the rift.

3.4 Horizontal Applications. ASTM C99, Standard Test Method for Modulus of Rupture of Dimension Stone, ASTM C170, Standard Test Method for Compressive Strength of Dimension Stone, and ASTM C880, Standard Test Method for Flexural Strength of Dimension Stone test results are not suitable to use for horizontal (floor) applications where the thickness of the stone tile being used is less than 1¼" (30 mm).

3.5 Limitations of Thin Stone Pavers. It is the position of the Natural Stone Institute that stones less than 1¼" (30 mm), when used for paving, do not possess any structural qualities other than abrasion resistance. The flexural, compressive, and breaking strengths these thin stones have will not materially improve the engineering quality of the designed surface. These thin stones are furnished for their aesthetic appearance and to supply abrasion resistance only.

4.0 ABSORPTION AND BULK SPECIFIC GRAVITY TESTING OF DIMENSION STONE

4.1 Water absorption is a measure of the porosity of a stone and can be an indicator of its susceptibility to damage during freezing. A stone that has greater water absorption will also tend to absorb liquid stains more readily. In general, the lowest water absorption is desired. The absorption is expressed as the percent weight change due to absorbed water. The maximum allowable water absorption for each type of stone is prescribed in the standard specifications for that specific stone. The required values range from 0.20% for marble to 12% for low-density limestone. According to ASTM C97, at least 5 specimens, as described for the density determination, are dried and weighed. It is important that the surface not be fractured by the cutting process because these fractures will increase water absorption. The specimens are then soaked in water for 48 hours, wiped dry, and weighed again. The difference in weights is divided by the dry weight and multiplied by 100 to give the percentage of water absorption. Variations in the wiping of the wet specimen before weighing will cause variations in the result. The standard test method describes removing the specimens from the water and surface drying with a damp cloth, but this is still somewhat subjective. A dryer wet specimen will result in a lower absorption number.

4.2 Specimen Thickness. This standard requires that the specimens have minimum dimensions of 2 inches (50 mm). However, sometimes the stone is not available in that thickness, especially flooring material, which may be only 3/4" (20 mm) or 3/8" (10 mm). Depending on the porosity of the stone, testing these thinner specimens may result in an "apparent" water absorption higher than if the standard-sized specimens were used. During the soaking, water may not be absorbed to the center of the standard specimen, but water might be absorbed to the center of the thinner specimens.

4.3 Slate. The water absorption test for slate, ASTM C121, uses different-size specimens. They should be 4" (100 mm) square and the "as cleft" thickness, which is typically ¼" to 3/8" (6.5 to 9.5 mm). Otherwise, the procedure is the same.

4.4 Stone Density. The density of the stone indicates the unit weight of the stone, which is necessary for the Architect or Engineer who is designing the structure to support the stone. The standard specifications prescribe minimum densities. The minimum densities are used to classify stones. For example, there are three classes of limestone, with each class having a different density as well as different strength requirements. Generally, a higher-density stone is probably harder, less porous, and stronger, but this is not always the case. Note that there is no density for slate specified in ASTM C629, although it could be determined, if desired, using the procedure of ASTM C97.

4.5 Specific Gravity is the ratio of the density of the stone to the density of water. If a stone has a specific gravity of 2.6, it is 2.6 times as heavy as water. Density is expressed as pounds per cubic foot (lb/ft^3) or kilograms per cubic meter (kg/m^3). The density in lb/ft^3 can be determined by multiplying the specific gravity by 62.4 (the weight of 1 cubic foot of water) or by multiplying by 1000 for the density in kg/m^3. One lb/ft^3 equals 16.02 kg/m^3. The specific gravity is the same in both measurement systems.

4.6 Stone Dry and Wet Weights. The dry weight of the stone specimen is divided by the volume. The specimen should be a cube, cylinder, or other regular solid with the dimensions between 2 and 3 inches (50 and 75 mm). The surface should be reasonably smooth, e.g., saw, core drill or better, but no chisels or tools which tend to fracture the stone. At least 5 specimens should be tested and the results averaged. The dry weight of each specimen is determined after drying 48 hours. The stone is then soaked in water for 48 hours, wiped almost dry, and weighed. It is then suspended in water by fine wire and the suspended weight is measured. The difference between the two weight measurements in grams is the volume in cubic centimeters (one cubic centimeter of water has a mass of 1 gram). The dry weight in grams divided by the volume in cubic centimeters is the specific gravity. The specific gravity is multiplied by 62.4 to obtain the density in lb/ft^3. Subtracting a tare weight of the suspended wire in water provides a correction for the mass of the fine wire.

4.6.1 This method of measuring the volume is based on the principle that a body suspended in water has an apparent weight loss equal to the volume of water displaced. In the metric system, the 1 cubic centimeter of water has a weight of 1 gram. In other words, there is a buoyant force on the object equal to the weight of the water displaced.

5.0 STRENGTH TESTING OF DIMENSION STONE

5.1 Compressive Loads and Strength. The loads on a material such as stone are expressed as the applied force divided by the area which must bear the material. For example, the compressive (crushing) load on a floor caused by a flat-bottomed round planter is the weight of the planter (including the soil and plants) divided by the area of the bottom of the planter. The compressive strength of the floor is the maximum compressive load the floor material can bear without crushing or deforming more than is allowed. In practice, the allowable loads in actual use are less than the maximum loads that a material can withstand during testing, to provide a safety factor. In all structural design, the maximum material strengths are reduced by a safety factor to establish the allowable design strengths. The safety factor allows for variations in the material strength, possible overloads in use, and similar considerations.

5.2 Strength Units of Measure. The strengths are expressed as pounds/square inch (psi) or pascals (Pa). A pascal is a force of 1 newton per square meter. Occasionally, the strength is expressed as kilograms/square meter (kg/m^2), which is technically incorrect because the kilogram is a unit of mass while the newton is a unit of force (or weight). In the U.S. system, we tend to think of mass and weight interchangeably. Therefore, when a weight or force is intended, the term used is pound force (lbf).

The following conversions can be used:
1 lbf/in^2(psi) = 6,895 pascals (Pa)
1 lbf/in^2 (psi) = 4.882 kilograms/square meter (kg/m^2)
1 kg/m^2 = 9.807 Pa
The terms kilopascal (kPa) and megapascal (MPa) are used for 1,000 Pa and 1,000,000 Pa, respectively.

5.3 Compressive Strength of Dimension Stone. Compressive strength is a measure of the resistance to crushing loads. If one were to build a stone wall, for example, the stone at the bottom would have to withstand the compressive load of the weight of the stones above. A stone floor must be able to bear the crushing loads of people, furniture, and other objects on the floor. The compressive strength is the maximum load per unit area that the stone can bear without crushing. A higher compressive strength indicates that the stone can withstand a higher crushing load. The required values range from 1,800 psi (12.45 MPa) for marble to 19,000 psi (131 MPa) for granite. To determine the compressive strength, at least 5 specimens are tested in ASTM C170. They should be cubes at least 2" to 3" (50 to 75 mm) on each side. Each face must be perfectly flat and they must be parallel or perpendicular with each other. Faces must be smooth with no tool marks and there should be no nicks at the corners. The faces must be honed or polished with no saw marks or other tool marks remaining. Any flaws in the specimens can result in a lower compressive strength. In some instances, the testing laboratory may have to refinish the specimens to produce surfaces sufficiently flat for testing.

5.3.1 The compressive strength can be determined in the dry or wet condition and with the load parallel or perpendicular to the rift. For the dry and wet conditions, the specimens are dried or soaked for 48 hours as described in the density test. For the compressive strength testing, the specimen is placed on the flat plate of the testing machine and increasing loads are applied to the top of the specimen through another flat plate. The test apparatus allows the top plate to swivel on a ball joint to adjust for any slight slope on the top of the specimen. The rift of the specimens should be vertical for the load to be parallel to the rift, or horizontal for the load to be perpendicular to the rift.

5.4 Bending Strength. The tests for modulus of rupture, ASTM C99 and ASTM C120 (Slate), and for flexural strength, ASTM C880, determine the strength of the stone in bending. A stone or door lintel must resist the bending loads from the weight of the stone. A veneer must bear bending loads, between anchor points, from exterior wind loads or persons leaning against interior veneers. Floor stone must bridge possible gaps in the grout or thin-set support. For all three tests, the stone specimens are supported near the ends and a downward load applied to the top. The modulus of rupture tests, ASTM C99 and ASTM C120, prescribe applying the load to a single point at mid-span. The flexural strength test, ASTM C880, prescribes applying the load simultaneously to two points, each one quarter of the span from the end support. The flexural strength is expressed as lb/in^2 or Pa. A higher flexural strength or modulus of rupture indicates a higher bending strength. The required minimum values range from 400 psi (2.8 MPa) for low-density limestone to 10.3 MPa for granite.

5.5 Modulus of Rupture of Dimension Stone. ASTM C99 requires a minimum of 5 specimens that are 4"x 8"x 2¼" (100 x 200 x 60 mm) thick. All of the faces, except the ends, must be flat and be parallel or perpendicular with each other. The faces must be smooth with no tool marks and there should be no nicks at the corners. The faces should be honed or polished with no saw marks or other tool marks remaining. Any flaws in the specimens can result in an apparent low modulus of rupture strength. The flexural (bending) strength may be tested in a dry or wet condition and with the load parallel or perpendicular to the rift. The specimens must be dried or soaked for 48 hours. For the modulus of rupture test, the stone specimen is laid flat on two crosswise parallel steel edges 7" (175 mm) apart. The 7" (175 mm) span allows the 8" (200 mm) long specimen to overhang the supports by ½" (12.5 mm) at each end. The supports of the fixture are gimbaled to accommodate any warp of the test specimen and prevent the introduction of torsional stresses applied to the stone. The test load, or force, is applied to the center of the top of the specimen through another crosswise edge. The load is increased until the specimen breaks. The flexural strength is then calculated from a formula based on the geometry of the test condition.

5.5.1 If the specimens are to be tested with the load perpendicular to the rift, then the rift plane must be parallel to the 4" x 8" (100 x 200 mm) faces. Returning to the card deck analogy, the "deck" of the specimen must be placed flat on the supports. If the specimens are to be tested with the load parallel to the rift, the plane of the rift must be parallel to the 2¼" x 4" (60 x 100 mm) ends of the specimen. In the analogy, several decks would have to be stacked up to a height corresponding to the 8" (200 mm) specimen length, and the card stack or specimen would be placed so the cards are on edge with each card parallel to the supporting edges. This is illustrated in ASTM C99.

5.5.2 In general, the flexural strength with the load parallel to the rift will be less than that with the load perpendicular to the rift. The variation would be greater for a stone with a more pronounced rift than for a stone with a rift less distinct.

5.6 Flexure Testing of Slate. The modulus of rupture testing for slate, specified in ASTM C120, is somewhat different than

C99. The specimens are 12" x 1½" x 1" (300 x 38 x 25 mm) thick. Rubbing or sanding the cleft faces achieves the specified 1" (25 mm) thickness. Six specimens are required: 3 with length parallel to the rift, and 3 with length perpendicular to the rift. For the test, the span between the supporting knife edges is 10" (250 mm).

While these test methods are useful, they have certain limitations. Since the specimen for ASTM C99 is always 2¼" (60 mm) thick or 1" (25 mm) for ASTM C120, the test does not indicate any reduction in the strength for thinner stone when used as a veneer or for flooring. They are valid for thicker sections. Because of the midspan loading, any weakness that is not in the center third (approximately) of the specimen will usually not affect the strength value determined by the test. These limitations are overcome by the flexural strength test of ASTM C880.

5.7 Flexure Testing of Dimension Stone. The flexural strength test of ASTM C880 is similar to the modulus of rupture tests, with two significant differences. First, the stone is tested at the thickness at which it will be used. The test span is proportional to that thickness by a ratio of 10:1. Thus any reduction in the bending strength due to the stone structure, e.g., grain size, grain cementing, etc., will be reflected in the test results. The test span is 10 times the thickness, but the actual length of the specimens should be about 12 times the thickness to allow for some overhang. The width is 1½ times the thickness, but, if the thickness is less than 2.67" (70 mm), the width is 4" (100 mm). If specimens for an exterior building veneer are 4" x 1¼" x 15" (100 x 30 x 380 mm), the test span should be 12.5. For a 3/8" (10 mm) floor tile, the specimens would be 4" x 3/8" x 4½" (100 x 38 x 120 mm) and the test span would be 3.75" (95 mm). As for modulus of rupture specimens, all faces, except the ends, must be flat and be parallel or perpendicular with each other. The faces must be smooth with no tool marks, and there should be no nicks at the corners. Faces should be honed or polished with no saw marks or other tool marks remaining. Any flaws in the specimens can result in a lower flexural strength. Since the length of the specimens serves only to provide sufficient overhang, exact length is not critical to the results.

5.7.1 The second difference that distinguishes the ASTM C880 flexural strength test from the modulus of rupture tests is that the flexural strength test is conducted with quarter-point loading. That is, the test load on the top of the specimen is not applied to a single location at midspan, but rather, the total test load is split, with half of the load applied at each of two points one quarter of the span from the supports, In this way, the entire center half of the specimen is subjected to the same maximum bending forces. Thus any local weakness, as from a vein, is more likely to be reflected in the resulting flexural (bending) strength.

5.7.2 The flexural strength test can be performed in the dry or wet condition and with the load parallel or perpendicular to the rift. The stone specimens are dried, or are soaked in water, for 48 hours. The rift directions are the same as described for the modulus of rupture test. At least 5 specimens are tested for each condition, and the results averaged.

5.7.3 As in the modulus of rupture test, the load is increased until the specimen breaks. Then the flexural strength is calculated using a formula based on the geometry of the test conditions.

5.8 Flooring Applications. There are two additional considerations for stone used for flooring: the wear or abrasion resistance, as measured by ASTM C241, and slip resistance as measured by its coefficient of friction, formerly evaluated according to ASTM C1028. This test method was withdrawn in 2014 and no replacement method was offered. See section 5.11, below, for an explanation.

5.9 Abrasion Resistance of Stone Subjected to Foot Traffic. Wear resistance is an essential characteristic that will determine whether a stone is suitable for use as a floor. The abrasion test of ASTM C241 results in an index number proportional to the volume of material abraded or worn off the stone during the test. The abrasion index numbers are scaled to generally range between 0 and 100. The ASTM specifications for stone list a minimum abrasion index for each type of stone. Marble and limestone, for example, should have an index of at least 10 (12 in heavy traffic areas); quartzitic sandstone and slate should have an index of 8; and granite, 25.

5.9.1 During the test, the weight loss of stone specimens is measured before and after being abraded, and then the density of the specimen is determined. The abrasion index is calculated using the average weight, the abrasion weight loss, and the density.

5.9.2 The test requires 3 specimens, 2"(50 mm) square and 1" (25 mm) thick. One 2" (50 mm) square face should have the finish to be evaluated, e.g., polished, honed, etc. The others may have saw marks, but should not be cut in a manner that fractures the stone because the fractures would affect the density determination.

5.9.3 The stones are abraded using a machine developed by Kessler. The machine includes a horizontal, round, cast iron "lap" about 9" (225 mm) in diameter, which rotates at a speed of 45 revolutions per minute (rpm). The specimens are mounted in a holder that rotates in the same direction as the lap, but at a different speed. While the lap and the specimen rotate, an abrasive flows onto the lap to abrade the bottom of the specimens. Each specimen supports a load of 2,000 grams, which includes the weight of the specimen holder, but not the specimen itself.

5.9.4 For the test, the stones are dried for 48 hours and weighed. The specimens are then abraded in the Kessler machine for 5 minutes (225 revolutions at 45 rpm), dusted off, and weighed. Knowing the dry weight of the specimens, they are soaked in water for at least 1 hour, and a bulk density is determined in the same way as the density procedure of ASTM C97. However, the abrasion specimen is thinner than that required by ASTM C97 and the specimen is not soaked for 48 hours. Consequently, the density may not be exactly the same as determined by ASTM C97.

5.10 The abrasion resistance index, which is proportional to the volume abraded, is calculated for each specimen using the average weight (before and after abrading), the weight loss, and the apparent density. An abrasion resistance index will usually be in a numeric value less than 100, but not always.

5.10.1 There are two concerns regarding this test method. First, it is not always possible to obtain specimens that are 1" (25 mm) thick. Although the ASTM method does not indicate it, specimens of other thicknesses can be determined by adjusting the 2,000-gram load on the specimen so that the load on the bottom of the specimen, the abrading face, is the same as it would be if the specimen were actually 1" (25 mm) thick. For a specimen ¾" (20 mm) thick, the 2,000 grams would be increased by the mass of the missing ¼" (6.5 mm) thickness of the specimen.

5.10.2 The second concern is the abrasive. ASTM C97 specifies a particular abrasive that is no longer being produced. The ASTM committee is currently conducting round-robin tests among different laboratories to determine a possible correction factor or a different test method which will produce abrasion index numbers that are the same as from the methods of ASTM C241, so that new test results can be compared with earlier results. In the meantime, test laboratories have had to develop a correction factor by comparing the results for stones having different abrasion resistances, e.g., soft and medium marble and granite, using the old and currently available abrasives.

5.11 Coefficient of Friction Testing. Slippery floors are a safety hazard, thus some measure of slip resistance is needed to evaluate stone and its finish as a floor material. Traditionally in the stone industry, slip resistance was evaluated by measuring the static coefficient of friction (the force required to <u>initiate</u> slipping divided by the normal force) per the ASTM C1028 method. This test method was withdrawn in 2014, for two reasons:

1. The load application is not automated, and therefore substantial operator influence is experienced in the load application rate, directional bias, and uniformity.
2. Since the test apparatus takes some time to set up, wet condition tests can produce a suction, referred to by many as "sticktion", preventing it from providing reliable data for testing in wet conditions. It can in fact produce data suggesting that frictional properties are improved by the wetting of the substrate and no replacement method was offered.

To address these concerns, the ANSI accredited standards committee A108, of which the Tile Council of North America (TCNA) is the secretariat, developed an entirely new procedure which measures not static, but dynamic friction to assess walkway safety. The new procedure first published in the ANSI A137.1-2012 document was entitled the "DCOF AcuTest℠" method. It uses a commercially available instrument, the BOT-3000 (Binary Output Tribometer), but with very specific protocols regarding the redressing of the test foot between tests to ensure reliability and repeatability. Building on a large collection of data previously obtained by German researchers, substantial additional data was collected to develop the new more reliable and repeatable method of COF measurement. In 2017, the test procedure, which was originally part of ANSI 137.1, was published as a standalone document entitled ANSI A326.3 *Standard Test Method for Measuring Dynamic Coefficient of Friction of Hard Surface Flooring Materials*. Its primary improvement versus the previous version is that the procedure now specifically addresses in situ testing in addition to laboratory testing.

5.12 Other Stone Selection Considerations.

5.12.1 Other considerations for selecting exterior stones are the freeze/thaw capabilities of the stone in extreme climates. Also, the effect of ultraviolet light on the fading or changing of color of certain dimension stones. Tests are available for these considerations.

5.12.2 Sealants, seals, and gaskets for exterior applications are also considerations in the overall design of the building, and terminologies relating to these are available from ASTM under C717, and specific tests are also available.

5.12.3 Considerations for testing and evaluating stone must include petrographic and mineralogical data. The use of stone can be a factor directly related to whether it is an igneous rock like granite, a sedimentary rock like limestone, or a metamorphic rock like marble. The petrographic information may indicate a stone's elastic condition to change, or absorption degrees, or determine its strength and durability, as does the mineral content of the stone. The mineralogical information is important to see if the stone contains any minerals that may cause rust (as with stones containing ferrous minerals), exfoliation like some carbon stones, or minerals that may decompose and change due to weather conditions. The silicates in granite weather better than the carbonates of marble or limestones. The performance of a stone is related to its composition, and this is why some stones are more brittle than others, and why some stones, like common limestone, become harder when exposed to air through a process called "curing."

5.12.4 In designing stone exterior facades, consider the environmental conditions: rain, snow, hail, freezing and high temperature variations, and others. The stone must be resistant to weathering and decay. Carbon monoxide, sulfates, and other atmospheric pollutants form an acid, and with rainwater, can corrode certain stones over the course of time.

6.0 OTHER ASSOCIATIONS FOR ADDITIONAL INFORMATION

American Geosciences Institute (AGI)
www.americangeosciences.org

American Society of Civil Engineers (ASCE)
www.asce.org

American Concrete Institute (ACI)
www.concrete.org

American Institute of Steel Construction (AISC)
www.aisc.org

American Iron and Steel Institute (AISI)
www.steel.org

American Society of Landscape Architects (ASLA)
www.asla.org

Construction Specifications Institute (CSI)
www.csiresources.org

International Masonry Institute (IMI)
www.imiweb.org

Masonry Institute of America (MIA)
www.masonryinstitute.org

National Association of Architectural Metal Manufacturers (NAAMM)
www.naamm.org

National Tile Contractors Association (NTCA)
www.tile-assn.com

Precast/Prestressed Concrete Institute (PCI)
www.pci.org

Tile Council of North America (TCNA)
www.tcnatile.com

Special Note: A worldwide directory of ASTM-approved testing laboratories is available from ASTM International, www.astm.org.

NSI Bookstore Resources:
Reprints of this chapter, along with the Dimension Stone Selection chapter, can be purchased in a separate publication from the NSI Bookstore. The "Stone Selection & Stone Testing" technical module includes the contents of both chapters and additional illustrations and pictures.

GRANITE

1.0 GENERAL

1.1 Related Documents

1.1.1 Drawings and general provisions, including General and Supplementary Conditions of the Contract and Division I Specification sections, apply to this section.

1.2 Applicable Publications

1.2.1 The following publications listed here and referred to thereafter by alphanumeric code designation only, form a part of this specification to the extent indicated by the references thereto:

1.2.2 ASTM International (ASTM):

1.2.2.1 C615, Standard Specification for Granite Dimension Stone

1.2.2.2 A666, Standard Specification for Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar

1.2.2.3 B221, Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes

1.2.2.4 C97, Standard Test Methods for Absorption and Bulk Specific Gravity of Dimension Stone

1.2.2.5 C99, Standard Test Method for Modulus of Rupture of Dimension Stone

1.2.2.6 C119, Standard Terminology Relating to Dimension Stone

1.2.2.7 C170, Standard Test Method for Compressive Strength of Dimension Stone

1.2.2.8 C241, Standard Test Method for Abrasion Resistance of Stone Subjected to Foot Traffic

1.2.2.9 C270, Standard Specification for Mortar for Unit Masonry

1.2.2.10 C295, Standard Guide for Petrographic Examination of Aggregates for Concrete

1.2.2.11 C880, Standard Test Method for Flexural Strength of Dimension Stone

1.2.2.12 C1201, Standard Test Method for Structural Performance of Exterior Dimension Stone Cladding Systems by Uniform Static Air Pressure Difference

1.2.2.13 C1242, Standard Guide for Selection, Design, and Installation of Exterior Dimension Stone Anchors and Anchoring Systems

1.2.2.14 C1352, Standard Test Method for Flexural Modulus of Elasticity of Dimension Stone

1.2.2.15 C1353, Standard Test Method for Abrasion Resistance of Dimension Stone Subjected to Foot Traffic Using a Rotary Platform Abraser

1.2.2.16 C1354, Standard Test Method for Strength of Individual Stone Anchorages in Dimension Stone

1.2.2.17 C1515, Standard Guide for Cleaning of Exterior Dimension Stone, Vertical and Horizontal Surfaces, New or Existing

1.2.2.18 C1528, Standard Guide for Selection of Dimension Stone for Exterior Use

1.2.2.19 C1721, Standard Guide for Petrographic Examination of Dimension Stone

1.2.2.20 C1722, Standard Guide for Repair and Restoration of Dimension Stone

1.2.3 Natural Stone Institute (NSI):

1.2.3.1 Membership, Products and Services Directory

1.2.3.2 Dimension Stone Design Manual

1.2.3.3 Additional publications may be available from the NSI Bookstore. Go online at www.naturalstoneinstitute.org

1.2.4 National Building Granite Quarries Association (NBGQA)

1.2.4.1 Specifications for Architectural Granite

1.3 Scope of Included Work

1.3.1 The work to be completed under this contract includes all labor and materials required for the furnishing and installation of all granite work shown or called for on the contract drawings, specifications, and addenda.

1.4 Definition of Terms

1.4.1 The definitions of trade terms used in this specification shall be those published by NSI, NBGQA, or ASTM International.

1.5 Source of Supply

1.5.1 All granite shall be obtained from quarries having adequate capacity and facilities to meet the specified requirements, and from a firm equipped to process the material promptly on order and in strict accord with specifications. The Specifying Authority (architect, designer, engineer, contracting officer, end user, etc.) reserves the right to approve the Material Supplier prior to the award of this contract. Stone and workmanship quality shall be in accordance with Industry Standards and Practices as set forth by the NSI.

1.6 Samples

1.6.1 The Granite Contractor shall submit through the General Contractor, for approval by the Specifying Authority, at least two sets of samples of the various kinds of granite specified. The sample size shall be 1'-0" x 1'-0" (300 mm x 300 mm) minimum and shall represent approximately the finish, texture, and anticipated range of colors to be supplied. One set of approved samples shall be retained by the Specifying Authority, and one set shall be returned to the Granite Supplier for record and guidance. It is noted herein that granite is a natural material and will have intrinsic variations in color, markings, and other characteristics. Depending on granite selected and quantity required, a range mockup may be used to further define the characteristics of the material. Cost of mockup, if required, shall not be included in this section.

1.6.2 Prior to fabrication, an inspection and approval by the Specifying Authority and/or General Contractor and/or End User of the finished slabs is recommended to understand the finish and full range of the material.

1.7 Shop Drawings

1.7.1 The Granite Contractor shall submit through the General Contractor, for approval by the Specifying Authority, sufficient sets of shop drawings, showing general layout, jointing, anchoring, stone thickness, and other pertinent information. These drawings shall show all bedding, bonding, jointing, and anchoring details along with the net piece dimensions of each granite unit. One copy of the approved shop drawings shall be retained by the Specifying Authority, one copy shall be retained by the General Contractor, and one copy returned to the Granite Contractor for fabrication. NO FABRICATION OF GRANITE SHALL BE STARTED UNTIL SUCH DRAWINGS HAVE BEEN FULLY APPROVED AND MARKED AS SUCH. The Granite Contractor shall not be responsible for determining, making, or verifying (1) design, structural, wind, seismic, or other design loads; (2) engineering estimates; (3) plans or specifications; or (4) the types, sizes, or locations of anchors, unless specifically added to the scope of work.

1.8 Defective Work

1.8.1 Any piece of granite showing flaws or imperfections upon receipt at the storage yard or building site shall be referred to the Specifying Authority for determination as to responsibility and decision as to whether it shall be rejected, patched, or redressed for use.

1.9 Repairing Damaged Stone

1.9.1 Chips at the edges or corners may be patched, provided the structural integrity of the stone is not affected and the patch matches the color and finish of the natural stone so that it does not detract from the stone's appearance.

2.0 MATERIALS

2.1 Granite

2.1.1 General: All granite shall be of standard architectural grade, free of cracks, seams, starts, or other traits which may impair its structural integrity or function. Inherent color variations characteristic of the quarry from which it is obtained will be acceptable. Texture and finish shall be within the range of samples approved by the Specifying Authority.

2.1.1.2 ASTM C615 [C97] [C99] [C170] [C241/C1353] [C880] See the chart of applicable ASTM standards and tests in the Appendix.

2.1.2 Schedule: Granite shall be provided as follows:

2.1.2.1 For (*state location on building*) (*state name and color*) granite with a (*type*) finish, supplied by (*name company or list several approved suppliers*).

2.1.2.2 Provide information as in (1) for each different granite/finish combination in the project.

2.1.3 Finishes: Finishes listed in the schedule shall conform with definitions by NSI, NBGQA, or ASTM International.

2.2 Setting Mortar

2.2.1 Mortar for setting shall be Type N, as defined in ASTM C270, Standard Specification for Mortar for Unit Masonry. All mixing, handling, and placing procedures shall be in accordance with ASTM C270.

2.3 Pointing Mortar

2.3.1 Mortar for pointing shall be Type N, as defined in ASTM C270 (Standard Specification for Mortar for Unit Masonry). All mixing, handling, and placing procedures shall be in accordance with ASTM C270.

2.4 Sealants and Backup Material (If Applicable)

2.4.1 Where specified, (*state type or name of sealant*) shall be used for the sealing of joints. The backup material used with the sealant shall be (*identify material*).

2.5 Anchors, Cramps, and Dowels

2.5.1 All anchorage components shall be of 300 Series stainless steel (refer to ASTM A666) or aluminum (refer to ASTM B221) with strength and durability properties meeting or exceeding those of 6063-T6. Anchor types and assemblies shall comply with ASTM C1242. Reliance on adhesives alone for material attachment will not be permitted.

3.0 FABRICATION

3.1 Beds and Joints

3.1.1 Bed and joint width shall be determined by analysis of anticipated building movements and designed to accommodate such movements without inducing undue stresses in the stone panels or joint filler materials. Expansion joints shall be designed and located to accommodate larger movements.

3.2 Backs of Pieces

3.2.1 Backs of pieces shall be sawn or roughly dressed to approximately true planes. Back surfaces shall be free of any matter that may create staining.

3.3 Moldings, Washes, and Drips

3.3.1 Moldings, washes, and drips shall be constant in profile throughout their entire length, in strict conformity with details shown on approved shop drawings. The finish quality on these surfaces shall match the finish quality of the flat surfaces on the building.

3.4 Back-checking and Fitting to Structure or Frame

3.4.1 Stone coming in contact with structural work shall be back-checked as indicated on the approved shop drawings. Stones resting on structural work shall have beds shaped to fit the supports as required.

3.4.2 Maintain a minimum of 1" (25 mm) between stone backs and adjacent structure. (Note: many bolted connections will require more space than this; 2"(50 mm) space may be more desirable. Large-scale details should illustrate and control these conditions.)

3.5 Cutting for Anchoring, Supporting, and Lifting Devices

3.5.1 Holes and sinkages shall be cut in stones for all anchors, cramps, dowels, and other tieback and support devices per industry standard practice or approved shop drawings. However, additional anchor holes may be drilled at job site by Granite Contractor to facilitate alignment.

3.5.2 No holes or sinkages will be provided for Granite Contractor's handling devices unless arrangement for this service is made by the Granite Contractor with the Granite Fabricator.

[NOTE: It is not recommended that lewis pins be used for stones less than 3½" (90 mm) thick.]

3.6 Cutting and Drilling for Other Trades

3.6.1 Any miscellaneous cutting and drilling of stone necessary to accommodate other trades will be done by the Granite Fabricator only when necessary information is furnished in time to be shown on the shop drawings and details, and when work can be executed before fabrication. Cutting and fitting, due to job site conditions, will be the responsibility of the Granite Contractor.

3.6.2 Incidental cutting such as for window frame clips, etc., which is normally not considered to be the responsibility of the Stone Supplier, will be provided only by arrangement by the General Contractor and Granite Contractor with the Granite Fabricator.

3.7 Carving and Models

3.7.1 All carving shall be done by skilled Stone Carvers in a correct and artistic manner, in strict accordance with the spirit and intent of the approved shop drawing, or from models furnished or approved by the Specifying Authority.

4.0 SHIPPING AND HANDLING

4.1 Packing and Loading

4.1.1 Finished granite shall be carefully packed and loaded for shipment using all reasonable and customary precautions against damage in transit. No material which may cause staining or discoloration shall be used for blocking or packing. (See "6.2 Protection of Finished Work" in this chapter.)

4.2 Site Storage

4.2.1 Upon receipt at the building site, stone shall remain in the factory-prepared bundles until beginning of the installation. Bundles shall be staged in an area which is least susceptible to damage from ongoing construction activity. Once unbundled, the granite shall be stacked on timber or platforms at least 2" (50 mm) above the ground, and the utmost care shall be taken to prevent staining or impact damage of the granite. If storage is to be prolonged, polyethylene or other suitable, nonstaining film shall be placed between any wood and finished surfaces of the granite.

4.2.2 Any holes or slots in the granite which are capable of collecting water shall be temporarily covered or plugged to prevent freezing of collected water. Such covers or plugs are to be removed immediately prior to installation of the piece.

5.0 INSTALLATION

5.1 General Installation

5.1.1 Installation shall be accomplished with competent, experienced Stone Setters, in accordance with the approved shop drawings.

5.1.2 All granite pieces shall be identified with a unique piece number corresponding with the number on the shop drawings. Interchanging of numbered pieces is not permitted.

5.1.3 Granite shall be free of any ice or frost at time of installation. Salt shall not be used for the purpose of melting ice, frost, or snow on the granite pieces. Adequate protection measures shall be taken to ensure that exposed surfaces of the stone shall be kept free of mortar at all times.

5.2 Mortar Setting of Granite

5.2.1 Clean base materials to remove dirt or other foreign matter.

5.2.2 Saturate concrete substrate several hours prior to setting granite. Prepare and place mortar in accordance with ASTM C270. Thoroughly wet stones prior to setting in mortar bed. Apply neat cement parge of approximate 1/16" (1.5 mm) thickness to granite units prior to placing on mortar bed. Tamp stones into place using a rubber or plastic mallet to obtain full contact with the setting bed and proper stone unit alignment.

5.3 Mortar Joints

5.3.1 Mortar joints shall be raked out to a depth of ½" to ¾" (12 to 20 mm). Apply pointing mortar in layers not exceeding 3/8" (10 mm) and allow each layer to get hard to the touch before the next layer is applied. Tool finished joints with a concave tool having a diameter approximately 1/8" (3 mm) greater than the joint width.

5.3.2 Care shall be taken to keep expansion joints free of mortar, which would compromise their function.

5.4 Anchorage

5.4.1 All granite shall be anchored in accordance with the approved shop drawings.

5.4.2 To the furthest extent possible, all anchor preparations in granite units shall be shop-applied.

5.4.3 All anchorage devices and anchor hole/slot fillers shall be in accordance with ASTM C1242. Care must be taken to ensure that any holes capable of retaining water are filled after use to prevent water collection and freezing.

5.5 Sealant Joints

5.5.1 Where so specified, joints requiring sealant shall be first filled with a closed-cell ethafoam rope backer rod. The backer rod shall be installed to a depth that provides optimum sealant profile after tooling.

5.5.2 If recommended by the Sealant Manufacturer, primers shall be applied to the substrate surfaces according to the manufacturer's directions prior to application of the joint sealant.

5.6 Expansion Joints

5.6.1 It is not the intent of this specification to make control or expansion-joint recommendations for a specific project. The Specifying Authority must specify control or expansion joints and show locations and details on drawings.

5.7 Caulking

5.7.1 Where so specified, joints shall be pointed with the sealant(s) specified in Section 2.4 after first installing the specified backup material and applying a primer if required, all in strict accordance with the printed instructions of the Sealant Manufacturer.

5.7.2 All sealants shall be tooled to ensure maximum adhesion to the contact surfaces.

5.8 Weep Tubes

5.8.1 Plastic or other weep tubes shall be placed in joints where moisture may accumulate within the wall, such as at base of cavity, continuous angles, flashing, etc., or as shown on architectural drawings.

6.0 CLEANING AND PROTECTION

6.1 Cleaning

6.1.1 Granite shall be cleaned after installation and all pointing or caulking is complete. All dirt, excess mortar, weld splatter, stains, and other defacements shall be removed.

6.1.2 All cleaning methods shall be in accordance with ASTM C1515.

6.2 Protection of Finished Work

6.2.1 Granite installation in progress shall be protected with film or fabric tarps secured over the work.

6.2.2 After the granite is installed, it shall be the responsibility of the General Contractor to properly and adequately protect it from damage until all trades are finished. This responsibility includes the stone cleaning costs prior to the required final inspection. Where lumber is required for protection, care should be taken to protect the granite from staining by the lumber, using plastic film or other suitable materials. Any fasteners used in construction of temporary protection fixtures shall be corrosion resistant.

6.2.3 Finishes commonly available are defined as follows:

6.2.3.1 Polished: Mirror gloss, with sharp reflections.

6.2.3.2 Honed: Dull sheen, without reflections.

6.2.3.3 Fine Rubbed: Smooth and free from scratches; no sheen.

6.2.3.4 Rubbed: Plain surface with occasional slight "trails" or scratches.

6.2.3.5 Shot Ground: Plain surface with pronounced circular markings or "trails" having no regular pattern.

6.2.3.6 Thermal (Flamed): Finish produced by application of high-temperature flame to the surface. Large surfaces may have shadow lines caused by overlapping of the torch. This finish will vary in texture and depth between different types of granite, as the finish is largely dependent upon the granite structure of the stone.

6.2.3.7 Sandblasted, Coarse Stippled: Coarse plain surface produced by blasting with an abrasive; coarseness varies with type of preparatory finish and grain structure of the granite.

6.2.3.8 Sandblasted, Fine Stippled: Plain surface, slightly pebbled, with occasional slight "trails" or scratches.

6.2.3.9 Bush-hammered, 8-cut: Fine bush-hammered finish, interrupted by parallel markings not over 3/32" (2.5 mm) apart. A corrugated finish, smoother near arris lines and on small surfaces.

6.2.3.10 Bush-hammered, 6-cut: Medium bush-hammered finish, similar to but coarser than 8-cut, with markings not more than 1/8" (3 mm) apart.

6.2.3.11 Bush-hammered, 4-cut: Coarse bush-hammered finish with same characteristics as 6-cut, but with markings not more than 7/32" (5.5 mm) apart.

6.2.3.12 Sawn: Relatively plain surface with texture ranging from wire sawn (a close approximation of a rubbed finish), to shot sawn, with scorings 3/32" (2.5 mm) in depth. Gang saws produce parallel scorings; rotary or circular saws make circular scorings. Shot-sawn surfaces should be cleaned to remove all rust stains.

6.2.3.13 Split Faced: Stone on which the face has been broken to an approximate plane.

6.2.3.14 Rock (pitch) Faced: Similar to split faced, except that the face of the stone is pitched to a given line and plane producing a bold appearance rather than the comparatively straight face obtained in split face.

6.2.3.15 Jet Washed: After certain treatment finishes on stone, such as flaming, a high pressure jet wash can be used to assist in cleaning the stone and bringing back more color to the stone. Some producers have the machinery to use high pressure water with additives which gives a jet washed finish that looks like a flamed finish, yet maintains the color in the stone.

6.2.4 Minimum Thickness: The suggested minimum thickness for all exterior veneer is as follows:

6.2.4.1 Percussion produced finishes, such as **bush-hammered** (sometimes referred to as a **pointed finish**), require a 1¼" (30 mm) thick slab minimum to apply.

6.2.4.2 Other finishes can usually be applied to any thickness slab, with the exception of some granites not being able to withstand thermal finishing processes in thicknesses less than 1¼".

6.2.4.3 Determination of proper stone thickness must be evaluated using the following criteria:

- Piece Size.
- Final Face Finish.
- Anchoring Detail.
- Structural Design Load Requirements.
- Flexural Strength of the Granite.

6.2.5 Minimum safety factors of 3 to 1 minimum on granite flexural stresses and 4 to 1 minimum on anchorage components in granite are recommended.

6.2.6 Ashlar or veneer used as a facing requires a setting space of at least 1" (25 mm), as measured from the nominal thickness of the piece.

6.2.7 Bed and Joint Width. The minimum recommended bed and joint width is ¼" (6 mm) for exteriors and 1/8" (3 mm) for interiors.

6.2.8 Sawn backs. Because of physical characteristics, most granites cannot be split to a thickness less than 1/3 of the lesser face dimension. Consequently, sawn backs (see 3.4 in this chapter) should be specified for most veneers, and are frequently specified also for thicker ashlar, because of design considerations.

6.2.9 Staining. Granite should be protected from wet (green) wood, oils, mud, construction waste, and asphalt compounds. Contact Fabricator or Granite Contractor for proper remedies to staining problems that occur.

PRODUCT DESCRIPTION – Granite

1.0 GEOLOGICAL CLASSIFICATION

1.1 The American Geological Institute (AGI) defines granite as an intrusive igneous rock (cooled slowly in the deep upper part of the Earth's crust) composed of 25% to 35% quartz and over 50% potassium- and sodium-rich feldspars, with a common accessory mineral of less than 20%, usually muscovite (clear mica), biotite (dark, iron-bearing mica), or hornblende (amphibole).

1.2 The commercial stone industry, depending on the supplier or organization, loosely accepts various granite-like stones under the label of "granite." These include, among others, banded or massive, nonbanded gneiss, and a few quartz-based stones. Such stones are marketed as "granitelike" or "granitoid," though they are not true granite.[1] Gneisses, high level metamorphic stone, are included in the granite category by commercial interests.

1.3 The quartz-based stones are definitely not granite, but rather the silica-cemented sedimentary stone quartzite or its metamorphic equivalent, orthoquartzite. Quartzite, and especially orthoquartzite, have a distinct cleft or cleavage at a mica-rich parting. Knowing the difference between true granite and granitelike stone helps the stone industry professional to understand the physical properties, performance, and ultimately, the comparative quality of these natural materials.

1.4 Granite, as defined by the AGI, usually has three to four basic mineral components:

1.4.1 Quartz (SiO_2 ±25-35%), appears as irregular, watery-looking, or translucent grains.

1.4.2 Orthoclase Feldspar ($KAlSi_3O_8$ ≈20-80%). In most, but not all, commercial, geologic granites, the light-colored minerals, white- to flesh-colored are orthoclase feldspar.

1.4.3 Plagioclase Feldspar ($NaAlSi_3O_8$ to $CaAl_2Si_3O_8$ ≈20-80%) features darker gray to bluish grains, with some grains exhibiting fine, grooved lines and/or an iridescent sheen. Sometimes the mineral is a light, creamy color, nearly indistinguishable from orthoclase, except for the occasional presence of the fine lines.

[1] The following terms are derivations of the word *granite*, which are now obsolete because their definitions have become obscured and imprecise: *granide, granilite, granitelle, granitello, granitine, and granolite*. The use of these terms commercially is not recommended.

1.4.4 Dark accessory minerals (→20%) biotite and hornblende are complex silicates with all the elements in quartz, orthoclase feldspar, and plagioclase feldspar, plus iron and magnesium, which gives these minerals their dark color. Magnetite (Fe_3O_2) is often a trace mineral (±2-4%) in granite, and easily recognized by its strongly magnetic property. It, too, is black and opaque. Magnetite has a hardness rating of H=6, polishes well, has a metallic appearance, and is opaque (i.e., it does not transmit light even when very thin).

1.4.5 All of these granitic minerals have a Mohs Scale[2] hardness rating of H=7 or H=6 with the exception of biotite, which has a variable hardness of 2.5 to 4.5, depending on the angle of the polished surface in relation to the edges of the "books" of sheets that biotite mica crystals exhibit. Thus, biotite does not polish well and appears as small, rough spots on a polished surface. This is not a flaw in either the stone or polishing, but simply the way biotite is—softer than all other minerals in granite. Biotite hardness makes little difference in most applications, as the overwhelmingly dominant feldspar and quartz minerals are much harder. Biotite "plucks" slightly in polishing, but generally not when in use.

1.5 Granitization. Earth scientists came to realize that much granite is associated with metamorphic stone of extremely high levels. These are often **massive, nonbanded granites** with no noticeable mineral segregation into bands. Many examples come from, but are not limited to, some Far Eastern locations and Sri Lanka. These often have a strong presence of **red garnet**[3], a mineral indicative of metamorphism. Geologic granite, in terms of mineral content, can be formed by **granitization**, a true metamorphic process by which a solid rock is converted to granite by entry and/or exit of material or change of chemical components without going through a liquid or molten state.

1.6 Gneiss, a true metamorphic stone that exhibits strong mineral segregation in the form of contorted bands indicating metamorphic origin, is universally included in the granite group by the stone industry. **Banded gneiss** is a classical rock end member of the metamorphic process of high pressure, time, temperature, and the presence of fluids that begins with the sedimentary rock shale and proceeds through slate, to phyllite, then schist and finally, banded gneiss—from low to high levels of metamorphic rank.

2.0 COLOR AND VEINING

2.1 The color of a granite is governed largely by that of the feldspar, usually the most abundant mineral. However, it may be modified to some extent by the quartz, hornblende, or mica, if considerable amounts are present. Almost white, light gray, dark gray, green, pink, and red granites are common. Uniform color distribution is usually a desirable feature. Lighter-colored granites are the average composition of continental crust, while darker granites are more likely associated with or influenced by nearby oceanic composition stone.

2.2 Dark, granular igneous rocks, classified petrographically as anorthosite, basalt, diabase, diorite, and gabbro, are also used as dimension stone, and are classed commercially as "black granite."

[2] See Appendix for information about the Mohs Scale of mineral hardness.

[3] Garnet is most often noticeable when red, but also occurs in light green and light yellow.

3.0 TEXTURE

3.1 The term "texture," as applied to granite, means size, degree of uniformity, and arrangement of constituent minerals.

3.2 The texture of granite is determined by the size and arrangement of mineral grains. Uniform grain size usually is demanded in commercial granites. Grain size varies greatly in different types of granite.

3.3 Uniform distribution of the minerals is as important as uniform grain size. Light and dark minerals should be distributed evenly throughout the rock mass, for this gives uniform color and texture. Many commercial deposits display remarkable homogeneity; the rock may not vary in color or texture for many feet, either vertically or horizontally.

4.0 FINISHES

4.1 Granite surfaces may be finished in a number of ways. See the listing of typical finishes on page 5-7 of this chapter.

5.0 THICKNESS

5.1 Standard nominal thicknesses for granite are generally 3/8", ¾", 1¼", 1½", 2", 3", 4", 6", and 8" (10 mm, 20 mm, 30 mm, 40 mm, 50 mm, 75 mm, 100 mm, 150 mm, and 200 mm).

6.0 SIZES

6.1 Granite is a product of nature with hundreds of varieties available, each possessing unique characteristics. Little can be done to alter the condition in which nature presents these varieties to us. Therefore, size may become a limiting factor to consider in the selection of a particular granite.

6.2 A jointing scheme that permits the use of smaller sizes of granite will greatly facilitate selection and delivery. The NSI Member/Supplier should assist in final approval.

7.0 PRODUCT SAMPLING

7.1 Granites are formed by nature; thus there are variations in the tonal qualities of the stones. However, it is these natural differences that make granites unique, valuable, and highly desirable. Because of these variations, selection of a granite should never be made on the basis of one sample only. It is recommended that selection be based on viewing sufficient samples to show the complete range of colors of the desired stone. NSI Members can provide these range samples.

8.0 PROPER USAGE TIPS

8.1 Recommendation for commercial floors:

8.1.1 Minimum ¾" (20 mm) thickness.

8.1.2 A honed finish.

8.1.3 A minimum hardness value of 25 as measured by ASTM C241/C1353.

8.2 Avoid the use of gypsum or molding plaster setting spots for the installation of stone.

9.0 VENEER CUTTING

9.1 Quarry blocks are reduced to slabs by a gang saw or wire saw. The gang saw consists of a series of steel blades set parallel in a frame that moves forward and backward. They are fed a cutting abrasive in a stream of water.

TECHNICAL DATA – Granite

1.0 PROPERTIES OF GRANITE DIMENSION STONE

1.1 In centuries past, relatively little importance was attached to the ultimate physical capabilities of most building materials. Rule of thumb was a common structural design criterion. As a result, the widely used materials of the day, for the most part natural rather than manmade materials, were seldom stressed to their ultimate limits.

1.2 In present-day construction, this is far from being true. Performance requirements are daily becoming more demanding. In striving for taller structures, greater spans, firmer foundations, thinner walls and floors, stronger frames, and generally more efficient buildings with more usable space, today's Architects and Engineers must get the most out of the materials with which they work.

1.3 Granite is a product of nature and not always subject to the rules of consistent behavior that may apply to manufactured building materials.

1.4 Physical property values of stone may, however, be measured using the standard test methods approved by the Dimension Stone Committee C18 of ASTM International. The NSI and Member companies are represented on the ASTM committee and are active in its technical work of establishing proper test methods and specifications consistent with the latest technology.

1.5 Final design should always be based on specific values for the stone variety ultimately to be installed. These values may be obtained from the Stone Supplier. All materials are not suitable for all uses. In order to avoid mistaken selections, tests for material values should be made prior to final material selection.

1.6 Physical Properties of Granite
(This historical data and information are provided only as a guideline. Recommended minimums or maximums are established and provided by ASTM International.)*

<u>Property</u> **<u>Range of Values</u>**

Compressive Strength (C170)
lbs/in² 4,700-60,000
Recommended (min): 19,000

Flexural Strength (C880)
lbs/in² 700-5,500
Recommended (min): 1,200

Modulus of Elasticity (C1352)** (in millions)
lbs/in² 2.0-10.0

Density (C97), lb/ft^3 150-200
Recommended (min): 160

Coefficient of Thermal Expansion,
in/in/°F.......................4.7 x 10^{-6} average

Modulus of Rupture (C99)
lbs/in² 1,000-3,000
Recommended (min): 1,500

Absorption % (by weight) 0.02-0.40
Recommended (max): 0.40

Abrasion Resistance H_a..................... 20-90
Recommended (min): 25

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* Test methods described in current ASTM standards.
** Also known as Young's Modulus.

2.0 STRENGTH (ASTM C99, C170, C880)

2.1 Values for modulus of rupture, compressive strength, and flexural strength are ascertained by testing specimens of granite under laboratory conditions until they fail.

The C170 procedure is used for determining the compressive strength of a granite specimen. A cube or cylinder of 2" to 3" in all dimensions is crushed under a hydraulic ram and the compressive strength is calculated as the total load divided by the area of the specimen. Compressive strength of granite is seldom a factor in design, as the compressive strength is many times the anticipated compressive stresses. This value is most often used for comparison of stone types or as a general strength benchmark for the material.

2.2 The C99 and C880 procedures are both used for determining bending strength. The C99 procedure is much older, and the test protocol is seldom modified, so data obtained from this test has some value for comparison to historical data or between different stone types. As a measure of resistance to bending loads, it is not considered to be a representative modeling of panel behaviors in building applications. The ratio of beam length to beam depth is very small, resulting in what is referred to as "thick beam behavior." The results of this test are usually artificially high due to the thick beam behavior and high shear stresses in the loaded specimen

2.3 The C880 procedure is much preferred when testing granite for resistance to bending stresses. The procedure calls for a span-to-depth ratio of 10:1, which eliminates the influence of thick beam behavior. Furthermore, the test allows specimen modification to allow the use of actual building cladding thickness and actual finish, which provides a better representation of the stone behavior in the cladding application. This procedure also uses a four-point bending fixture, which provides a constant stress region over approximately 50% of the specimen. This provides a greater chance that the weakest point of the specimen will fall within this region and produce more reliable data for design use.

3.0 FIRE RESISTANCE

3.1 Stone is not combustible according to underwriters' ratings, and therefore is considered a fire-resistant material. Because of its thermal conductivity, heat transfer is fairly rapid. Most stone is not considered a highly rated thermal insulator.

3.2 Underwriters' fire-resistance ratings evaluate whether or not a material will burn, as well as how long it will keep surrounding combustible materials from reaching temperatures that will cause them to ignite. Methods of estimating fire-resistance periods of masonry walls and partitions utilizing component laminae are given in "Fire Resistance Classifications of Building Construction," BMS92, National Bureau of Standards.

4.0 ABRASION RESISTANCE (ASTM C241/C1353)

4.1 Abrasion resistance is a property of stone that should be tested per ASTM C241/C1353 to provide an indication of the stone's wearing qualities when exposed to foot traffic.

4.2 The hardness and uniform wearing qualities of most granites make them extremely desirable and economically practical for floors and stairs. Varieties with an abrasive hardness (H_a/I_w) of 25 or more, as measured by ASTM C241/C1353 tests, are recommended for use as flooring subject to normal foot traffic.

5.0 FACTORS AFFECTING PROPERTIES

5.1 The ultimate test of a building material is its ability to have and maintain the necessary structural strength, as well as beauty of appearance and low cost of maintenance, over the useful life of the structure. Experience has proven that stone meets this test as few other building materials can. Studies have shown that the durability of most stones is little affected by cycles of weather. This is because most have a low rate of moisture absorption.

6.0 SAFETY FACTORS

6.1 Good engineering practice requires that allowable design stress must provide a margin of safety in any structural element. As a necessary precaution against such conditions as wind, ice, snow, impact, temperature changes, and imperfect workmanship, these allowable stresses must be smaller than those that produce failure.

6.2 Within the accepted limits of safe design practice, the closer the allowable load is to the ultimate failure load in a structure, the more efficient is the use of the material and the less the cost of the construction.

6.3 Contemporary building design does not usually employ granite as part of the structural frame, but rather as an independent unit, a curtain wall, or veneer. Therefore, the primary concern in such cases is with wind or seismic loads. Safety factors of 3.0 for the granite and 4.0 for anchorage assemblies are recommended. Where the stone is to be subjected to concentrated loading, such as stair treads or lintels supported only at the ends, a factor of 4.0 or greater should be used.

6.4 These safety factors may be adjusted using sound engineering principles and judgment.

6.5 As buildings become taller and individual stone slab veneer becomes larger in area, the lateral forces due to wind loads must be considered. Wind tunnel tests are often used on major structures to determine wind dynamics and force magnitude.

7.0 SEISMIC CONSIDERATIONS

7.1 Seismic considerations generally require that low buildings be stiff, and that tall buildings be relatively flexible. Design of connections must account for seismically induced horizontal loading. Local building codes vary and must always be checked to determine specific requirements for each area. The National Bureau of Standards has published two documents on the topic: "Earthquake Resistant Masonry Construction," NBS Science Series 106; and "Abnormal Loading on Buildings and Progressive Collapse: An Annotated Bibliography," NBS Science Series 67. The U.S. Army Corps of Engineers has also published TM 5-809-10, "Seismic Design for Buildings."

8.0 EFFLORESCENCE AND STAINING

8.1 Efflorescence is a salt deposit, usually white in color, which appears on exterior surfaces of masonry walls. The efflorescence-producing salts found in masonry are usually sulfates of sodium, potassium, magnesium, calcium, and iron. Salts that are chlorides of sodium, calcium, and potassium will sometimes appear, but they are so highly soluble in water that they will be washed off by rain.

8.2 The water-soluble salts causing efflorescence come from other materials in the wall. The salts exist in small amounts and are leached to the surface by water percolating through the wall. The most feasible means of prevention is to stop the entrance of large amounts of water. Absorption from the face will not cause efflorescence unless there are open joints.

8.3 Some of the salt crystals may form in the stone's pores near the surface. Crystal growth (recrystallization) in the pores can cause stress on the walls of the pores and cause the stone to flake off. If the conditions bringing about this action persist, scaling may continue and flake off, one layer after another. For this to happen, large amounts of water must enter the wall and contain large amounts of salts.

8.4 Research indicates that staining and discoloration occurring on new buildings are caused by the action of water percolating through concrete, from which soluble alkali salts are leached. The salts are then carried by the water through the stone, where partially oxidized organic matter is picked up. This is then transported to the surface of the stone, where it is deposited as a stain as the water evaporates.

8.5 This staining phenomenon is similar to efflorescence, except that it involves organic material. It does not harm the stone, other than leaving an objectionable appearance during or soon after erection. However, if left alone, the stain is removed naturally by the action of the elements, usually in the course of a few months.

8.6 Granite is one of the most durable of all building materials because the quartz and feldspar in it are highly resistant to normal weathering. Feldspars will, however, disintegrate slowly if exposed to an acid-bearing atmosphere, as in regions where hydrocarbons are prevalent. All granites disintegrate very slowly under repeated contraction and expansion due to diurnal and seasonal temperature changes, but under ordinary atmospheric conditions, granite will endure for years without significant change in color or durability.

9.0 PITTING IN GRANITE

9.1 Granites are made up of several different minerals, each having a different hardness. They can contain feldspars, biotites, amphiboles, ferrous titanium oxides, and other mineral combinations. For comparison, on the Mohs Scale, diamonds are the hardest substance, with a hardness of 10. By comparison, feldspars have a hardness of 6.5 to 7, which is still quite hard and durable. Biotites, the black minerals throughout the slab, are by contrast very soft (2.5 to 4.5) and flake easily. All true granites have biotite in their composition. Because biotites are soft and flaky, the first few layers are removed during the polishing process, causing pits. Some granites have more biotites throughout their composition than others. The higher the biotite content of the stone, the more pits it will have. All polished igneous/metamorphic rock will have varying degrees of pits, depending on the amount of biotites, muscovite, and phlogopite.

9.2 Pitting does not make the granite less durable or of inferior quality. Pits exist in all granites and should be expected when dealing with a natural, polished stone containing several types of minerals with different hardnesses.

10.0 BACTERIA

10.1 Bacteria requires several things in order to thrive and grow: oxygen, water, sunlight, nutrients, and a substrate to form on. The minerals in granite are toxic to bacteria. As a result, there is no habitable environment for the bacteria to live and grow on a granite surface.

11.0 RADON AND GRANITE

11.1 **Radon** is a naturally occurring gas generated by the decay of trace amounts of uranium found in the Earth's crust. It is an unstable gas that quickly breaks down and dissipates in the air.

11.2 Radon is measured in units called picocuries per liter (pCi/l). A picocurie is one trillionth (10^{-12}) of a curie, which is the amount of radioactivity emitted by a gram of radium. The U.S. Environmental Protection Agency has established 4 pCi/l as the standard for indoor air; 20 pCi/l represents the maximum amount of exposure to radium that is now allowed by U.S. regulations.

11.3 **Measurements of Radon from Granite Countertops.** "Over 500 measurements of radon emissions from granite have been published in the peer reviewed scientific literature.[4]" This study and other radon and radiation information and test results may be found at https://www.naturalstoneinstitute.org/radon/. None of the research found a single stone that would be a health risk to homeowners.

12.0 CAUTION ABOUT ENHANCED GRANITE

12.1 Several methodologies are being used to enhance varieties of granite. Caution, in some cases avoidance, should be exercised for the following methodologies:

12.1.1 Tinting. The adding of color dyes in sealer-type products to make the color of the stone conform to a more pleasing one. This is a short term "fix," as the color will bleed out from the stone when it is exposed to the sun, or is otherwise used.

12.1.2 Epoxy (polyester) Filling. Several varieties of over-burdened stones that do not meet the ASTM criteria for Granite Dimension Stone are being filled with epoxy or polyester resins (similar to the typical filling techniques employed in travertine) and marketed for a variety of uses. This type of stone is generally not suitable for wet or exterior applications.

12.1.3 Resin filling. This process is being performed to reduce the effects of "pits" in granite. Once treated, these stones are required to be marketed as "filled." Verify with the Producer and the End User that the type of fill being used is both safe and acceptable for the application intended.

[4] Natural Stone Countertops and Radon, 2008. Environmental Health & Engineering, publisher.

NOTES:

LIMESTONE

1.0 GENERAL

1.1 Related Documents

1.1.1 Drawings and general provisions, including General and Supplementary Conditions of the Contract and Division I Specification sections, apply to this section.

1.2 Applicable Publications

1.2.1 The following publications listed here and referred to thereafter by alphanumeric code designation only, form a part of this specification to the extent indicated by the references thereto:

1.2.2 ASTM International (ASTM):

1.2.2.1 C568, Standard Specification for Limestone Dimension Stone

1.2.2.2 C97, Standard Test Methods for Absorption and Bulk Specific Gravity of Dimension Stone

1.2.2.3 C99, Standard Test Method for Modulus of Rupture of Dimension Stone

1.2.2.4 C170, Standard Test Method for Compressive Strength of Dimension Stone

1.2.2.5 C241/C1353, Standard Test Method for Abrasion Resistance of Stone Subjected to Foot Traffic

1.2.2.6 C880, Standard Test Method for Flexural Strength of Dimension Stone

1.2.3 Natural Stone Institute (NSI):

1.2.3.1 Membership, Products, and Services Directory

1.2.3.2 Dimension Stone Design Manual

1.2.3.3 Additional publications may be available from the NSI Bookstore. Go online at www.naturalstoneinstitute.org.

1.2.4 Indiana Limestone Institute of America (ILI)

1.2.4.1 Indiana Limestone Handbook

1.3 Scope of Included Work

1.3.1 The work to be completed under this contract includes all labor and materials required for the furnishing and installation of all limestone work shown or called for on the contract drawings, specifications, and addenda.

1.4 Definition of Terms

1.4.1 The definitions of trade terms used in this specification shall be those published by the NSI, ILI, or ASTM International.

1.5 Source of Supply

1.5.1 All limestone shall be obtained from quarries having adequate capacity and facilities to meet the specified requirements, and from a firm equipped to process the material promptly on order and in strict accord with specifications. The Specifying Authority (architect, designer, engineer, contracting officer, end user etc.) reserves the right to approve the Material Supplier prior to the award of this contract. Stone and workmanship quality shall be in accordance with Industry Standards and Practices as set forth by the NSI.

1.6 Samples

1.6.1 The Limestone Contractor shall submit through the General Contractor, for approval by the Specifying Authority, at least two sets of samples of the various kinds of limestone specified. The sample size shall be 1'-0" x 1'-0" (300 mm x 300 mm) and shall represent approximately the finish, texture, and anticipated range of color to be supplied. One set of approved samples shall be retained by the Specifying Authority, and one set shall be returned to the Limestone Supplier for his/her record and guidance. It is noted herein that limestone is a natural material and will have intrinsic variations in color, markings, and other characteristics. Depending on limestone selected and quantity required, a range mockup may be used to further define the characteristics of the material. Cost of mockup, if required, shall not be included in this section.

1.6.2 Prior to fabrication, an inspection and approval by the Specifying Authority (and/or General Contractor and/or End User) of a representative number of the finished slabs may be desirable to understand the finish and full range of the material.

1.7 Shop Drawings

1.7.1 The Limestone Contractor shall submit through the General Contractor, for approval by the Specifying Authority, sufficient sets of shop drawings, showing general layout, jointing, anchoring, stone thickness, and other pertinent information. These drawings shall show all bedding, bonding, jointing, and anchoring details along with the net piece dimensions of each limestone unit. One copy of the approved shop drawings shall be retained by the Specifying Authority, one copy shall be retained by the General Contractor, and one copy returned to the Limestone Contractor for fabrication. All jointing as shown by the Specifying Authority on the contract drawings shall be followed, unless modifications are agreed upon in writing, or indicated upon the approved shop drawings. If the contract drawings do not show the intent of the jointing, it will be the fabricator's responsibility to establish the jointing in accordance with industry standards and practices.

1.7.2 The cutting and setting drawings shall be based upon and follow the drawings and full size details prepared by the Specifying Authority except where it is agreed in writing or shown on the approved shop drawings that changes be made. Each stone indicated on the setting drawings shall bear the corresponding number marked on an unexposed surface. Provision for the anchoring, doweling, and cramping of work, in keeping with standard practices, and for the support of stone by shelf angles and loose steel, etc., when required, shall be clearly indicated on the shop drawings. NO FABRICATION OF LIMESTONE SHALL BE STARTED UNTIL SUCH DRAWINGS HAVE BEEN FULLY APPROVED AND MARKED AS SUCH. The Limestone Contractor shall not be responsible for determining, making, or verifying (1) design, structural, wind, seismic, or other design loads; (2) engineering estimates; (3) plans or specifications; or (4) the types, sizes, or locations of anchors, unless specifically added to the scope of work.

1.8 Defective Work

1.8.1 Any piece of limestone showing flaws or imperfections upon receipt at the storage yard or building site shall be referred to the Specifying Authority for determination as to responsibility and decision as to whether it shall be rejected, patched, or redressed for use.

1.9 Repairing Damaged Stone

1.9.1 Repair of stone is an accepted practice and will be permitted. Some chipping is expected; repair of small chips is not required if it does not detract from the overall appearance of the work, or impair the effectiveness of the mortar or sealant. The criteria for acceptance of chips and repairs will be per standards and practices of the industry unless other criteria are mutually agreed upon in writing by the Limestone Contractor and the Specifying Authority.

2.0 MATERIALS

2.1 Limestone

2.1.1 General: All limestone shall be of standard architectural grade, free of cracks, seams, or other traits which may impair its structural integrity or function. Inherent color variations characteristic of the quarry from which it is obtained will be acceptable. Texture and finish shall be approved by the Specifying Authority as shown in the samples.

2.1.2 ASTM C568 [C97] [C99] [C170] [C241/C1353] [C880] See the chart of applicable ASTM standards and tests in the Appendix.

2.1.3 Schedule: Limestone shall be provided as follows:

2.1.3.1 For (*state location on building*) (state name, grade (*if applicable*), and (*color*) limestone with a (*type*) finish, supplied by (*name company or list several approved suppliers*).

2.1.3.2 Provide information as in (1) for each different limestone/finish combination in the project.

2.1.4 Finishes: Finishes listed in the schedule shall conform with definitions by the NSI, ILI, or ASTM International.

2.2 Setting Mortar

2.2.1 Cement used with limestone shall be white portland cement, ASTM C150, or white masonry cement, ASTM C91. Non-staining cement (at the present time there are few masonry cement mortars produced labeled nonstaining) shall contain not more than 0.03% of water-soluble alkali when determined in accordance with procedure #15, calculation #16 of ASTM C91 or Federal Specification SS-C181C. However, if a large amount of normal cement has been used in the backup (underlayment) material, and if an effective water barrier has not been provided between the stone and the backup or underlayment, the use of nonstaining cement may not prevent all discoloration. Discoloration will disappear as the stone dries.

2.2.2 The addition of hydrated lime or like amounts of ground limestone may increase initial shrinkage, but the improved working qualities and the water retention will enable the mixture to adjust to the initial shrinkage and will give good bonding strength in both horizontal and vertical joints. Hydrated lime should conform to ASTM C207 Type S.

2.2.3 Sand should comply with ASTM C144.

2.2.4 Mixing water must be potable quality.

2.2.5 Mortar mixes vary in proportions from a hard mixture (1:1:4) to a flexible mixture (1:1:9). Hard mixes can be expected to set up stress conditions between the stone and mortar in joints since the thermal coefficient of mortar expansion is greater than that of stone. In paving installations, stress is often sufficient to break the bond between the stone and the substrate. Flexible mortars are not suitable for exterior work.

2.2.6 The Indiana Limestone Institute recommends a 1:1:6 or Type N mortar be used with Indiana limestone.

2.3 Pointing Mortar

2.3.1 Pointing mortar shall be composed of one part (white or other) portland cement, one part hydrated lime, and six parts white sand passing a #16 sieve.

2.4 Sealants and Backup Material (if Applicable)

2.4.1 Where specified, (state type or name of sealant) shall be used for the pointing of joints. The backup material used with the sealant shall be (identify material).

2.5 Anchors, Cramps, and Dowels

2.5.1 The Limestone Contractor shall furnish and set all anchors shown on approved shop drawings unless otherwise specified. All anchors shall be fabricated from Type 304 or 316 stainless steel or other suitable nonferrous metal. Multipart anchors may contain metal other than stainless steel provided such metal is not embedded in sinkages in the limestone.

2.6 Stain Prevention

2.6.1 Where necessary, such as when limestone is used at/below grade or at horizontal water stops, specify one or both of the following systems:

2.6.1.1 Dampproof unexposed stone surfaces. Joint surfaces should be dampproofed only to within 1" of finished surface when using bituminous solutions.

2.6.1.2 Dampproof all concrete surfaces on which limestone will rest. Dampproof adjacent concrete structure, haunches, etc.

2.7 Adjacent To Water

2.7.1 Limestone used in areas adjacent to water that is chemically purified should be tested to ensure that there is no reaction between the stone and the purification chemicals.

(See Horizontal Surfaces chapter for more information.)

3.0 FABRICATION

3.1 Beds and Joints

3.1.1 All stone shall be cut accurately to shape and dimensions and full to the square, with jointing as shown on approved drawings. All exposed faces shall be dressed true. Beds and joints shall be at right angles to the face, and joints shall have a uniform thickness of 3/8" (10 mm) unless otherwise shown or noted on drawings.

3.1.2 Reglets for flashing, etc., shall be cut in the stone where so indicated on the drawings. All flashing, whether installed by the Stone Contractor or others, must be installed with nonstaining, oil-free caulk.

3.2 Backs of Pieces

3.2.1 Backs of pieces shall be sawn or roughly dressed to approximately true planes. Back surfaces shall be free of any matter that may create staining.

3.3 Moldings, Washes, and Drips

3.3.1 Moldings, washes, and drips shall be constant in profile throughout their entire length, in strict conformity with details shown on approved shop drawings. The finish quality on these surfaces shall match the finish quality of the flat surfaces on the building.

3.4 Back-checking and Fitting to Structure or Frame

3.4.1 Stone coming in contact with structural work shall be back-checked as indicated on the approved shop drawings. Stones resting on structural work shall have beds shaped to fit the supports as required.

3.4.2 Maintain a minimum of 1" (25 mm) between stone backs and adjacent structure. (Note: many bolted connections will require more space than this; 2" (50 mm) space may be more desirable. Large-scale details should illustrate and control these conditions.)

3.5 Cutting for Anchoring, Supporting, and Lifting Devices

3.5.1 Holes and sinkages shall be cut in stones for all anchors, cramps, dowels, and other tieback and support devices per industry standard practice or approved shop drawings. However, additional anchor holes may be drilled at job site by Limestone Contractor to facilitate alignment.

3.5.2 No holes or sinkages will be provided for Limestone Contractor's handling devices unless arrangement for this service is made by the Limestone Contractor with the Limestone Fabricator.

NOTE: It is not recommended that lewis pins be used for stones less than 3½" (90 mm) thick.

3.6 Cutting and Drilling for Other Trades

3.6.1 Any miscellaneous cutting and drilling of stone necessary to accommodate other trades will be done by the Limestone Fabricator only when necessary information is furnished in time to be shown on the shop drawings and details, and when work can be executed before fabrication. Cutting and fitting, due to job site conditions, will be the responsibility of the Limestone Contractor.

3.6.2 Incidental cutting such as for window frame clips, etc., which is normally not considered to be the responsibility of the Stone Supplier, will be provided only by arrangement by the General Contractor and Limestone Contractor with the Limestone Fabricator.

3.7 Carving and Models

3.7.1 All carving shall be done by skilled Stone Carvers in a correct and artistic manner, in strict accordance with the spirit and intent of the approved shop drawing, or from models furnished or approved by the Specifying Authority.

4.0 SHIPPING AND HANDLING

4.1 Packing and Loading

4.1.1 The cut limestone shall be carefully packed for transportation with exercise of all customary and reasonable precautions against damage in transit. All limestone under this contract shall be loaded and shipped in the sequence and quantities mutually agreed upon by the General Contractor, Limestone Contractor, and the Limestone Fabricator.

4.2 Unloading and Storage at Job Site

4.2.1 Receipt, storage, and protection of limestone work prior to and during installation shall be the responsibility of the Limestone Contractor.

4.2.2 All limestone shall be received and unloaded at the site with necessary care in handling to avoid damaging or soiling.

4.2.3 Stones shall be stored above the ground on nonstaining skids (cypress, white pine, poplar, or yellow pine without an excessive amount of resin). Chemically treated wood should not be used. DO NOT USE CHESTNUT, WALNUT, OAK, FIR, AND OTHER WOODS CONTAINING TANNIN. Completely dry limestone shall be covered with nonstaining waterproof paper, clean canvas, or polyethylene.

5.0 INSTALLATION

5.1 General Installation

5.1.1 Installation shall be accomplished with competent, experienced Stone Setters, in accordance with the approved shop drawings.

5.1.2 All limestone pieces shall be identified with a unique piece number corresponding with the number on the shop drawings. Interchanging of numbered pieces is not permitted.

5.1.3 Limestone shall be free of any ice or frost at time of installation. Salt shall not be used for the purpose of melting ice, frost, or snow on the limestone pieces.

5.1.4 Adequate protection measures shall be taken to ensure that exposed surfaces of the stone shall be kept free of mortar at all times.

5.2 Mortar Setting

5.2.1 All limestone shall be set accurately in strict accordance with the contract, approved shop drawings, and specifications. White portland cement with a low-alkali content is recommended.

5.2.2 Cut limestone is customarily shipped as it comes from its final operation in the supplier's plant. Its surfaces and joints may be covered with dust or saw slush, especially those pieces which have not been exposed to rain in stacking areas. Cleaning prior to installation or erection of cut limestone is typically not required where the existence of dust or saw slush does not impede the erection process or the application of joint sealants or pointing. The exception to this rule is interior stonework. Thoroughly clean interior stones prior to installation and protect the work once in place from construction traffic. Among the methods used is washing with a fiber brush and soap powder, followed by a thorough rinsing with clear water. Further information on cleaning can be found in section 6.1 of this document.

5.2.3 All stone joint surfaces not thoroughly wet shall be drenched with clear water just prior to setting.

5.2.4 Except as otherwise specially noted, every stone shall be set in full beds of mortar with all vertical joints slushed full. Completely fill all anchor, dowel, and similar holes. All bed and vertical joints shall be 3/8" (10 mm) unless otherwise noted.

5.2.5 Plastic setting pads shall be placed under heavy stones, column drums, etc., in the same thickness as the joint, and in sufficient quantity to avoid squeezing mortar out. Heavy stones or projecting courses shall not be set until mortar in courses below has hardened sufficiently to avoid squeezing.

5.2.6 While joints can be tooled when initial set has occurred, pointing cut stone after setting, rather than full bed setting and finishing in one operation reduces a condition which tends to produce spalling and leakage. It is generally best to set the stone and rake out the mortar to a depth of ½" to 1½" (12 to 38 mm) for pointing with mortar or sealant at a later date. If pointed with sealant, the raked depth and sealant applications shall conform to manufacturer's instructions.

5.2.7 Projecting stones shall be securely propped or anchored until the wall above is set.

5.2.8 Only the ends of lugged sills and steps shall be embedded in mortar. Balance of joint shall be left open until finally pointed.

5.2.9 All cornice, copings, projecting belt courses, other projecting courses, steps, and platforms (in general, all stone areas either partially or totally horizontal) should be set with unfilled vertical joints. After setting, insert properly sized backup material or backer rod to proper depth, and gun in sealant.

In cold weather, the International Masonry Industry All Weather Council re-commendations for setting from 40ºF to 20ºF (4ºC to -6ºC) shall be followed, except that no additives shall be used in the setting mortar, and below 20ºF (-6ºC), all work shall be done in heated enclosures.

5.2.10 Individually set thin tile [nominal 3/8" (10 mm) thick] on vertical surfaces exceeding 8' (2.5 m) is not recommended.

5.3 Anchorage

5.3.1 All limestone shall be anchored in accordance with the approved shop drawings.

5.3.2 To the furthest extent possible, all anchor preparations in limestone units shall be shop-applied.

5.3.3 All anchorage devices and anchor hole/slot fillers shall be in accordance with ASTM C1242. Care must be taken to ensure that any holes capable of retaining water are filled after use to prevent water collection and freezing.

5.4 Sealant Joints

5.4.1 Where so specified, joints requiring sealant shall be first filled with a closed-cell ethafoam rope backer rod. The backer rod shall be installed to a depth that provides optimum sealant profile after tooling.

5.4.2 If recommended by the Sealant Manufacturer, primers shall be applied to the substrate surfaces according to the manufacturer's directions prior to application of the joint sealant.

5.5 Expansion Joints

5.5.1 Joints shall be adequate to allow for thermal and structural differential movement.

5.5.2 Filler material for these joints shall be nonstaining.

5.5.3 It is not the intent of this specification to make control or expansion-joint recommendations for a specific project. The Specifying Authority must specify expansion and control joints and show location and details on the drawings.

5.5.4 NSI recommends a maximum area of 400 square feet (37 m^2) between expansion/control joints for horizontal surfaces. In areas where there are large sections of natural light, this area should be reduced dependent on the quantity of natural light entering the area. In glass ceiling atriums, it has been shown that 120 square feet (11 m^2) is the maximum area that an expansion/control joint should encamp.

5.6 Caulking

5.6.1 Where so specified, joints shall be pointed with the sealant(s) specified in Section 2.4, after first installing the specified backup material and applying a primer if required, all in strict accordance with the printed instructions of the Sealant Manufacturer.

5.6.2 All sealants shall be tooled to ensure maximum adhesion to the contact surfaces.

5.7 Weep Tubes

5.7.1 Plastic or other weep tubes shall be placed in joints where moisture may accumulate within the wall, such as at base of cavity, continuous angles, flashing, etc., or as shown on architectural drawings.

6.0 CLEANING AND PROTECTION

6.1 Cleaning

6.1.1 Among the methods most frequently used to clean cut limestone are washing with a fiber brush and soap powder, followed by a thorough rinsing with clear water. Pressure washing is another option, and often the required pressure can be delivered from ordinary hose taps. Greater water pressure can be used in some situations if delivered by a wide-angle nozzle from a distance no closer than one foot to the stone surfaces. Most often a lower pressure and greater distance will be equally effective. Suppliers or trade associations representing the specified limestone should be contacted for pressure recommendations for their particular product.

6.1.2 Special consideration and protection shall be provided when brickwork is cleaned above the limestone. Strong acid compounds used for cleaning brick will burn and discolor the limestone.

6.1.3 In general, sand-blasting, wire brushes or acids should never be used on limestone. When circumstances arise that cause one or more of these methods to be considered, suppliers or trade associations representing the specified limestone should be contacted for recommendations.

6.2 Protection of Finished Work

6.2.1 During construction, tops of walls shall be carefully covered at night and especially during any precipitation or other inclement weather.

6.2.2 At all times, walls shall be adequately protected from droppings.

6.2.3 Whenever necessary, substantial wooden covering shall be placed to protect the stonework. Nonstaining building paper or membrane shall be used under the wood. Maintain all covering until removed to permit the final cleaning of the stonework.

6.2.4 The Limestone Contractor will outline the needs for protection in writing to the General Contractor. The General Contractor shall be responsible for protection of the finished work until all trades are finished. This responsibility includes the stone cleaning costs prior to the final inspection.

PRODUCT DESCRIPTION – Limestone

1.0 GEOLOGICAL CLASSIFICATION

1.1 **Limestone** is a sedimentary stone with at least 50% by weight calcite or calcium carbonate ($CaCO_3$) content[1]. However, commercial limestone usually has a much higher percentage of calcium carbonate than 50%. Limestone is a "clastic" sedimentary stone. Almost all limestone is composed of grains or fragments of biologic origin, ranging from fossils or organically derived grains that weigh a mere fraction of an ounce, to dinosaur bones that may weigh tons (though the latter is an extremely rare example). Most limestone is marine in origin, composed of micro-sized fossils of marine invertebrate organisms rather like the shells found on most beaches. Limestone composed of inorganic, precipitated calcium carbonate is rare, and even more rare is limestone of igneous origin called *carbonatites*,[2] found in diamond-bearing rock. In former times it was thought that pure, fine-grained limestone was a precipitate from marine waters super enriched with calcium carbonate, but that is not the case; almost all fine-grained limestone is of biological origin.

1.2 Limestone is a carbonate stone, that is, it has the $-CO_3$ radical combined with the calcium atom. Other carbonate minerals seen in dimension stone are the carbonates siderite ($FeCO_3$), magnesite ($MgCO_3$), and dolomite $Ca,Mg(CO_3)_2$. Dolomite is both a mineral and a stone, and is used extensively as a commercial limestone. The origin of dolomite is post depositional; it is chemically transformed from a pure calcium limestone after deposition and burial, and sometimes, after total cementation. Thus the dolomitization process of a limestone is termed a "diagenetic" chemical process in which magnesium ions are inserted into the calcium carbonate molecules to make dolomite, both the mineral and rock.

1.3 All the carbonate minerals mentioned share certain chemical and physical properties: they are all approximately the same hardness (H=3) on the Mohs Scale[3]; all have three good cleavages (i.e., they easily break into parallelograms, indicating they have the same atomic geometry); and they all react in some manner to cold, dilute hydrochloric acid and other dilute acids.

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[1] *The Glossary of Geology*, 2nd ed., 1980, Bates and Jackson eds., Amer. Geol. Inst.

[2] *Carbonatites* often occur in *kimberlite* pipes, a rare and special kind of geologic formation in which diamonds are found.

[3] See Appendix for the Mohs Scale of mineral hardness.

1.4 Since limestone by definition must be at least 50% calcium carbonate, the other 50% can be one of various clasts or minerals of other kinds of stone. These include clay, silt, quartz or other sands, pebbles, and especially fossils– usually calcite or aragonite (a mineral with the same chemistry as calcite ($CaCO_3$), but with an unstable atomic geometry unlike calcite, which has a stable atomic geometry.

1.5 It is proper to add a descriptive prefix in identifying types of stone; for example, muddy or shaly limestone, or silty, sandy, or pebbly conglomeratic limestone.

1.6 Dolomite, the stone, is a calcium-magnesium carbonate classed in the dimension stone industry as "limestone," and is important commercially not only due to the large amount quarried and sold, but because of two special physical properties of dolomite:

1.6.1 Dolomite is somewhat less soluble than calcite, enough so that dolomite generally exhibits somewhat greater weathering resistance in exterior applications. The standard procedure to test for calcite is to put a drop of dilute hydrochloric acid (HCl), ≈10% or less, on the mineral. A vigorous "fizzing" reaction occurs immediately, a positive indication of calcite. By contrast, a drop of dilute HCl on dolomite mineral or stone produces no reaction unless the dolomite is pulverized first; then a fizzing reaction is observed, but it will be less vigorous than with calcite.

1.6.2 Dolomite hardness H=3.5 is slightly harder than calcite. Calcite hardness is H=3 by comparison, a human fingernail is H=2.5, and the mineral fluorite (CaF_2) is H=4. Thus dolomite hardness at 3.5 will scratch the softer calcite. Although this doesn't seem like much of a difference, it is enough of an increase to provide longer service life in high abrasion applications, for instance, for entrance steps.

1.7 In general, limestone diluted with too much clay, sand, or other noncarbonate grains is not acceptable as dimension stone—it may not be well enough cemented to hold together, the clays may wash out, or if sandy, the sands may wash or weather out too easily, or the stone will not take an acceptable finish.

1.8 Clay is the source of coloring in many limestones, because it contains the iron oxides that yield yellow through red stain; thus, a very small component of clay may be acceptable in commercial limestone. A simple chemical analysis of a limestone will indicate precisely the percent of calcite composition, while a petrographic examination would establish the characteristics of the calcite/clay mixture. Large inclusions or bands of clay seriously weaken the stone.

1.9 Recrystallization of any limestone is usually initiated with burial, and the deeper the burial, the more pervasive is the recrystallization. Grain size has much to do with the process of recrystallization in some types of limestone; it appears to proceed rapidly in some very fine-grained limestones, perhaps accelerated by trace amounts of biological material and the larger amount of surface area of multiple small grains. Marbles by geological definition are metamorphic limestones. It is often nearly impossible to differentiate a strongly recrystallized limestone from a marble because the two behave exactly the same; thus in commercial practice, the differentiation is often incorrectly stated, but the error may be of little or no importance. If the exact name and origin is needed, a metamorphic marble can be identified by indications of strain in calcite crystals observed in a petrographic thin-section.

1.10 Many fossiliferous limestones are of exceptional biological interest as they form in a variety of mostly marine environments much studied for baseline standards against which modern environments are compared. These would include constructional biological reefs, barrier reefs like Australia's Great Barrier Reef, lagoons and carbonate tidal flats similar to the back side of Andros Island in the Bahamas, or Florida Bay. Fossiliferous limestone has fascinated mankind since ancient times, and continues to be a stone in high demand. Fossils over three billion years old are studied from carbonate rocks. Fossiliferous limestone preserves the only record of life available for the period of Earth history prior to the advent of mankind, and retains the charisma associated with unknown creatures from times long past.

2.0 COLOR AND VEINING

2.1 The color, veinings, clouds, mottlings, and shadings in limestone are caused by substances included in minor amounts during formation. These include iron-bearing minerals, clay, and organic material thought to be residual from the soft parts of tiny marine animals. Most of these dark materials are found between calcite crystals or the shell materials, and some shells and calcite crystals are darker than others. Colors of biologic inclusions are strongly affected by the environment of deposition, e.g., whether bottom conditions are aerobic or anaerobic. Iron oxides make the pinks, yellows, browns, and reds. Most grays, blue-grays, and blacks are of bituminous origin.

3.0 TEXTURE

3.1 The term "texture," as applied to limestone, means size, degree of uniformity, and arrangement of constituent minerals.

3.2 Limestone contains a number of distinguishable natural characteristics, including calcite streaks or spots, fossils or shell formations, pit holes, reedy formations, open texture streaks, honeycomb formations, iron spots, travertine-like formations, and grain-formation changes. One or a combination of these characteristics will affect the texture.

4.0 FINISHES

4.1 Limestone surfaces may be finished in a number of ways. Typical finishes are:

4.1.1 Honed: A satin smooth surface with little or no gloss.

4.1.2 Smooth: Smooth finish, with minimum of surface interruption.

4.1.3 Plucked: A rough texture.
4.1.4 Abrasive: A flat, nonreflective surface.

4.1.5 Sawn: A comparatively rough surface; can be chat, shot, sand, or diamond sawn.

4.1.6 Polished: Mirror gloss, with sharp reflections.

4.1.7 Bush-hammered: Textured surface that varies from subtle to rough.

4.1.8 Thermal (Flamed): Finish produced by application of high-temperature flame to the surface. Large surfaces may have shadow lines caused by overlapping of the torch. This finish will vary in texture and depth between different types of limestone, as the finish is largely dependent upon the limestone structure of the stone. The thermal method is not commonly used on limestone.

4.1.9 Antiqued: A finish that replicates rusticated or distressed textures.

4.1.10 Tumbled: A weathered, aging finish created when the stone is tumbled with sand, pebbles, or steel bearings.

4.1.10.1 Other finishes such as machine tooled are available and it should be noted that not all finishes may be applicable to all limestones.

4.1.11 Some stone finishes can affect strength and durability. Examples are bush-hammered and thermal finishes, which reduce a stone's thickness, making it more vulnerable to weakening from exposure to freeze and thaw cycles.

4.1.12 The type of finish desired may affect the final cost. For further information on cost differences between various finishes contact NSI member companies.

5.0 THICKNESS

5.1 Standard nominal thicknesses for limestone are generally 3/8", ¾", 1¼", 1½", 2", 2¼", 2½", 3", 3½", and 4" (10 mm, 20 mm, 30 mm, 38 mm, 50 mm, 60 mm, 75 mm, 90 mm, 100 mm). The recommended thicknesses vary depending on the type of limestone used.

5.2 Cutting can be made to exact metric measurements through conversion of U.S. Conventional System values to SI International System units. See conversion table in the Appendix.

Note that as limestone is cut thinner, its tensile strength is diminished.

6.0 SIZES

6.1 Limestone is a product of nature with many varieties available, each possessing unique characteristics. Little can be done to alter the condition in which nature presents these varieties to us. Therefore, size may become a limiting factor to consider in the selection of a particular limestone.

6.2 NSI Members should be consulted for specific size information for a particular stone and its desired use. A jointing scheme which permits the use of smaller sizes of limestone may greatly facilitate selection and delivery. The NSI Member/Supplier should assist in the final scheme approval.

7.0 PRODUCT SAMPLING

7.1 Limestone is formed by nature; thus there are variations in the tonal qualities of the stones. However, it is these natural variations that make limestone unique, valuable, and highly desirable. Because of these variations, selection of a limestone should never be made on the basis of one sample only. It is recommended that selection be based on viewing sufficient samples to show the general range of colors of the desired stone. NSI Members can provide these range samples.

8.0 PROPER USAGE TIPS

8.1 Recommendation for commercial floors:

8.1.1 Minimum ¾" (20 mm) thickness.

8.1.2 A honed finish.

8.1.3 A minimum hardness value of 10 as measured by ASTM C241/C1353.

8.2 Avoid the use of gypsum or molding plaster setting spots for the installation of limestone.

9.0 VENEER CUTTING

9.1 Quarry blocks are reduced to slabs by a gang saw, belt saw, or wire saw. The gang saw consists of a series of steel blades set parallel in a frame that moves forward and backward. They are fed a cutting abrasive in a stream of water. See illustration at end of chapter 7.

10.0 DAMPPROOFING

10.1 Some limestones have moisture absorption rates which will cause bleeding of setting or joint materials. If unsure, test the limestone for tolerance of the setting material. Wetting the joint surfaces prior to applying the mortar and avoiding the use of too much water in the mix may reduce the probability of such bleeding If necessary, edges and back faces must be dampproofed with materials that will bond with the setting/jointing material, but not cause bleeding.

TECHNICAL DATA – Limestone

1.0 PROPERTIES OF LIMESTONE DIMENSION STONE

1.1 In centuries past, relatively little importance was attached to the ultimate physical capabilities of most building materials. Rule of thumb was a common structural design criterion. As a result, the widely used materials of the day, for the most part natural rather than manmade materials, were seldom stressed to their ultimate limits.

1.2 In present-day construction, this is far from being true. Performance requirements are daily become more demanding. In striving for taller structures, greater spans, firmer foundations, thinner walls and floors, stronger frames, and generally more efficient buildings with more usable space, today's Architects and Engineers must get the most out of the materials with which they work.

1.3 Limestone is a product of nature and not always subject to the rules of consistent behavior that may apply to manufactured building materials.

1.4. Physical property values of limestone may, however, be measured using the standard test methods approved by the Dimension Stone Committee C18 of ASTM International. The NSI and Member companies are represented on the ASTM committee and are active in its technical work of establishing proper test methods and specifications consistent with the latest technology.

1.5 Final design should always be based on specific values for the stone variety ultimately to be installed. These values may be obtained from the Stone Supplier. All materials are not suitable for all uses. In order to avoid mistaken selections, tests for material values should be made prior to final material selection.

1.6 Physical Properties of Limestone. (This historical data and information are provided only as a guideline. Recommended minimums or maximums are established and provided by ASTM International.)[4]

Property **Range of Values**

Compressive Strength (C170)
lbs/in² 1,600-32,000
Recommended (min):
1,800 (low density),
4,000 (medium density),
8,000 (high density)

Property **Range of Values**

Flexural Strength (C880)
lbs/in² 400-2,700

Modulus of Elasticity[5] (in millions)
lbs/in² 0.6-1.4

Density, lb/ft³ (C97) 110-185
Recommended (min):
110 (low density),
135 (medium density),
160 (high density)

Coefficient of Thermal Expansion,
in/in/°F........................ 4.4×10^{-6} average

Modulus of Rupture (C99) lbs/in²…400-1000
Recommended (min):
400 (low density),
500 (medium density),
1,000 (high density)

Absorption % (by weight) (C97)… 0.6-29.0
Recommended (max):
12.0 (low density),
7.5 (medium density),
3.0 (high density)

Abrasion Resistance (H_a/I_w) (C241/C1353)
…3.0-33.0
Recommended (min): 10

[4] Test methods described in current ASTM standards.

[5] Also known as Young's Modulus.

2.0 STRENGTH (ASTM C99, C170, C880)

2.1 Values for modulus of rupture, compressive strength, and flexural strength are ascertained by testing specimens of limestone under laboratory conditions until they fail.

2.2 Size and finish of test samples required by the standard ASTM test methods may not reflect the actual performance of stone when used in lesser thicknesses or with other finishes that affect strength. For this reason, the Modulus of Rupture (C99) test is recommended when the stone to be used will be two or more inches thick. The Flexural Strength (C880) test is recommended when the stone thickness will be less than two inches.

2.3 The strength of a limestone is a measure of its ability to resist stresses. There are several varieties in the limestone group, including calcarenite, coquina, dolomite, micro-crystalline, oolitic, travertine, and re-crystallized. Their strength depends on several factors, such as the rift and cleavage of the calcite crystals, the degree of cementation, the interlocking of the calcite crystals, and the nature of any cementing materials present.

3.0 FIRE RESISTANCE

3.1 Stone is not combustible according to underwriters' ratings, and therefore is considered a fire-resistant material. Because of its thermal conductivity, heat transfer is fairly rapid. Most stone is not considered a highly rated thermal insulator.

3.2 Underwriters' fire-resistance ratings evaluate whether or not a material will burn, as well as how long it will keep surrounding combustible materials from reaching temperatures which will cause them to ignite. Methods of estimating fire resistance periods of masonry walls and partitions utilizing component laminae are given in "Fire Resistance Classifications of Building Construction," BMS92, National Bureau of Standards.

4.0 ABRASION RESISTANCE (ASTM C241/C1353)

4.1 Abrasion resistance is a property of stone that should be tested per ASTM C241/C1353 to provide an indication of the stone's wearing qualities when exposed to foot traffic.

4.2 The hardness and uniform wearing qualities of most limestones make them extremely desirable and economically practical for floors and stairs. Varieties with an abrasive hardness (H_a) of 10 or more, as measured by ASTM C241/C1353 tests, are recommended for use as flooring exposed to normal foot traffic. A minimum abrasive hardness of 12 is recommended for commercial floors, stair treads, and platforms subject to heavy foot traffic. If floors are constructed with two or more stone varieties, the Ha values of the stones must not differ by more than 5, or the floor surface will not wear evenly and uniformly.

5.0 FACTORS AFFECTING PROPERTIES

5.1 The ultimate test of a building material is its ability to have and maintain the necessary structural strength, as well as beauty of appearance and low cost of maintenance over the useful life of the structure. Experience has proven that limestone meets this test as few other building materials can. Studies have shown that the durability of most limestones is little affected by cycles of weather. This is because most have a low rate of moisture absorption.

5.2 Limestone exterior paving is not recommended for environments where de-icing chemicals may be used to melt ice and snow because these chemicals will damage most limestone.

5.3 Exteriors of gray or black limestones with a bituminous or carbon composition should be avoided as the action of atmosphere agents will rapidly cause the surface to deteriorate.

6.0 SAFETY FACTORS

6.1 Good engineering practice requires that allowable design stress must provide a margin of safety in any structural element. As a necessary precaution against such conditions as wind, ice, snow, impact, temperature changes, and imperfect workmanship, these allowable stresses must be smaller than those which produce failure.

6.2 For a particular construction, the closer the allowable load is to the ultimate failure load, the more efficient is the use of the material and the less the cost of the construction.

6.3 Contemporary building design does not usually employ stone as part of the structural frame, but rather as an independent unit, a curtain wall, or veneer. Therefore, the primary concern in such cases is with wind or seismic loads, and a safety factor of 8.0 is recommended. Where the stone is to be subjected to concentrated loading, such as stair treads or lintels supported only at the ends, a factor of 10.0 should be used. These safety factors may be adjusted using sound engineering principles and judgment.

6.4 As buildings become taller and individual stone-slab veneer becomes larger in area, the lateral forces due to wind loads must be considered. Wind tunnel tests are often used on major structures to determine wind dynamics and force magnitude. Reinforcement is sometimes necessary for large dimension slab veneer in critical areas.

7.0 SEISMIC CONSIDERATIONS

7.1 Seismic considerations generally require that low buildings be stiff, and that tall buildings be relatively flexible. Design of connections must account for seismically induced horizontal loading. Local building codes vary and must always be checked to determine specific requirements for each area. The National Bureau of Standards has published two documents on the topic: “Earthquake Resistant Masonry Construction,” NBS Science Series 106; and “Abnormal Loading on Buildings and Progressive Collapse: An Annotated Bibliography,” NBS Science Series 67. The U.S. Army Corps of Engineers has also published TM 5-809-10, “Seismic Design for Buildings.”

8.0 EFFLORESCENCE AND STAINING

8.1 Efflorescence is a salt deposit, usually white in color that occasionally appears on exterior surfaces of masonry walls. The efflorescence-producing salts found in masonry are usually sulfates of sodium, potassium, magnesium, calcium, and iron. Salts which are chlorides of sodium, calcium, and potassium will sometimes appear, but they are so highly soluble in water that they will be washed off by rain.

8.2 The water-soluble salts causing efflorescence come from other materials in the wall. The salts exist in small amounts and are leached to the surface by water percolating through the walls. The most feasible means of prevention is to stop the entrance of large amounts of water. Absorption from the face will not cause efflorescence unless there are open joints.

8.3 Limestone is seldom injured by efflorescence. However, some of the salt crystals may form in the pores near the surface. Crystal growth (recrystallization) in the pores can cause stress on the walls of the pores and cause the stone to flake off. If the conditions bringing about this action persist, scaling may continue and flake off one layer after another. For this to happen, large amounts of water must enter the wall and must contain large amounts of salts.

8.4 Staining or discoloration occurring on new buildings can be a brown stain found on buff limestone, or a dark gray stain on gray limestone. Research indicates that the stains are caused by the action of water percolating through cement from which soluble alkali salts are leached. The salts are then carried through the stone, where partially oxidized organic matter is picked up. This is then transported to the surface of the stone, where it is deposited as a stain as evaporation of the water takes place.

8.5 This staining phenomenon is similar to efflorescence except that it involves organic material. It does not harm the stone other than leaving an objectionable appearance during or soon after erection. However, if left alone, the stain is removed naturally by the action of the elements, usually in the course of a few months.

8.6 A considerable amount of water passing through the stone is necessary to bring out conspicuous discolorations. Proper precautions taken during construction of the walls will usually prevent such troubles. A simple and helpful expedient is to provide frequent weep holes in the base course and above shelf angles. These should be placed in the vertical joints so they can be sloped upward from the front to back.

8.7 Stains sometimes appear on the base course when limestone is in contact with soil, due to the carrying of soluble salts and some colored soil constituents up through and to the surface of the stone by capillary action. Almost all soils contain soluble salts. Therefore, this staining phenomenon should disappear when the source of moisture is eliminated.

8.8 Avoid contact between soil and stone. Dampproofing treatments of either a bituminous or cementitious nature may be used as a barrier to the ground water or construction moisture causing these stains.

9.0 THERMAL EXPANSION

9.1 The thermal expansion of limestone is an important consideration where limestone is used with dissimilar materials to form large units that are rigidly fixed.

9.2 The coefficient of thermal expansion varies from one variety to another; actual thermal characteristics of a specific limestone should be obtained from the Quarrier or Fabricator before making a final selection.

NOTES:

MARBLE AND ONYX

1.0 GENERAL

1.1 Related Documents

1.1.1 Drawings and general provisions, including General and Supplementary Conditions of the Contract and Division I Specification sections, apply to this section.

1.2 Applicable Publications

1.2.1 The following publications listed here and referred to thereafter by alphanumeric code designation only, form a part of this specification to the extent indicated by the references thereto:

1.2.2 ASTM International (ASTM):

1.2.2.1 C503, Standard Specification for Marble Dimension Stone

1.2.2.2 C97, Standard Test Methods for Absorption and Bulk Specific Gravity of Dimension Stone

1.2.2.3 C99, Standard Test Method for Modulus of Rupture of Dimension Stone

1.2.2.4 C170, Standard Test Method for Compressive Strength of Dimension Stone

1.2.2.5 C241 Standard Test Method for Abrasion Resistance of Stone Subjected to Foot Traffic

1.2.2.6 C880, Standard Test Method for Flexural Strength of Dimension Stone

1.2.2.7 C1353, Standard Test Method for Abrasion Resistance of Dimension Stone Subjected to Foot Traffic Using a Rotary Platform Abraser

1.2.3 Natural Stone Institute (NSI):

1.2.3.1 Membership, Products, and Services Directory

1.2.3.2 Dimension Stone Design Manual

1.2.3.3 Additional publications may be available from the NSI Bookstore. Go online at www.naturalstoneinstitute.org.

1.3 Scope of Included Work

1.3.1 The work to be completed under this contract includes all labor and materials required for the furnishing and installation of all marble work shown or called for on the contract drawings, specifications, and addenda.

1.4 Definition of Terms

1.4.1 The definitions of trade terms used in this specification shall be those published by the NSI or ASTM International.

1.5 Source of Supply

1.5.1 All marble shall be obtained from quarries having adequate capacity and facilities to meet the specified requirements, and by a firm equipped to process the material promptly on order and in strict accord with specifications. The Specifying Authority (architect, designer, engineer, contracting officer, end user, etc.) reserves the right to approve the Material Supplier prior to the award of this contract. Stone and workmanship quality shall be in accordance with Industry Standards and Practices as set forth by the NSI.

1.6 Samples

1.6.1 The Marble Contractor shall submit through the General Contractor, for approval by the Specifying Authority, at least two sets of samples of the various kinds of marble specified. The sample size shall be 1'-0" x 1'-0" (300 mm x 300 mm) and shall represent approximately the finish, texture, and anticipated range of color to be supplied.

Where necessary to show variations in color and markings, larger samples or range sets of samples should be submitted. If marble is to be matched, a minimum of two sets each containing four matched samples showing proposed veining and range of color in each set must be supplied. Samples designating finished face shall be clearly labeled on the back with the name of the marble, the group classification for soundness, and the use for which the marble is intended. One set of samples shall be retained by the Specifying Authority, and one set shall be returned to the Marble Supplier for his/her record and guidance. It is noted herein that marble is a natural material and will have intrinsic variations in color, markings, and other characteristics. Depending on the marble selected and quantity required, a range mockup may be used to further define the characteristics of the material. Cost of mockup, if required, shall not be included in this section.

1.6.2 Prior to fabrication, an inspection and approval by the Specifying Authority and/or General Contractor and/or End User of the finished slabs is recommended to understand the finish and full range of the material.

1.7 Shop Drawings

1.7.1 The Marble Contractor shall submit through the General Contractor, for approval by the Specifying Authority, sufficient sets of shop drawings showing general layout, jointing, anchoring, stone thickness, and such other pertinent information. These drawings shall show all bedding, bonding, jointing, and anchoring details along with the net piece dimensions of each marble unit. One copy of approved drawings shall be retained by the Specifying Authority, one copy shall be retained by the General Contractor, and one copy returned to the Marble Contractor for fabrication. NO FABRICATION OF MARBLE SHALL BE STARTED UNTIL SUCH DRAWINGS HAVE BEEN FULLY APPROVED AND MARKED AS SUCH. The General Contractor shall furnish all field dimensions necessary for fabrication. If measurements are not established and guaranteed in advance, the Marble Contractor shall obtain and verify measurements at the building. The General Contractor shall be responsible for all reasonable assistance to the Marble Contractor, including the services of an Engineer, if required, for the establishment of levels, bench marks, and the like. The Marble Contractor shall not be responsible for determining, making, or verifying (1) design, structural, wind, seismic, or other design loads; (2) engineering estimates; (3) plans or specifications; or (4) the types, sizes, or locations of anchors, unless specifically added to the scope of work.

1.8 Defective Work

1.8.1 Any piece of marble or onyx showing flaws or imperfections upon receipt at the storage yard or building site shall be referred to the Specifying Authority for determination as to responsibility and decision as to whether it shall be rejected, patched, or redressed for use.

1.9 Repairing Damaged Stone

1.9.1 Small chips at the edges or corners of marble may be patched provided the structural integrity of the stone is not affected and the patch matches the color and finish of the marble so that the patch does not detract from the stone's appearance.

2.0 MATERIALS

2.1 Marble

2.1.1 General: All marble shall be of kind or kinds shown on the Architect's drawing or as specified herein, conforming to or within the range of approved samples and in accordance with the characteristics and working qualities set forth under their respective Soundness Group Classifications, A, B, C, or D, as defined by the Marble Institute of America. Care shall be taken in selection to produce as harmonious effects as possible. Patching and waxing, where permitted under the Marble Institute of America Group Classifications, shall be carefully done to conform to the marble's general character and finish. Texture and finish shall be within the range of sample(s) approved by the Specifying Authority.

2.1.1.1 ASTM C503 [C97] [C99] [C170] [C241/C1353] [C880] See the chart of applicable ASTM standards and tests in the Appendix.

2.1.2 Schedule: Marble shall be provided as follows:

2.1.2.1 For (*state location on building*) (*state name and color*) marble with a (*type*) finish, supplied by (*name company or list several approved suppliers*).

2.1.2.2 Provide information as in (1) for each different marble/finish combination in the project.

2.1.3 Finishes: Finishes listed in the schedule shall conform with definitions by NSI or ASTM International.

2.1.3.1 Polish Finish: A mirror-like, glossy surface which brings out the full color and character of the marble. This finish is not recommended for exterior or commercial floor use.

2.1.3.2 Honed Finish: A velvety smooth surface with little or no gloss.

2.1.3.3 Abrasive Finish: A flat, nonglossy surface usually recommended for exterior use.

2.2 Setting Mortar (And Adhesives)

2.2.1 Portland cement shall conform to the requirements of the Standard Specifications for Portland Cement, ASTM C150. White portland cement is recommended for white or light colored marble. Nonstaining cement shall conform to the requirements of the Standard Specifications for Masonry Cement, ASTM C91.

2.2.2 Sand. All sand shall be clean, free from organic and other deleterious matter likely to stain the finished work, and shall be screened as required for the desired results.

2.2.3 Portland cement shrinkage-reducing accelerator used with portland cement to give it the quick-setting characteristics of plaster of paris, shall be a nonstaining admixture that will not corrode anchors or dowels.

2.2.4 Nonstaining adhesive shall be of a type that will not stain the marble, that is not affected by temperature changes or moisture, and that adheres with strong suction to all clean surfaces.

2.3 Pointing Mortar

2.3.1 Mortar for pointing shall be Type N, as defined in ASTM C270 (Standard Specification for Mortar for Unit Masonry). All mixing, handling, and placing procedures shall be in accordance with ASTM C270.

2.4 Sealants and Backup Material (if Applicable)

2.4.1 Where specified (*state type or name of sealant*) shall be used for the pointing of joints. The backup material used with the sealant shall be (*identify material*).

2.4.2 Sealants, used for pointing to exclude moisture and provide a joint that will remain plastic for many years, shall be nonstaining.

2.5 Anchors, Cramps, and Dowels

2.5.1 Anchors, cramps, and dowels shall be made of corrosion-resistant metals. Special cramps, dowels, and the like shall be used where shown on shop drawings, but elsewhere, #8 copper or stainless steel wire anchors shall be used. It shall be the responsibility of the Marble Contractor to anchor all marble securely. For standing marble, the following practices usually prevail:

2.5.1.1 A minimum of four anchors should be provided for pieces up to 12 square feet (1 m^2), with two additional anchors for each additional 8 square feet (0.75 m^2) of surface area. Shims used to maintain joints shall be plastic.

2.5.1.2 Use of copper wire for anchors to be installed over 12' (3.5 m) off the ground is not recommended.

3.0 FABRICATION

3.1 Beds and Joints

3.1.1 Bed and joint width shall be determined by analysis of anticipated building movements and designed to accommodate such movements without inducing undue stresses in the stone panels or joint filler materials. Expansion joints shall be designed and located to accommodate larger movements.

3.2 Backs of Pieces

3.2.1 Backs of pieces shall be sawn or roughly dressed to approximately true planes. Back surfaces shall be free of any matter that may create staining.

3.3 Moldings, Washes, and Drips

3.3.1 Moldings, washes, and drips shall be constant in profile throughout their entire length, in strict conformity with details shown on approved shop drawings. The finish quality on these surfaces shall match the finish quality of the flat surfaces on the building.

3.4 Back-Checking and Fitting to Structure or Frame

3.4.1 Stone coming in contact with structural work shall be back-checked as indicated on the approved shop drawings. Stones resting on structural work shall have beds shaped to fit the supports as required.

3.4.2 Maintain a minimum of 1" (25 mm) between stone backs and adjacent structure. (Note: many bolted connections will require more space than this; 2" (50 mm) space may be more desirable. Large-scale details should illustrate and control these conditions.)

3.5 Cutting for Anchoring, Supporting, and Lifting Devices

3.5.1 Holes and sinkages shall be cut in stones for all anchors, cramps, dowels, and other tieback and support devices per industry standard practice or approved shop drawings. However, additional anchor holes shall be drilled at job site by Marble Contractor to facilitate alignment.

3.5.2 No holes or sinkages will be provided for Marble Contractor’s handling devices unless arrangement for this service is made by the Marble Contractor with the Marble Fabricator.

NOTE: It is not recommended that lewis pins be used for stones less than 3½" (90 mm) thick.

3.6 Cutting and Drilling for Other Trades

3.6.1 Any miscellaneous cutting and drilling of stone necessary to accommodate other trades will be done by the Marble Fabricator only when necessary information is furnished in time to be shown on the shop drawings and details, and when work can be executed before fabrication. Cutting and fitting, due to job site conditions, will be the responsibility of the Marble Contractor.

3.6.2 Incidental cutting such as for window frame clips, etc., which is normally not considered to be the responsibility of the Stone Supplier, will be provided only by arrangement by the General Contractor and Marble Contractor with the Marble Fabricator.

3.7 Carving and Models

3.7.1 All carving shall be done by skilled Stone Carvers in a correct and artistic manner, in strict accordance with the spirit and intent of the approved shop drawing, or from models furnished or approved by the Specifying Authority.

4.0 SHIPPING AND HANDLING

4.1 Packing and Loading

4.1.1 Finished marble shall be carefully packed and loaded for shipment using all reasonable and customary precautions against damage in transit. No material which may cause staining or discoloration shall be used for blocking or packing.

4.2 Site Storage

4.2.1 It shall be the responsibility of the Marble Contractor to receive, store, and protect the marble from damage by others after it is delivered to the job site and prior to its erection in the building. All marble shall be received and unloaded at the site with care in handling to avoid damage or soiling. If marble is stored outside, it shall be covered with nonstaining waterproof paper, clean canvas, or polyethylene.

5.0 INSTALLATION

5.1 General Installation

5.1.1 Installation shall be accomplished with competent, experienced Stone Setters, in accordance with the approved shop drawings.

5.1.2 All marble and onyx pieces shall be identified with a unique piece number corresponding with the number on the shop drawings. Interchanging of numbered pieces is not permitted.

5.1.3 Marble and onyx shall be free of any ice or frost at time of installation. Salt shall not be used for the purpose of melting ice, frost, or snow on the stone pieces.

Adequate protection measures shall be taken to ensure that exposed surfaces of the stone shall be kept free of mortar at all times.

5.2 Mortar Setting of Marble and Onyx

5.2.1 Floor Marble

5.2.1.1 Floor Preparation. It is the General Contractor's responsibility to clean all subfloor surfaces to remove dirt, dust, debris, and loose particles immediately prior to setting marble floor and to ensure that the area to receive the stone flooring meets the deflection standards of the industry.

5.2.1.2 Curing Compounds. Curing compounds of any kind shall not be used on the slab on which floor marble is to be directly set. If a curing compound is present, it is the General Contractor's responsibility to remove it by scarifying the slab.

5.2.1.3 Before being set, all marble shall be clean and free of foreign matter of any kind.

5.2.1.4 Mortar Bed. The mortar bed to receive the marble tile shall consist of 1 part portland cement to not more than 4 to 5 parts of clean, sharp sand mixed quite dry for tamping. White portland cement is recommended for light-colored marbles.

5.2.1.5 Marble Tamped. The marble shall be tamped with a suitable mallet until firmly bedded to the proper level of the floor.

5.2.1.6 Marble Removed. The marble shall then be removed and the back parged with wet cement or the bed sprinkled with water and cement. In the latter procedure, the back of the marble shall be wet. The method of fully buttering edges of the marble as it is laid is equally approved.

5.2.1.7 Joints. Joints between the marble pieces shall show an even width when laid and finished.

5.2.1.8 Traffic after Installation. The floor shall be roped off for 24 hours after installation and then grouted with water and white portland cement grout or nonstaining dry set portland cement grout.

5.2.1.9 Timeline for Additional Cleaning. Cleaning or additional surfacing, if required, shall not be undertaken until the new floor is at least seven days old.

5.2.1.10 Thin-set Method. The thin set method of installing marble tile employing the use of dry-set portland cement mortars is recommended for thin marble tiles [nominal 3/8" (9.5 mm) thick] where optimum setting space is not available. Subfloor shall be clean, smooth-finished, and level.

5.2.1.10.1 Stone dust must be washed off the back face of stone pavers prior to installation. Apply mortar with flat side of trowel over an area that can be covered with tile while mortar remains plastic. Within ten minutes, and using a notched trowel sized to facilitate the proper coverage, comb mortar to obtain an even-setting bed without scraping the backing material. Key the mortar into the substrate with the flat side of the trowel. Comb with the notched side of the trowel in one direction. Firmly press stone tiles into the mortar and move them perpendicularly across the ridges, forward and back approximately 1/8" to ¼" (3 to 6.5 mm) to flatten the ridges and fill the valleys. Ensure a maximum mortar thickness of 3/32" (2.5 mm) between stone tile and backing after stone tile has been tamped into place. Stone tile shall not be applied to skinned-over mortar. Alternatively, back butter the stone tiles to ensure 100% contact. In either method, ensure 100% contact on 3/8" (9.5 mm) tile; not less than 80% contact on ¾" (20 mm) or thicker material, noting that all corners and edges of stone tiles must always be fully supported, and contact shall always be 100% in exterior and/or water-susceptible conditions.

5.2.2 Interior Veneer Marble

5.2.2.1 The marble shall be set by spotting with cement mortar and the use of concealed anchors secured in the wall backing.

5.2.3 Marble Wall Tile

5.2.3.1 Individually set thin tile [nominal 3/8" (9.5 mm) thick] on vertical surfaces exceeding 15'-0" (4.5 m) is not recommended. Where thin marble tile is installed, nonstaining adhesives or thin-set mortars may be used as setting beds.

5.2.4 Toilet and Shower Compartments

5.2.4.1 Stiles and partitions shall be assembled with concealed dowel fastenings or corrosion-resistant angles, three in height of stall.

5.2.4.2 For ceiling-hung units, metal supporting members in ceiling are to be furnished and installed by the General Contractor.

5.3 Mortar Joints

5.3.1 Mortar joints shall be raked out to a depth of ½" to ¾" (12.5 to 20 mm). Apply pointing mortar in layers not exceeding 3/8" (9.5 mm) and allow each layer to get hard to the touch before the next layer is applied. Tool finished joints with a concave tool having a diameter approximately 1/8" (3 mm) greater than the joint width.

5.3.2 Care shall be taken to keep expansion joints free of mortar, which would compromise their function.

5.4 Anchorage

5.4.1 All marble shall be anchored or doweled in accordance with the approved shop drawings.

5.4.2 To the furthest extent possible, all anchor preparations in the marble units shall be shop-applied.

5.4.3 All anchorage devices and anchor hole/slot fillers shall be in accordance with ASTM C1242. Care must be taken to ensure that any holes capable of retaining water are filled after use to prevent water collection and freezing.

5.5 Sealant Joints

5.5.1 Where so specified, joints requiring sealant shall be first filled with a closed-cell ethafoam rope backer rod. The backer rod shall be installed to a depth that provides optimum sealant profile after tooling.

5.5.2 If recommended by the Sealant Manufacturer, primers shall be applied to the substrate surfaces according to the manufacturer's directions prior to application of the joint sealant.

5.6 Expansion Joints

5.6.1 It is not the intent of this specification to make control or expansion-joint recommendations for a specific project. The Specifying Authority must specify control or expansion joints and show locations and details on drawings.

5.7 Caulking

5.7.1 Where so specified, joints shall be pointed with the sealant(s) specified in Section 2.4, after first installing the specified backup material and applying a primer if required, all in strict accordance with the printed instructions of the Sealant Manufacturer.

5.7.2 All sealants shall be tooled to ensure maximum adhesion to the contact surfaces.

5.8 Weep Tubes

5.8.1 Plastic or other weep tubes shall be placed in joints where moisture may accumulate within the wall, such as at base of cavity, continuous angles, flashing, etc., or as shown on architectural drawings.

6.0 CLEANING AND PROTECTION

6.1 Cleaning

6.1.1 Marble shall be shop cleaned at the time of final fabrication. It shall also be cleaned after installation and all pointing or caulking is completed. All dirt, excess mortar, weld splatter, stains, and other defacements shall be removed.

6.1.2 All cleaning methods shall be in accordance with ASTM C1515.

6.1.3 Stiff bristle fiber brushes may be used, but the use of wire brushes or of acid type cleaning agents and other solutions which may cause discoloration is expressly prohibited. Fabricator should be contacted before cleaners other than neutral detergents are used.

6.2 Protection of Finished Work

6.2.1 After the marble work is installed, it shall be the responsibility of the General Contractor to see that it is properly and adequately protected from damage or stains until all trades are finished. This responsibility includes the stone cleaning costs prior to the required final inspection. The Marble Contractor will outline the needs for protection, in writing, to the General Contractor. For the protection of projecting members, corners, window stools, and saddles, wood guards using lumber that will not stain or deface with marble shall be supplied, installed, and maintained by the General Contractor. All nails used shall be galvanized or nonrusting. Damage to finished marble by other trades shall be repaired or replaced at the expense of the General Contractor. Marble flooring shall be adequately protected by the General Contractor against traffic and other damage with nonstaining materials without cost to the Marble Contractor.

6.2.2 All marble work in progress shall be protected at all times during construction by use of a strong, impervious film or fabric securely held in place.

PRODUCT DESCRIPTION – Marble and Onyx

1.0 GEOLOGICAL CLASSIFICATION

1.1 Marble is geologically defined as a metamorphic rock predominately consisting of fine- to coarse-grained, recrystallized calcite ($CaCO_3$), and/or dolomite, ($CaMg(CO_3)_2$), which has a texture of relatively uniform crystals ranging from very large (inches) to very fine, small, uniform sized crystals[1]. Two aspects of the definition are important to the stone industry professionals and scientists alike: It is *metamorphic* and, it is *recrystallized*; that is, many marbles are formed by processes of recrystallization and/or metamorphism and have recrystallized textures that obscure most previous texture and depositional features.

1.1.1 A commercial definition equally important and long used in the industry is that marble is any crystallized carbonate rock and certain types of limestone that take a polish and can be used as architectural or ornamental stone[2]. The dimension stone industry traditionally includes other types of stone, such as onyx, in the same classification as marble.

1.1.2 Almost all metamorphic marbles are developed by high pressures in the process of metamorphism, while recrystallization of limestone can occur under normal overburden pressures in thick sedimentary sequences. Obviously, due to the high pressures of metamorphism, it is expected that metamorphic marble is tighter, denser, and more fracture-free than other kinds of marble, and generally that is true. Metamorphic marble and recrystallized limestone will not be differentiated in the remainder of this discourse unless otherwise noted.

1.1.3 In commercial usage, descriptives may be added that refer to a marble's color, e.g., *white* or *blue* marble. More useful to the trade because of the necessity to judge the properties and behavior of the stone, is the scientific convention of referring to the mineralogical content of the stone, such as *dolomitic* marble or *sandy* marble, indicating marbles with some dolomite or sand content. Assuming the marble user knows something about the properties of the minerals, an idea of the stone's behavior can be anticipated.

1.1.4 Colors. In dolomitic marble, the dolomite often weathers to a tan or buff color from the oxidation of a slight amount of iron released from the marble. The chemical series of dolomite, with the end members of $CaMg(CO_3)_2$ to $CaFe(CO_3)_2$ is continuous from 100% Ca to 100% Fe, so many dolomitic marbles, while nearly white when cut, will probably weather slightly buff to tan due to the

[1] Adapted from: Bates, R. L. and J. A. Jackson, eds., 1980, *Glossary of Geology*, 2nd Edition, American Geological Institute, 1980.
[2] Ibid.

release of iron, which then oxidizes to iron oxides that yield the characteristic colors from off-white to tan, buff, yellow to red, and dark brown to the stone as a whole. In dolomitic marble these colors are often uniformly distributed. Bands, streaks, or swirls of distinct color may have other explanations relating to the stone's original deposition and subsequent geological formation.

1.1.5 Calcite, the dominant mineral of marble, occurs in many colors. Among the many common trace-amount impurities that color marbles are organic matter (generally gray to black), chlorite[3] (generally light green to yellowish-green), epidote[4] (the same green as above), and minor amounts of land-derived clays, silts, and sands. These clastic silicate sediments may already be stained with iron to yield any color from very light buff to dark brown, and almost any red color; or the silicate grains themselves may contain trace amounts of iron available by chemical release to stain and color. Other known coloring agents are too numerous to mention here. Iron is by far the most common.

1.1.6 Impurities are often confused with other features that can be found in marble, most of which are primary depositional features[5] or artifacts of chemical changes prior to, during, or subsequent to metamorphism and/or re-crystallization. Such features are intrinsic to the character of many exotic marbles, making some rare types quite valuable. Conversely, the same features could be detractions, weakening the stone or making it unattractive, thus rendering it unsuitable as a decorative dimension stone.

1.1.7 Geological origin. Limestone that begins as an accumulation of shelly debris, mostly fragmental but also including whole shells, is mostly the aragonite form of $CaCO_3$. Original sediment usually has a matrix of organically derived, clay-sized carbonate grains of aragonite. If buried, compacted, and cemented, it takes about 50 to 60 million years under standard conditions of temperature and pressure for aragonite to convert to calcite. In addition to fossils, other features, artifacts of deposition, may also be preserved. Examples include voids, often the internal void space of shells of clams and snails. Commonly, these are filled in with carbonate dust that has crystallized solid. Voids of any origin commonly contain calcite crystals totally filling in the void space.

1.1.8 Cross-bedding and ripple marks on the sea floor are visibly preserved, as are raindrop imprints and mud cracks from shrinkage during exposure and drying that form if the surface is exposed to air, for example at low tide, and then buried, preserving the features. There are many more examples, some of which are called "faults," but are entirely natural. Most of these features formed at the time of deposition disappear and are lost in the recrystallization process of limestone or in pressure-related metamorphism. Some of these primary features can be detrimental, as they could weaken stone.

1.1.9 Another kind of feature, known as a *stylolite*, is formed as a result of geochemical processes either after burial or cementation and long geologic aging. A stylolite is a spiked surface within and usually parallel or subparallel to a bedding planes. Stylolites are evidence of dissolution along fractures or

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[3] *Chlorite* is a very complex hydrous silicate of magnesium, iron, and aluminum has a platy habit. It is soft, flexible (micalike, but not elastic), and usually an alteration product in igneous or low-grade metamorphic stone, or is transported into sedimentary sequences.

[4] *Epidote* is often found with chlorite and has about the same color range. It is a complex, low-grade, metamorphic hydrous silicate of iron, calcium, and aluminum. Being very hard, heavy, and insoluble, it weathers out of metamorphic terrain and can be deposited in near-shore marine deposits of carbonate debris, lending its green color to marble.

[5] *Primary depositional features* are developed at the time of deposition of sedimentary particles.

partings, possibly initiated by a thin film of dark organic matter. Such dissolution can remove several feet of section in a carbonate sequence. These lines become increasingly irregular in a vertical plane as dissolution proceeds at varying rates from place to place along the surface. Stylolites can occur in any carbonate rock from limestone to metamorphic marble, and are purely a phenomenon of chemical dissolution. Stylolites are identifiable as a thin, spiky, or crenellated black line.

1.1.10 Other minerals found in marbles include the various common carbonate minerals previously mentioned. One, magnesite ($MgCO_3$), is characteristic of the metamorphic marbles and not usually found in recrystallized, limestone-type marbles. A generally undesirable mineral, pyrite (FeS_2) or iron sulfide may also occur in marble and are alteration minerals formed after deposition and during the metamorphism and recrystallization phase from small amounts of entrained sulfates or fluids containing dissolved, sulfur-bearing salts that enter the stone during its burial history.

1.1.11 Pyrite will occur as discrete cubic crystals, finely disseminated, or as masses in marble. It is hard (H=6+ on the Mohs scale[6]) and sometimes has an attractive, brassy appearance–it will bleed ugly stains from oxidation during repeated water incursion. Pyrite is often found disseminated throughout shelly limestone, a natural occurrence with biological materials deposited in anoxic conditions (without oxygen). Pyrite exposed on the face of cut and polished stone easily reacts with moisture to form the undesirable and difficult to remove staining. Its brassy metallic luster is not necessarily unattractive, but not for use in wet environments.

1.1.12 The accessory mineral variation found in marble is diverse and dependent on the geologic origin and burial history of the limestone or marble. If the marble was in contact with granite or volcanic igneous rock, then the accessory minerals may include a suite of complex carbonates and silicates. If the marble is in contact with, or influenced by other complex metamorphic stone, then it may have complex carbonate/metamorphic minerals other than the few already mentioned. It is geologic factors like these that can produce the highly colorful and complex marbles seen in both antique and modern works. Such stones may occur in limited deposits. The more common and universally used marbles from antiquity to the present are mostly calcite, many close to ±99% calcium carbonate, found in large deposits with adequate reserves for extended quarrying.

1.1.13 The great variety of colorful, often exotic marbles from Italy is formed in juxtaposition to intrusive and extrusive igneous rocks and/or a variety of metamorphics. Italy has an exceedingly complex geology, with active igneous activity and nearly every known level of metamorphism, as well as a variety of sedimentary deposits. Italy also has experienced remarkable dry periods clearly indicated by the kinds of sedimentary rocks surrounding the Mediterranean (e.g., mottled red marbles), dating from when the area was an empty, desert-like basin before the Straits of Gibraltar opened to flood the present Mediterranean Sea.

1.1.14 Physical and Chemical Properties of Calcite. To understand the stone, one must first understand the minerals. Many of the desirable qualities and many of the problems commonly encountered with marble are direct consequences of the properties of calcite, the dominant mineral, or in some cases, the less abundant accessory minerals. A review of the physical and chemical properties of calcite follows:

1.1.14.1 Crystals. Calcite crystals are found in several different and predictable crystal shapes exactly controlled by atomic geometry

[6] See Appendix for the Mohs Scale of mineral hardness.

of the $CaCO_3$ molecule. Crystals may grow in isolated free spaces or voids called "vugs[7]" or in open fractures or in masses like an entire sequence of stone. More geometrically complex crystals, if they occur, are generally unrecognizable from randomly oriented cuts on polished marble surfaces. Both fractures and vugs eventually fill completely with crystals, often obscuring their former existence. The most common calcite crystal shapes are parallelograms or truncated, faceted, or tapering prisms[8]. Fractures are generally identifiable even if filled, while a totally infilled vug is easily overlooked. Fractures may be a potential line of breakage, but a small, closed vug, being virtually unrecognized on a polished surface, is of little significance to the commercial quality of a stone.

1.1.14.2 Cleavage. Calcite has a definite geometric molecular structure; i.e., the atoms of calcium, oxygen, and carbon are always arranged in a fixed geometry such that three planes of weakness occur not at 90°, along which calcite crystals will generally break.[9] The result is a parallelogram-shape fragment with very flat sides. This is termed *cleavage*. It reflects atomic planes of weakness that predetermine how and where a mineral will break apart. Other minerals may have one, to as many as six, cleavages. Any two exactly parallel sides constitute one cleavage. Thus, a six-sided parallelogram of calcite exhibits three cleavages, with one for each pair of parallel sides. A cleavage face is very flat. It may be stepped but the stepped surfaces are exactly parallel and reflect light as a single surface.

1.1.14.3 Color. Calcite can be any color from black to white (the most common), and colorless clear or transparent. It can be almost any other color of the spectrum. Calcite is also easily dyed with proprietary dyes and techniques. Many are organic compounds that have limited longevity in sunlight and thus fade in time. Or these manmade dyes wash out from chemical spills and ordinary cleaning compounds. Dyed stone of any kind should be considered with extreme caution for these reasons.

1.1.14.4 Composition. Calcite is a carbonate of calcium or $CaCO_3$. While calcite is the most abundant component, carbonates of iron, manganese, magnesium, zinc, and strontium are sometimes present. Many other carbonates and hydrous carbonate minerals of various metals such as lead, barium, and copper are rarely seen in commercial marble.

1.1.14.5 Acid Reaction. Calcite effervesces—reacts and bubbles vigorously in dilute hydrochloric acid. This is a positive diagnostic chemical property of calcite. Calcite can dissolve without visible bubbling in the presence of other kinds of dilute acids or even acidic liquids, such as red wine and salad vinegars. In acidic atmospheres with sulfur, marble is not only etched, but will react with very dilute sulfuric acid in moist air to form a powdery calcium sulfate, the mineral gypsum.

1.1.14.6 Optical Character. Optically clear cleavage fragments–parallelograms–of calcite have the curious optical property of double refraction. Objects or print seen through the cleavage fragment will appear as a double image. The varietal name for optically clear calcite is *Iceland Spar*[10].

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[7] *Vugs* are mostly small to microscopic, but some have been found large enough to walk into. A vug in limestone, dolomite, or marble may contain crystals of calcite in addition to some of the other mentioned accessory minerals.

[8] Calcite is rarely found in the unusual crystalline form of fibrous masses. Because the individual fiber-like bundles of crystals are so small, it is easily carved and has been mistakenly called alabaster, though it is not the true gypsum-based material.

[9] In addition to cleavage, any mineral can be fractured other than along known planes of weakness in atomic geometry. Such noncleavage breaks are always very irregular and rough. Fracture and cleavage may be microscopic in scale.

[10] Named after Iceland, where it is found in abundance. Some specialized 19th century microscopes utilized the optical characteristics of Iceland Spar and incorporated a pair of precisely cleaved parallelogram-shaped calcite crystals. Such instruments are now obsolete.

1.1.14.7 Anisotropy. Calcite is one of many minerals that exhibit different values of physical and chemical properties on different crystal sides or optical directions in its crystalline shape. These variable properties, changes in numerical values in different crystallographic directions, are known as *anisotropic* properties. The differences, although very slight numerically, add up from thousands to hundreds of thousands of crystalline mineral grains, to significant totals that profoundly affect stone performance when dealing with polished slabs of fine-grained crystalline calcite. These slight, but important differences and behavioral characteristics must be dealt with in the engineering design of marble installations. The anisotropic properties of calcite that most seriously affect marble performance are:

1.1.14.7.1 Solubility. Slight differences of solubility on one or more of the three calcite cleavages in the crystalline parallelogram-shaped crystals. The differential number may be very small, but the cumulative effect can be a serious problem in an installation.

1.1.14.7.2 Ease of Cleavage. The ease of cleaving may be minutely different for each of the three cleavages of a cleavage fragment, thus allowing preferential slippage to occur. Although slight, in total it allows visible and permanent dislocations to accumulate, ultimately leading to failure in some thinner sheets of marble.

1.1.14.7.3 Thermal Expansion and Contraction. Varies with the various faces and optical direction in crystals. For example, calcite thermal expansion occurs in one crystallographic direction, while thermal contraction occurs in crystallographic directions normal to the direction of expansion.

1.1.15 Thermal Hysteresis. Thin sheets of certain marbles can sometimes fail under the combined effects of the aforementioned anisotropic properties. Engineering practice recognizes the collective phenomena as *thermal hysteresis*. *Hysteresis* is defined as "a lag in the return of an elastically deformed body to its original shape after the load has been removed. One of the effects of anisotropy and repeated thermal cycles is to defer and/or arrest the elastic rebound that would normally occur with hysteresis.

1.1.15.1 Events that can occur in calcite crystals in marble because of anisotropy and thermal hysteresis include:

1.1.15.1.1 Measurable extension on a surface due to repeated, cyclic heating from the sun or some other heat source.

1.1.15.1.2 Differential linear increases across the front of thin panels vs. the back sides can yield bowing, pillowing, or dishing of the sheet if too thin.

1.1.15.1.3 Changes of intracrystalline pressures, either increased or decreased, from distorted shape, induces growth of calcite crystals or dissolution of calcite (on different crystal surfaces). Both chemical effects tend to reduce strength and induce failure.

1.1.15.1.4 Strained or distorted crystals accumulate from repeated heating cycles and become permanent.

1.1.15.1.5 Microfractures develop from expansion or distortion of crystals and slippage on cleavage.

1.1.15.1.6 Microfractures allow entrance of moisture and/or acid rain, which enlarges fractures by solution, and in some cases, loosely re-cements some areas and may at the same time initiate formation of gypsum and granulation inside the stone and on the surface. Both effects weaken stone, particularly on the backside of bowed or pillowed sheets when moisture is present.

1.1.15.1.7 Reduction in strength of marble sheets from the above microfractures and growth of softer, in-filling minerals.

1.1.15.1.8 Permanent distortion of shape: bowing, pillowing, and dishing, ultimately causing fractures and catastrophic failure.

1.1.15.1.9 Reduced aesthetic appearance.

1.1.15.2 Such events do not occur in all marbles. Anisotropic/hysteretic effects are most pronounced in the finer-grained, highly compacted, truly metamorphic marbles. Anisotropic- and thermal-hysteretic problems generally are not seen with marbles of large grain or crystal size, nor are they seen where the slabs are thick enough to counteract the forces and negate thermal differential between front and back sides of the stone when effective moisture control is practiced for back sides.

1.1.15.3 Problems with marble arising from anisotropy and thermal hysteresis can be avoided by intelligent stone selection, careful design, and engineering practices that recognize known chemical and physical properties and the effects of the variable properties in calcite.

1.1.15.4 An excellent and complete discussion of thermal hysteresis including actual test data and thickness recommendations has been written by Bernard Erlin[11] and published by ASTM International.

1.2 Onyx originates in the dripstone deposits of limestone caverns, where it forms stalactites, stalagmites, and other formations that can fill an entire cavern or void space. It is deposited by gentle, dripping water movement followed by evaporation between drops that deposits calcium carbonate from the water onto the formation, incrementally enlarging formations by thousandths of an inch or less per drop. Thus onyx is also a chemical sedimentary stone, and may envelop terrestrial fossil remains. Prehistoric human remains have been found encased in cavern onyx. Although this process of drop-by-drop addition of material does take time, large deposits of onyx begin to mature (filling caverns or fractures) in a relatively short period of geologic time.

1.2.1 Although onyx is occasionally called travertine, commercial practice generally distinguishes the two stones because of obvious differences that relate to their respective attractiveness. Onyx tends to be more crystalline, strongly banded and colored in browns to yellows and clear. It can be translucent, and light-colored varieties sliced thin are used for attractive backlit display panels or even light-admitting windows. By contrast, travertine displays large void spaces and abundant, visible porosity, and is in all cases an opaque stone. Onyx, like most limestone, will recrystallize in time (not a metamorphic process), often enhancing translucency. It is the material that cameos are made from, and cameo makers use the stone's colored bands to achieve artistic effects. Italy produces much onyx, and the cameos carved in Tuscany from highly-colored, banded onyx are world-renowned.

2.0 COLOR AND VEINING

2.1 The color, veinings, clouds, mottlings, and shadings in marble are caused by substances included in minor amounts during formation. Iron oxides make the pinks, yellows, browns, and reds. Most grays, blue grays, and blacks are of bituminous origin. Greens are caused by micas, chlorites, and silicates.

[11] Erlin, Bernard, "Contribution to a Better Understanding of the Mechanism Causing Dishing Failures of the Carrara Marble When Used for Outside on Building Facades." *Dimension Stone Cladding: Construction, Evaluation, and Repair*, ASTM STP 1394, ASTM International, 2000.

3.0 TEXTURE

3.1 The term "texture," as applied to marble, means size, degree of uniformity, and arrangement of constituent minerals. Grains of calcite, the chief constituent of most marbles, are crystalline and have definite cleavage that show bright, reflecting faces on a broken surface. In most marbles, however, the grains are elongated in one direction by the folding and placation of the beds.

4.0 FINISHES

4.1 Marble's surface may be finished in a number of ways. In general, smooth finishes tend to emphasize color and veining, whereas rough finishes tend to subdue the veining or markings.

4.2 Typical finishes for marble are:

4.2.1 Polished: A glossy surface that brings out the full color and character of the marble. It is not generally recommended for exterior use or commercial floors.

4.2.2 Honed: A satin-smooth surface with little or no gloss, recommended for commercial floors.

4.2.3 Abrasive: A flat, nonreflective surface, usually recommended for exterior use.

4.2.4 Other finishes, such as **axed**, **bush hammered**, **rock faced**, **rough sawn**, or **tooled,** are also available.

5.0 THICKNESS

5.1 Standard nominal thicknesses for marble veneer are ¾", 7/8", 1¼", 1½", and 2" (20 mm, 22 mm, 30 mm, 38 mm, and 50 mm). When a marble thinner than ¾" is specified, the ratio between thickness and overall size and the use of reinforcing backup materials must be considered. Marble thicker than 2" (20 mm) is usually regarded as cubic stock.

6.0 SIZES

6.1 Marble is a product of nature with hundreds of varieties available, each possessing distinct characteristics. Little can be done to alter the condition in which nature presents these varieties to us. Therefore, size may become a limiting factor to consider in the selection of marble. Check with the Stone Supplier as to the sizes that are available for the specific marble.

6.2 Selection and delivery can be greatly facilitated by a jointing scheme that permits the use of smaller sizes. A final jointing scheme should be agreed upon after the marble has been selected and the Marble Contractor has been consulted.

7.0 PRODUCT SAMPLING

7.1 Marble is formed by nature; thus, there are variations in the tonal qualities of the stones. However, it is these natural variations that make marbles unique, valuable, and highly desirable. Because of these variations, selection of marble should never be made on the basis of one sample only. It is recommended that selection be based on viewing sufficient samples to show the complete range of colors of the desired stone.

8.0 PROPER USAGE TIPS

8.1 Recommendation for commercial floors:

8.1.1 Minimum ¾" (20 mm) thickness.

8.1.2 A honed finish.

8.1.3 A minimum hardness value of 10 as measured by ASTM C241/C1353.

8.2 Avoid the use of gypsum or molding plaster setting spots for the installation of stone.

8.3 Avoid using Soundness Classification C and D marbles in wet areas, saunas, and steam rooms.

8.4 Certain green colored marbles may warp when installed with water based adhesives. Ask the Supplier for instructions.

9.0 VENEER CUTTING

9.1 Quarry blocks are reduced to slabs by a gang saw. The gang saw consists of a series of steel blades set parallel in a frame that moves forward and backward. The most productive and precision gang saws have diamond-tipped blades with individual hydraulic blade tensioners.

9.2 Marble blocks can be sawn either parallel or perpendicular to the bedding plane. The perpendicular cut is referred to as an across-the-bed or vein cut. The parallel cut is with-the-bed or fleuri cut. Some marbles produce a pleasing surface when sawed in either direction, and are available as either vein or fleuri. Other marbles produce a pleasing surface only when sawed in one direction, and are generally available only in that variety.

10.0 SOUNDNESS CLASSIFICATION

10.1 As a result of knowledge gained from extensive practical experience in the dimension stone industry, marbles have been classified into four groups known as the Marble Soundness Classification.

10.2 The groupings–A, B, C, and D–should be taken into account when specifying marble, for all marbles are not suitable for all building applications. This is particularly true of the comparatively fragile marbles classified under Groups C and D, which may require additional fabrication before or during installation.

10.3 The basis of this classification is the characteristics encountered in fabricating and has no reference whatsoever to the comparative merits or value of each type of marble. The classification indicates what method of fabrication is considered necessary and acceptable in each instance as based on standard trade practice and applies only to marble.

10.4 Classification of marble is done by NSI Member producers. A written warranty should be obtained from them prior to installation.

10.5 The four groups of Marble Soundness Classification are:

10.5.1 Group A marbles
Sound marbles with uniform and favorable working qualities containing no geological flaws or voids. They include completely metamorphosed limestone or dolostone, in which impurities such as clays and silt have reacted chemically with the calcite or dolomite to form other minerals. These stones have uniform working qualities, can be used on the exterior or interior, and do not require any filling or patching.

10.5.2 Group B marbles
Marbles similar in character to Group A, except that all the impurities have not changed into other minerals. Occasional small holes and voids are to be expected, and are characteristics of this group of marbles. The holes or voids are filled by the Marble Craftsman with epoxy, shellac, or polyester resin. (The terms "waxing,"[12] "sticking,"[13] and "filling" are common industry terms.) Filling is

[12] *Waxing* refers to the practice of filling minor surface imperfections such as voids or sand holes with melted shellac, cabinetmaker's wax or certain polyester compounds. It does not refer to the application of paste wax to make surfaces shinier.

[13] *Sticking* describes the butt edge repair of a broken piece, now generally done with dowels, cements, or epoxies. The pieces are "stuck" together; thus "sticking."

not intended to be noticeable to a great degree, perfectly color matched, or "glass" smooth. May be used on the exterior or interior.

10.5.3 Group C marbles

Marbles with some variations in working qualities. Geological flaws, voids, veins, and lines of separation are common. Many of the impurities have not changed into other minerals, and metamorphosis is not complete. This is the largest and most colorful group of marbles, and also contains significant holes, voids, lines of separation, and structural flaws. It is standard practice to repair these variations by use of reinforcing, liners, sticking together, filling with resin or cement, fabricating corners or missing stone with terrazzo and resin, and doing all other work necessary to hold the stone together to yield a finished product that is usable for architectural purposes. On completion, most repairs are visible and apparent, with a difference in light reflection. With few exceptions, these marbles are not suitable for exterior installation.

10.5.4 Group D marbles

Marbles similar to the preceding group, but containing a larger proportion of natural faults, maximum variations in working qualities, and requiring more of the same methods of finishing. Few stones carry this designation at this time; it is reserved for very laborious Group C stones.

10.6 The Marble Soundness Classifications indicate what method and amount of repair and fabrication are necessary prior to or during installation, as based on standard trade practices.

TECHNICAL DATA - Marble

1.0 PROPERTIES OF MARBLE DIMENSION STONE

1.1 In centuries past, relatively little importance was attached to the ultimate physical capabilities of most building materials. Rule of thumb was a common structural design criterion. As a result, the widely used materials of the day, for the most part natural rather than manmade, were seldom stressed to their ultimate limits.

1.2 In present-day construction, however, this is far from being true. Performance requirements are daily becoming more demanding. In striving for taller structures, greater spans, firmer foundations, thinner walls and floors, stronger frames, and generally more efficient buildings with more usable space, today's Architects and Engineers must get the most out of the materials with which they work.

1.3 Marble is a product of nature and not always subject to the rules of consistent behavior that may apply to manufactured building materials. It may not be proper for certain applications.

1.4 Physical property values of marble may, however, be measured using the standard test methods approved by the Dimension Stone Committee C18 of ASTM International. The values found when stone is tested for absorption, density, compressive strength, abrasion resistance, and flexural strength should be useful for the Designer and Engineer when preliminary construction calculations are being made. However, these tests should be made before the project specifications are written, not after. Member companies of the Marble Institute of America are represented on this committee and are active in its technical work of establishing proper test methods and specifications consistent with the latest technology.

1.5 The data shown in the following table is the result of testing sixteen domestic marble varieties at the Illinois Institute of Technology Research Institute, as well as historical data and information established and provided by ASTM International. Final design should always be based on specific values for the marble variety ultimately to be installed. These values may be obtained from the Marble Supplier.

1.6 Physical Properties of Marble*

Property	**Range of Values**
Compressive Strength (C170) lbs/in²	6,000-35,000
Recommended (min): 7,500	
Flexural Strength (C880) lbs/in²	600-4,900
Recommended (min): 1,000	
Modulus of Elasticity** (in millions) lbs/in²	1.5-5.0
Density, lb/ft^3 (C97)	140-185
Recommended (min): 162 (calcite), 175 (dolomite)	
Thermal Conductivity "k" $Btu/in/hr/ft^2/°F$	10.45-15.65
Water Vapor Permeability Perm-inch	0.324-4.460
Coefficient of Thermal Expansion in/in/°F	$3.7 \times 10^{-6} – 5.0 \times 10^{-6}$
Modulus of Rupture (C99) lbs/in²	1,000-4,000
Recommended (min): 1,000	
Absorption, by weight % (C97)	0.060-1.0
Recommended (max): 0.20	
Abrasion Resistance H_a/I_w (C241/C1353)	5.0-50.0
Recommended (min): 10	

* Test methods described in current ASTM standards.

** Also known as Young's Modulus.

2.0 STRENGTH (ASTM C170, ASTM C880)

2.1 The strength of a marble is the measure of its ability to resist stresses. This strength depends on several factors: the rift and cleavage of the crystals, the degree of cohesion, the interlocking of the crystals, and the nature of any cementing materials present.

3.0 FIRE RESISTANCE

3.1 Marbles are not combustible, according to underwriters' ratings, and so are considered a fire-resistant material. Because of its thermal conductivity, however, the heat transfer through marble is fairly rapid. Marble is not considered a highly rated thermal insulator.

3.2 Underwriters' fire resistance ratings evaluate whether or not a material will burn, as well as how long it will keep surrounding combustible materials from reaching temperatures which will cause them to ignite. Pilot plant tests at The Ohio State University Pyrotechnics Laboratory indicate that a 10-minute rating could be expected from 7/8" (22 mm) thick marble.

3.3 The use of an insulating material with marble substantially improves the fire rating, as shown below.

7/8" (22 mm) marble with 1" (25 mm) core of:

Paper Honeycomb	½ hour
Cement-Bonded Wood Excelsior	1 hour
Autoclaved Cellular Concrete	1½ hour

3.4 Methods of estimating fire resistance periods of masonry walls and partitions utilizing component laminae are given in "Fire Resistance Classifications of Building Construction," BMS92, National Bureau of Standards.

4.0 ABRASION RESISTANCE (ASTM C241/C1353)

4.1 Abrasion resistance is a property of stone that should be tested per ASTM C241/C1353 to provide an indication of the stone's wearing qualities when exposed to foot traffic.

4.2 The hardness and uniform wearing qualities of most marble varieties make them extremely desirable and economically practical for floors and stairs. Varieties with an ASTM C241/C1353 abrasive hardness rating (Ha) of 10 or more are recommended for use as flooring. A minimum abrasive hardness of 12.0 is recommended for commercial floors, stair treads, and platforms subject to heavy foot traffic. Surfaces of floors constructed with two or more varieties, with Ha differences more than 5, will not wear evenly and uniformly.

5.0 FACTORS AFFECTING PROPERTIES

5.1 The ultimate test of a building material is its ability to have and maintain the necessary structural strength, as well as beauty of appearance and low cost of maintenance over the useful life of the structure. Experience has proven that marble meets this test as few other building materials can.

5.2 Illinois Institute of Technology Research Institute's studies have shown that the durability of marble is little affected by cycles of weather. This is because of marble's low rate of moisture absorption. The rates of absorption of all the marbles studied were less than 1 percent by weight. Other masonry materials range upward from 4% to 12%.

6.0 SAFETY FACTORS

6.1 Good engineering practice requires that allowable design stress must provide a margin of safety in any structural element. As a necessary precaution against such conditions as wind, ice, snow, impact, temperature changes, and imperfect workmanship, these allowable stresses must be smaller than those which produce failure.

6.2 Within the accepted limits of safe design practice, the closer the allowable load is to the ultimate failure load, the more efficient is the use of the material, and the less the cost of the construction.

6.3 Contemporary design of buildings, exclusive of the monumental type, does not usually employ marble as part of the structural frame, but rather as an independent unit, a curtain wall, or veneer. Therefore, the primary concern in such cases is with wind load, and a safety factor of 5.0 is recommended. Where the marble is to be subjected to concentrated loading, such as stair treads or lintels supported only at the ends, a factor of 10.0 should be used.

As buildings become taller and individual stone slab veneer becomes larger in area, the lateral forces due to wind loads must be considered. Wind tunnel tests are often used on major structures to determine wind dynamics and force magnitude. Reinforcement is sometimes necessary for large-dimension slab veneer in critical areas.

7.0 SEISMIC CONSIDERATIONS

7.1 Seismic considerations generally require that low buildings be stiff, and that tall buildings be relatively flexible. Design of connections must account for seismically induced horizontal loading. Local building codes vary and must always be checked to determine specific requirements for each area.

7.2 Additional Readings:
The National Bureau of Standards has published two documents on the topic: "Earthquake Resistant Masonry Construction," NBS Science Series 106; and "Abnormal Loading on

Buildings and Progressive Collapse: An Annotated Bibliography," NBS Science Series 67.

The U.S. Army Corps of Engineers also published TM 5-809-10, "Seismic Design for Buildings."

8.0 EFFLORESCENCE AND STAINING

8.1 Efflorescence is a salt deposit, usually white in color that appears on exterior surfaces of masonry walls. The efflorescence producing salts found in masonry are usually sulfates of sodium, potassium, magnesium, calcium, and iron. Salts which are chlorides of sodium, calcium, and potassium will sometimes appear, but they are so highly soluble in water that they will be washed off by rain.

8.2 The water-soluble salts causing efflorescence come from other materials in the wall. The salts exist in small amounts and are leached to the surface by water percolating through the walls. The most feasible means of prevention is to stop the entrance of large amounts of water. Absorption from the face will not cause efflorescence unless there are open joints.

8.3 Marble is not injured by efflorescence. However, some of the salt crystals may form in the pores near the surface. Crystal growth (recrystallization) in the pores can put stress on the walls of the pores and cause the stone to flake off. If the conditions bringing about this action persist, scaling may continue and flake off one layer after another. For this to happen, large amounts of water must enter the wall and must contain large amounts of salts.

8.4 Research indicates that staining or discoloration occurring on new buildings is caused by the action of water percolating through concrete from which soluble alkali salts are leached. The salts are then carried through the marble, where partially oxidized organic matter is picked up. This is then transported to the surface of the stone, where it is deposited as a stain as evaporation of the water takes place.

8.5 This staining phenomenon is similar to efflorescence except that it involves organic material. It does not harm the marble other than leaving an objectionable appearance during or soon after erection. However, if left alone, the stain is removed naturally by the action of the elements, usually in the course of a few months.

8.6 A considerable amount of water passing through the stone is necessary to bring out conspicuous discolorations. Proper precautions taken during construction of the walls will usually prevent such troubles. A simple and helpful expedient is to provide frequent weep holes in the base course and above shelf angles. These should be placed in the vertical joints so they can be sloped upward from the front to back.

8.7 Stains sometimes appear on the base course when marble is in contact with soil, or on interior and exterior horizontal surfaces, due to the carrying of soluble salts and some colored soil constituents up through and to the surface of the stone by capillary action. Almost all soils and most of the veining in marble contain soluble salts. Therefore, this staining phenomenon is similar to the discoloration described previously, and will disappear when the source of moisture is eliminated. However, materials from the veining may remain on the stone's surface. In walls, provide venting so that moisture can escape through the venting rather than through the stone. On horizontal surfaces, the use of a vapor barrier between the setting bed and the concrete slab, or between the setting bed and the ground, is recommended.

9.0 HYSTERESIS

9.1 Hysteresis is a phenomenon that affects certain "true" marbles. Unlike most stones, which return to their original volumes after exposure to higher or lower temperature, these marbles show small increases in volume after each rise in temperature above the starting point. This can result in differential expansion within the stone, which is more likely to be accommodated or restrained in thick veneers than in thin ones.

9.2 If it is not restrained, bowing of the marble panels ensues and produces compressive forces in the backs of panels. This causes creep, which in turn leads to permanent deformation. "Dishing" also stretches the marble's face, which makes stones more porous and increases their vulnerability to corrosion from acids in the atmosphere and deterioration from freezing and thawing effects. If marbles with this tendency are selected, it is important to determine the minimum thickness needed to overcome effects of hysteresis by testing under conditions which simulate in place temperature gradients of the wall.

10.0 THERMAL EXPANSION

10.1 The thermal expansion of marble is an important consideration where marble is used with dissimilar materials to form large units which are rigidly fixed.

Laboratory tests for the coefficient of thermal expansion of marble indicate that after several cycles of heating and cooling, a residual expansion of about 0.20% of the original increase can be expected. This should be taken into account when computing clearances. The coefficient of thermal expansion varies from one variety to another, so the actual thermal characteristics of a specific marble should be obtained from the quarries or fabricator before making a final selection.

11.0 TRANSLUCENCE

11.1 The translucency of marble is one of its most intriguing attributes. Not all marbles possess this translucent quality, nor is the degree of translucence the same in all varieties that transmit some light.

11.2 Translucence is dependent, to a greater or lesser extent, on the following factors:

11.2.1 Crystal Structure: Marbles of certain crystal structure are especially adaptable to transmitting light.

11.2.2 Color: The white and lighter-colored marbles are generally more translucent.

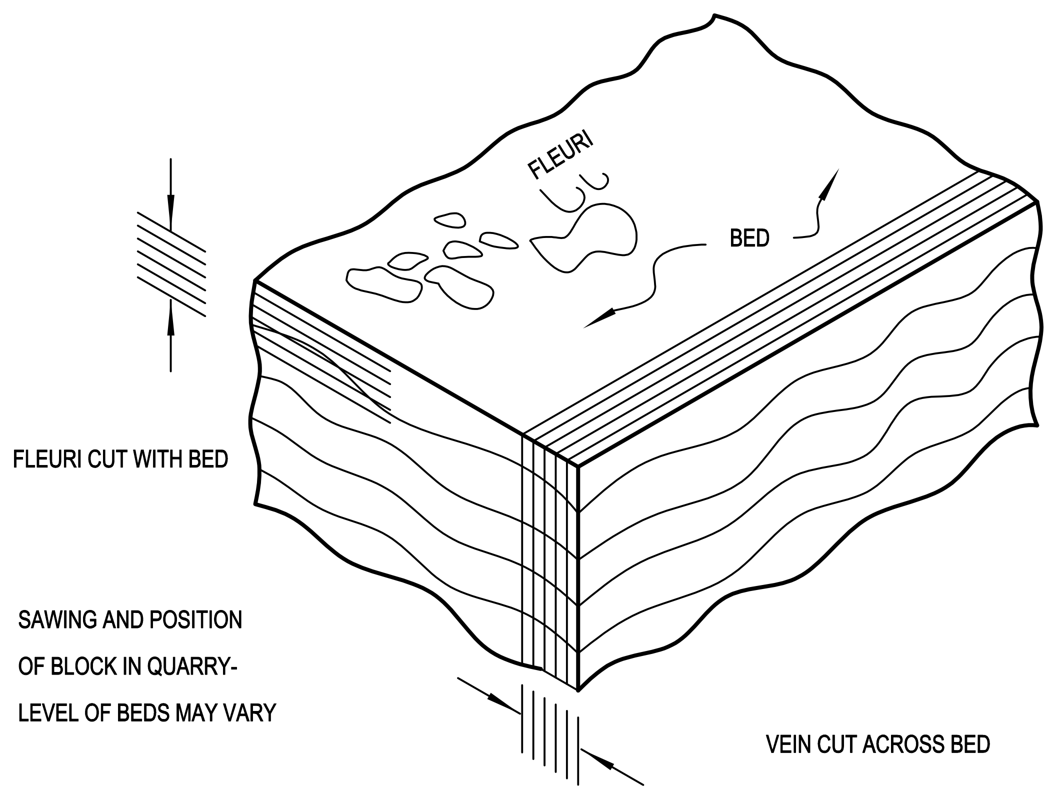
11.2.3 Thickness: The light transmission diminishes as panel thickness increases.

11.2.4 Surface Finish: Translucency is more apparent in smooth finishes than in rough finishes.

VENEER CUTTING

Quarry blocks are commonly reduced to slabs by a gang saw. The gang saw consists of a series of steel blades set parallel in a reciprocating frame.

Stone blocks can be sawed either parallel or perpendicular to the bedding plane. The perpendicular cut is referred to as am across-the-bed or veiny cut. The parallel cut is with-the-bed, or fleuri cut. Some stones produce a pleasing surface when sawed in either direction, and are available as either vein or fleuri. Other stones produce a pleasing and/or structurally sound surface only when sawed in one direction, and are therefore only available in that direction.



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RIFT & SAWING DIRECTIONS

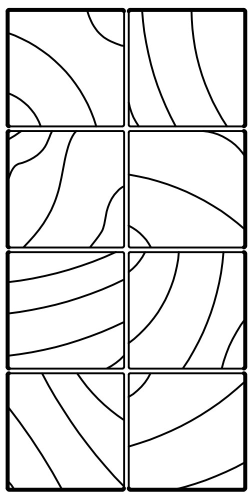
DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 7-D-1

SCALE: NOT TO SCALE

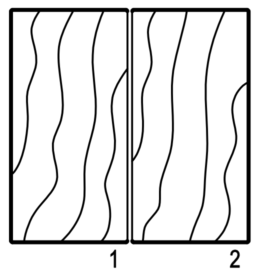
VENEER PATTERNS

Only certain stones lend themselves to specific veining pattern arrangements, such as side slip or end slip. This is because not all stones exhibit the near constant natural marking trend throughout the block that is required to accomplish these effects. Formal patterns require careful selection which often increases the costs of producing the stone veneer. Usually, a stone sawed in a veiny direction can be matched, while a stone sawed in a fleuri direction must be blended. Any desired pattern other than "blended" must be indicated on the contract bid documents to inform the stone contractor of the additional labor required.



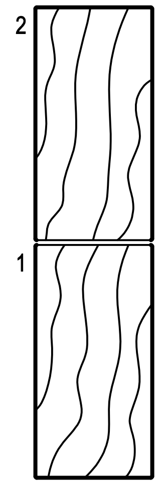
BLEND PATTERN

Panels of the same variety but not necessarily from the same block arranged at random. This scheme is followed when no other pattern is specified.



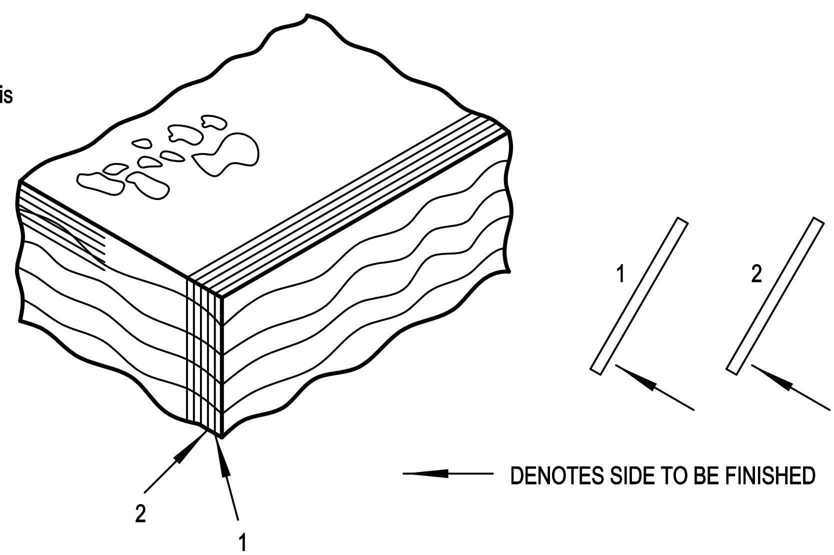
SIDE SLIP PATTERN

Panels are placed side by side to give a repetitive pattern and blended color in the horizontal.



END SLIP PATTERN

Panels from the same block are placed end to end in sequence to give a repetitive pattern and blended color in the vertical.



NATURAL STONE INSTITUTE	REV	DATE	VENEER VEIN PATTERNS
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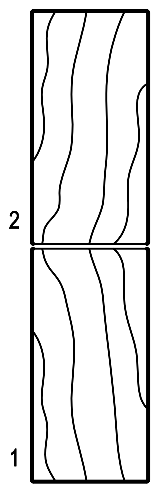
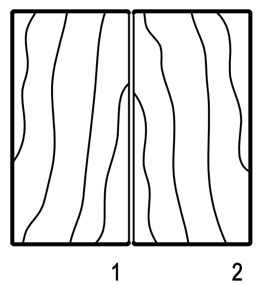
VENEER PATTERNS

Although the illustrations below depict a perfect match or mirror image of veining, such perfection is not realistic in actual stone veining. A portion of the block is lost due to the width of the saw kerf when the slabs are cut, and the veining position is likley to shift slightly across this offset. Brecciated marbles, for example, are extremely difficult to accurately cut into matched patterns. Ideally, jointery of the wall should plan for 4 panels of equal size.



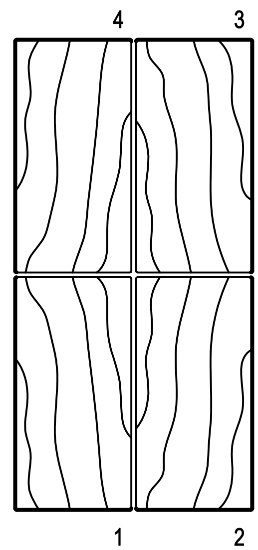
END MATCH PATTERN

The adjacent faces of panels 1 & 2 are finished.Panel 2 is inverted above panel 1.



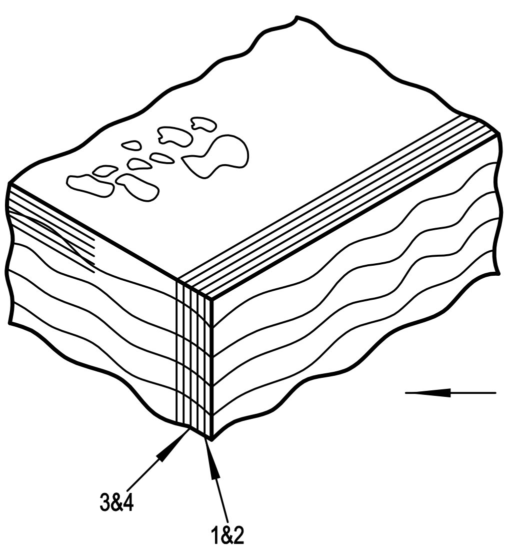
BOOK MATCH PATTERN

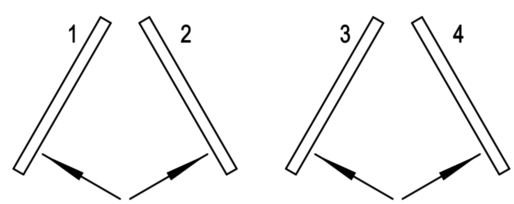
The adjacent faces of panels 1 & 2 are finished. Panel 2 is placed next to Panel 1 as the pages of a book are opened.



QUARTER OR DIAMOND MATCH PATTERN

Panels 1 & 2 are book matched. Panels 3 & 4 are book matched and then inverted over the top of panels 1 & 2.





← DENOTES SIDE TO BE FINISHED

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RIFT & SAWING DIRECTIONS

DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 7-D-3

SCALE: NOT TO SCALE

NOTES:

QUARTZ-BASED STONE

1.0 GENERAL

For purposes of this manual, Quartz-based stone refers to sandstone, quartzitic sandstone, and quartzite.

1.1 Related Documents

1.1.1 Drawings and general provisions, including General and Supplementary Conditions of the Contract and Division I Specification sections, apply to this section.

1.2 Applicable Publications

1.2.1 The following publications listed here and referred to thereafter by alphanumeric code designation only, form a part of this specification to the extent indicated by the references thereto:

1.2.2 ASTM International (ASTM):

1.2.2.1 C616, Standard Specification for Quartz-based Dimension Stone

1.2.2.2 C97, Standard Test Methods for Absorption and Bulk Specific Gravity of Dimension Stone

1.2.2.3 C99, Standard Test Method for Modulus of Rupture of Dimension Stone

1.2.2.4 C170, Standard Test Method for Compressive Strength of Dimension Stone

1.2.2.5 C241, Standard Test Method for Abrasion Resistance of Stone Subjected to Foot Traffic

1.2.2.6 C880, Standard Test Method for Flexural Strength of Dimension Stone

1.2.2.7 C1353, Standard Test Method for Abrasion Resistance of Dimension Stone Subjected to Foot Traffic Using a Rotary Platform Abraser

1.2.3 Natural Stone Institute (NSI):

1.2.3.1 Membership, Products, and Services Directory

1.2.3.2 Dimension Stone Design Manual

1.2.3.3 Additional publications may be available from the NSI Bookstore. Go online at www.naturalstoneinstitute.org.

1.3 Scope of Included Work

1.3.1 The work to be completed under this contract includes all labor and materials required for the furnishing and installation of all Quartz-based stonework shown or called for on the contract drawings, specifications, and addenda.

1.4 Definition of Terms

1.4.1 The definition of trade terms used in this specification shall be those published by the NSI or ASTM International.

1.5 Source of Supply

1.5.1 All Quartz-based stone shall be obtained from quarries having adequate capacity and facilities to meet the specified requirements and by a firm equipped to process the material promptly on order and in strict accord with specifications. The Specifying Authority (architect, designer, engineer, contracting officer, end user, etc.) reserves the right to approve the Material Supplier prior to the award of this contract. Stone and workmanship quality shall be in accordance with Industry Standards and Practices as set forth by the NSI.

1.6 Samples

1.6.1 The Quartz-based Stone Supplier shall submit through the General Contractor, for approval by the Specifying Authority, at least two sets of samples of the various kinds of Quartz-based stone specified. The sample size shall be 1'-0" x 1'-0" (300 mm x 300 mm) and shall represent approximately the finish, texture, and anticipated range of color to be supplied. One set of samples shall be retained by the Specifying Authority, and one set shall be returned to the Quartz-based Supplier for project record and guidance. It is noted herein that Quartz-based stone is a natural material and will have variations in color, markings, and other characteristics. Stone is a product of nature. It is not possible to guarantee that all the colors and markings of a large stone deposit will be present in every piece and that every characteristic will be uniformly present in other pieces. Depending on Quartz-based stone selected and quantity required, a range mockup may be required to further define the characteristics of the material. When required, the cost of the mockup shall be included in this section.

1.6.2 Prior to fabrication, an inspection and approval by the Specifying Authority (and/or General Contractor and/or End User) of a representative number of the finished slabs may be desirable to understand the finish and full range of the material

1.7 Shop Drawings

1.7.1 The Quartz-based Stone Supplier shall submit through the General Contractor, for approval by the Specifying Authority, sufficient sets of shop drawings showing general layout, jointing, anchoring, stock thickness, and such other pertinent information. These drawings shall show all bedding, bonding, jointing, and anchoring details along with the net piece dimensions for each Quartz-based unit. Setting numbers are to be shown, if applicable. One copy of the approved shop drawings shall be retained by the Specifying Authority, one copy shall be retained by the General Contractor, and one copy returned to the Quartz-based Stone supplier for fabrication. NO FABRICATION OF QUARTZ-BASED STONE SHALL BE STARTED UNTIL SUCH DRAWINGS HAVE BEEN FULLY APPROVED AND MARKED AS SUCH. The Quartz-based Stone Supplier shall not be responsible for determining, making, or verifying (1) design, structural, wind, seismic, or other design loads; (2) engineering estimates; (3) plans or specifications; or (4) the types, sizes, or locations of anchors, unless specifically added to the scope of work.

1.8 Defective Work

1.8.1 Any piece of Quartz-based stone showing flaws or imperfections upon receipt at the storage yard or building site shall be referred to the Specifying Authority for determination as to responsibility and decision as to whether it shall be rejected, patched, or redressed for use.

1.9 Repairing Damaged Stone

1.9.1 Chips at the edges or corners may be patched provided the structural integrity of the stone is not affected and provided the patch matches the color and finish of the natural stone so that it does not detract from the stone's appearance.

2.0 MATERIALS

2.1 Quartz-based Stone

2.1.1 General: All Quartz-based stone shall be of architectural standard grade, free of cracks, seams, starts, or other traits which may impair its structural integrity or function. Inherent color variations characteristic of the quarry from which it is obtained will be acceptable. Texture and finish shall be as shown in the sample(s) approved by the Specifying Authority.

2.1.2 ASTM C616 [C97] [C99] [C170] [C241/C1353] [C880] See the chart of applicable ASTM standards and tests in the Appendix.

2.1.3 Schedule: Quartz-based stone shall be provided as follows:

2.1.3.1 For (*state location on building*) (*state name and color*) Quartz-based stone with a (*type*) finish, supplied by (*name company or list several approved suppliers*).

2.1.3.2 Provide information as in (1) for each different Quartz-based stone/finish combination in the project.

2.1.4 Finishes: Available in cleft, chat sawn, and diamond sawn, sand sawn, honed, polished, rubbed, machine tooled, smooth planed, split face, and rock face.

2.1.5 Finishes listed in the schedule shall conform with definitions by the NSI or ASTM International.

2.2 Setting Mortar

2.2.1 Mortar for setting and pointing shall be one part portland cement and one part plastic lime hydrate to three to five parts of clean, nonstaining sand. It shall be mixed in small batches, using clean, nonalkaline water with a pH of 7 until it is thoroughly homogeneous, stiff, and plastic. After mixing, the mortar shall set for not less than one hour or more than two hours before being used.

2.3 Pointing Mortar

2.3.1 Mortar for pointing shall be Type N, as defined in ASTM C270 (Standard Specification for Mortar for Unit Masonry). All mixing, handling, and pacing procedures shall be in accordance with ASTM C270.

2.4 Sealants and Backup Material (If Applicable)

2.4.1 Where specified, (state type or name of sealant) shall be used for the pointing of joints. The backup material used with the sealant shall be (identify material). Joint sealants are to comply with ASTM C920. Submit samples for stain testing in accordance with ASTM D2203.

2.5 Anchors, Cramps, and Dowels

2.5.1 All wire anchors, cramps, dowels, and other anchoring devices shall be nonferrous metal of the types and sizes shown on approved shop drawings.

3.0 FABRICATION

3.1 Beds and Joints

3.1.1 Bed and head joint size shall be determined by analysis of anticipated building movements and designed to accommodate such movements without inducing undue stresses in the stone panels or joint filler materials. Expansion joints shall be designed and located to accommodate larger movements.

3.1.2 Some slight lippage and variation is natural and unavoidable where a rough finish face comes together at the sawed joints.

3.1.3 Joints ¼", 3/8", or ½" (6.5 mm, 9.5 mm, or 12.5 mm) are recommended between standard-size panels. All joints are to be water- and moisture-tight and caulked with a proper sealant.

3.2 Backs of Pieces

3.2.1 Backs of pieces shall be sawn or roughly dressed to approximately true planes. Back surfaces shall be free of any matter that may create staining.

3.3 Moldings, Washes, and Drips

3.3.1 Moldings, washes, and drips shall be constant in profile throughout their entire length, in strict conformity with details shown on approved shop drawings. The finish quality on these surfaces shall match the finish quality of the flat surfaces on the building.

3.4 Back-checking and Fitting to Structure or Frame

3.4.1 Stone coming in contact with structural work shall be back-checked as indicated on the approved shop drawings. Stones resting on structural work shall have beds shaped to fit the supports as required.

3.4.2 Maintain a minimum of 1" (25 mm) between stone backs and adjacent structure. (Note: many bolted connections will require more space than this; 2" (50 mm) space may be more desirable. Large-scale details should illustrate and control these conditions.)

3.5 Cutting for Anchoring, Supporting, and Lifting Devices

3.5.1 Holes and sinkages shall be cut in stones for all anchors, cramps, dowels, and other tieback and support devices per industry standard practice or approved shop drawings. However, additional anchor holes shall be drilled at job site by Quartz-based Stone Contractor to facilitate alignment.

3.5.2 No holes or sinkages will be provided for Quartz-based Stone Contractor's handling devices unless arrangement for this service is made by the Quartz-based Stone Contractor with the Quartz-based Stone Fabricator.

NOTE: It is not recommended that lewis pins be used for stones less than 3½" (90 mm) thick.

3.6 Cutting and Drilling for Other Trades

3.6.1 Any miscellaneous cutting and drilling of stone necessary to accommodate other trades will be done by the Quartz-based Stone Fabricator only when necessary information is furnished in time to be shown on the shop drawings and details, and when work can be executed before fabrication. Cutting and fitting, due to job site conditions, will be the responsibility of the Quartz-based Stone Contractor.

3.6.2 Incidental cutting such as for window frame clips, etc., which is normally not considered to be the responsibility of the Stone Supplier, will be provided only by arrangement by the General Contractor and Quartz-based Stone Contractor with the Quartz-based Stone Fabricator.

4.0 SHIPPING AND HANDLING

4.1 Packing and Loading

4.1.1 Finished Quartz-based stone shall be carefully packed and loaded for shipment using all reasonable and customary precautions against damage in transit. No material which may cause staining or discoloration shall be used for blocking or packing.

4.2 Site Storage

4.2.1 Upon receipt at the building site, stone shall remain in the factory-prepared bundles until beginning of the installation. Bundles shall be staged in an area which is least susceptible to damage from ongoing construction activity. Once unbundled, the granite shall be stacked on timber or platforms at least 2" (50 mm) above the ground, and the utmost care shall be taken to prevent staining or impact damage of the stone. If storage is to be prolonged, polyethylene or other suitable, nonstaining film shall be placed between any wood and finished surfaces of the stone. Polyethylene or other suitable, nonstaining film may also be required as protective covering.

5.0 INSTALLATION

5.1 General Installation

5.1.1 Installation shall be accomplished with competent, experienced Stone Setters, in accordance with the approved shop drawings.

5.1.2 All Quartz-based stone pieces shall be identified with a unique piece number corresponding with the number on the shop drawings. Interchanging of numbered pieces is not permitted.

5.1.3 Quartz-based stone shall be free of any ice or frost at time of installation. Salt shall not be used for the purpose of melting ice, frost, or snow on the stone pieces.

5.1.4 Adequate protection measures shall be taken to ensure that exposed surfaces of the stone shall be kept free of mortar at all times.

5.2 Mortar Setting

5.2.1 Unless otherwise shown on approved shop drawings, each piece shall be carefully laid in a full bed of mortar and tapped to a full and solid bearing. Exposed surfaces shall be kept free of mortar at all times.

5.2.2 If the thin-set method is used [for 5/8" (16 mm) thick stone] a dry-set portland cement mortar is applied with a 3/8" or ½" (9.5 or 12.5 mm) notched trowel with back buttering of the clean, moist tile surface.

5.2.3 Apply mortar with flat side of trowel over an area that can be covered with tile while mortar remains plastic. Within ten minutes and using a notched trowel of type recommended by Mortar Manufacturer, comb mortar to obtain even-setting bed without scraping backing material. Cover surface uniformly, with no bare spots, with sufficient mortar to ensure a minimum mortar thickness of 3/32" (2.5 mm) between tile and backing after tile has been tamped into place. Tile shall not be applied to skinned-over mortar. Average contact area shall be not less than 80%, except on exterior or shower installations, where contact shall be at least 95% when no less than three tiles are removed for inspection.

5.2.4 Veneer shall be set by spotting with gypsum molding plaster for interior use, or cement mortar and the use of concealed anchors secured in the wall backing.

5.2.5 Where thin wall tile [nominal 5/8" (16 mm) thick] is used, nonstaining adhesives or dry-set mortars may be employed. Individually set thin tile [nominal 3/8" (9.5 mm) thick] on vertical surfaces exceeding 8' (2.5 m) is not recommended.

5.2.6 Panels set in metal frames shall have rabbeted edges and a sealant for all joints to prevent moisture seepage. Hairpin spring anchors in the back of the panels make Quartz-based stone easily adaptable as facings for precast units and systems.

5.3 Mortar Joints

5.3.1 Mortar joints shall be raked out to a depth of ½" to ¾" (12.5 mm to 20 mm). Apply pointing mortar in layers not exceeding 3/8" (9.5 mm) and allow each layer to get hard to the touch before the next layer is applied. Tool finished joints with a concave tool having a diameter approximately 1/8" (3 mm) greater than the joint width.

5.3.2 Care shall be taken to keep expansion joints free of mortar, which would compromise their function.

5.4 Anchorage

5.4.1 The stone shall be anchored or doweled in accordance with the approved shop drawings.

5.4.2 To the furthest extent possible, all anchor preparations in the Quartz-based stone units shall be shop-applied.

5.4.3 All anchorage devices and anchor hole/slot fillers shall be in accordance with ASTM C1242. Care must be taken to ensure that any holes capable of retaining water are filled after use to prevent water collection and freezing.

5.5 Sealant Joints

5.5.1 Where so specified, joints requiring sealant shall be first filled with a closed-cell ethafoam rope backer rod. The backer rod shall be installed to a depth that provides optimum sealant profile after tooling.

5.5.2 If recommended by the Sealant Manufacturer, primers shall be applied to the substrate surfaces according to the manufacturer's directions prior to application of the joint sealant.

5.6 Expansion Joints

5.6.1 It is not the intent of this specification to make control or expansion-joint recommendations for a specific project. The Specifying Authority must specify control or expansion joints and show locations and details on drawings.

5.7 Caulking

5.7.1 Where so specified, joints shall be pointed with the sealant(s) specified in Section 2.4 after first installing the specified backup material and applying a primer if required, all in strict accordance with the printed instructions of the sealant manufacturer.

5.7.2 All sealants shall be tooled to ensure maximum adhesion to the contact surfaces.

5.8 Weep Tubes

5.8.1 Plastic or other weep tubes shall be placed in joints where moisture may accumulate within the wall, such as at base of cavity, continuous angles, flashing, etc., or as shown on architectural drawings.

6.0 CLEANING AND PROTECTION

6.1 Cleaning

6.1.1 Upon completion of various portions of work, all mortar stains, grease marks, and dirt should be removed by washing with a good grade of nonabrasive detergent with a pH of 7. Flush and clean with clear water. Floors can be swept, damp-mopped, or hosed off with clean water.

6.2 Protection of Finished Work

6.2.1 Quartz-based stone installation in progress shall be protected with film, fabric tarps, and wood for exposed edge protection secured over the work.

6.2.2 After the Quartz-based stone has been installed, it shall be the responsibility of the General Contractor to see that it is properly and adequately protected from damage and stains until all trades are finished. This responsibility includes the stone cleaning costs prior to the final inspection. The Quartz-based Stone Contractor will outline the needs for protection, in writing, to the General Contractor.

PRODUCT DESCRIPTION – Quartz-based Stone

1.0 GEOLOGICAL CLASSIFICATION

1.1 Most types of Quartz-based stones are clastic sedimentary stone, composed of particles or grains usually cemented with varying amounts of either hydrous silica or crystalline quartz. A notable exception is the chert group, including chert, agate, and flint, which are siliceous chemical sedimentary stones.

1.2 The following are the main groups of Quartz-based stone:

1.2.1 Quartz, Crystalline Quartz

1.2.2 Sandstone

1.2.3 Quartzite

1.2.4 Metaquartzite

1.2.5 Quartz Pebble Conglomerates

1.2.6 Metaconglomerates

1.2.7 Chert, Agate, Flint

1.3 The key to understanding all Quartz-based stone is the understanding of crystalline quartz as a mineral. The basic physical properties of quartz – with the possible exception of absorption and porosity – are the same as those of any Quartz-based stone.

1.4 Quartz (SiO_2) is composed of the two most abundant elements in the Earth's crust: silicon and oxygen, which respectively make up 28% and 47% by weight of our planet's lithosphere. Of all the common minerals, quartz lasts the longest in the environment. Most of the beaches in the world, with a few exceptions, are quartz sand.[1] Almost all other minerals are abraded away, broken up mechanically through weathering and transportation, or, if soluble, dissolved. Quartz is itself slightly soluble, giving rise to the chert deposits found in many sedimentary sequences.

1.5 Weathering of igneous, sedimentary, and metamorphic rocks releases grains of quartz sand. Water, gravity, and wind transport this rock debris (detritus) down mountains, hills, and highlands, and across the plains to lakes, seas, and into the oceans, depositing the debris on beaches and beyond to form into new sedimentary stone. During this natural process, soluble salts are released from the debris, and some of these salts ultimately run off into below-sea level lakes and into oceans as dissolved salts, giving the oceanic water its briny content.

1.6 Crystalline quartz has a fixed chemical composition: SiO_2. Some other quartz types occur as hydrous silica (SiO_2•NaH_2O), the mineral of chert, agate, flint, and fire opal. These stones are about H=6 to 6.5 on the Mohs Scale,[2] not quite as hard as crystalline quartz.

1.7 Physical properties of crystalline quartz:

1.7.1 Hardness. Quartz has a Mohs Scale hardness rating of 7. It can scratch minerals with a hardness of less than 7, such as calcite and feldspar, but cannot scratch other quartz or minerals with a hardness greater than 7, such as corundum and diamond.

1.7.2 Shape. Quartz crystals are always six-sided, elongate prisms with a pyramid-shaped termination usually on one end of the prism only. The prisms may be imperfect, but the angles between sides are always equal, even though the prismatic sides are very unequal in width.

1.7.3 Lack of Cleavage. Quartz does not have "cleavage," the weakness in molecular geometry along which a mineral consistently break.

1.7.4 Fracturing. When quartz fractures, it can break with dish-shaped, irregular surfaces.

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[1] A few beaches are entirely carbonate sand created by waves breaking up seashells into coarse, sand-sized grains. Some of these beaches have no land-derived silicate minerals or rock fragments. The beaches of Bermuda are a well-known example. There, the sands are pink from coloration derived from the remains of small, red, single-cell marine organisms. In Hawaii, there are beaches of only black or green volcanic sand with no quartz sand content.

[2] See Appendix for the Mohs Scale of mineral hardness.

The dished surfaces often have small concentric ridges giving it a "conchoidal" surface effect, after seashells with similar shapes and concentric ridges. Fractured quartz faces are rough, uneven, and never flat.[3]

1.7.5 Coloring. Quartz occurs naturally in a range of colors. Some colored quartz crystals are prized as semiprecious gems, e.g., citrine (yellow), amethyst (lavender to purple), and jasper (yellow, brown, red), to name a few. This natural coloring is due to micro inclusions or traces of other elements in the stone's chemistry. However, not all quartz available on the market is naturally colored. Artificial coloring processes are sometimes used in the gem industry to dye fractured crystalline quartz in colors not seen in nature, such as bright pink and fluorescent shades of green, yellow, and blue.

1.7.6 Electrical Properties. Quartz is "piezoelectric," an unusual electrical property that has no effect on the performance of the mineral in normal dimension stone applications. If squeezed, quartz generates an electrical current proportional to the amount of pressure applied. When a small current is generated on two opposing faces of a cut, ground quartz crystal, it vibrates electrically, acting as an oscillator at a frequency determined by the exact thickness of the crystal. These were used in communications equipment from the 1920s to the 1950s to control broadcast frequencies, but are now obsolete.

1.8 Sandstone is a nonmetamorphic sedimentary stone. When firmly cemented with silica, sandstone could be correctly identified as quartzite. However, it is suggested the name quartzite should be restricted for sandstone tightly cemented with homogeneous crystalline silica (quartz crystals).

1.9 Quartzite, the silica-cemented, unmetamorphosed variety, tends to occur in sedimentary units or beds, and the thicker quartzite ledges are generally more useful than the thinner occurrences. With thicker units of quartzite, the distinction between metamorphosed and unmetamorphosed types makes little difference to those in the stone industry. Quartzite breaks across grains, not around grains. Thus it is very hard (H=7), durable, and for practical purposes, not a soluble stone, making it a desirable material for some difficult installations where exposure to water may be a problem.

1.10 Metaquartzite. The metamorphic equivalent of quartzite is metaquartzite. Often difficult to differentiate from its nonmetamorphosed parent stone, metaquartzite has certain distinct features; for example, thin "partings" of clear mica often separate layers or bands of pure metaquartzite. Some deposits of the stone occur in layers only 1/8" to ½" (3 mm to 12.5 mm) thick, separated by the micaceous parting that allows easy separation or cleaving characteristic of mica sheets, due to weak molecular bonds.

1.11 These mica partings should not be confused with former bedding. The partings are a form of banding developed from the mineral segregation that occurs in the process of metamorphism. Thin metaquartzite is valued for use in flooring and decorative stone applications.

1.12 Quartz pebble conglomerates, unless silica-cemented, may tend to disaggregate rather easily, particularly if the quartz pebbles are highly rounded and smooth and the cement is not strong, especially if the cementing agent and matrix is the soluble mineral calcite or limestone. If the conglomeratic matrix is silica, then the stone will break through the quartz pebbles. A quartz pebble conglomerate may occasionally consist

[3] Crystalline Quartz can be deposited in a void *against* an existing crystal face of another mineral. The resulting flat face on quartz is an *artifact*, not originating as a consequence of the atomic geometry of quartz. The only true, flat quartz face is a crystal face.

of a variety of colored quartz pebbles including white, yellows, reds, black, and sometimes banded agate. A multicolored quartz pebble conglomerate with red siliceous cement is found on the Iberian Peninsula and in the Atlas Mountains of North Africa. This type is a valuable dimension stone.

1.13 Metaconglomerates. Metaquartz pebble conglomerates, like metaquartzite, will break through and not around grains and pebbles. Other strongly metamorphosed conglomerates have been squeezed under such high pressure that the quartz pebbles are flattened. The plane of flattening is normal (perpendicular to the direction of pressure), and flattened pebbles of hard quartz are a notable example of how high the pressures of metamorphism can be.

1.14 Chert, Agate, Flint. These are varietal names for hydrous silica deposits that can occur in beds or nodules. Chert, the preferred geological name, is classified as chemical sedimentary stone. Cherts are true chemical precipitates emplaced within a sedimentary sequence at some time after burial and perhaps before cementation.

1.15 Some cherts, like red jasper, are valuable as semiprecious stones sold and used by gemstone hobbyists. Banded or lace agate can be valuable for jewelry or as an exceedingly rare and expensive dimension stone. Entire fireplace mantles and part of the surround have been made from large, exquisite sheets of agate. Because it is softer than crystalline quartz, Agate was often the material used to carve mortars and pestles for use in 19th century pharmacies. It was also used to make marbles for the game popular with 19th and early 20th century children.

2.0 COLOR AND VEINING

2.1 The color, veinings, clouds, mottlings, and shadings in Quartz-based stone are caused by substances included during formation.

2.2 The purest Quartz-based stones are nearly white. Colors are primarily due to iron oxides. The presence of limonite usually yields yellow, brown, and buff shades; the presence of hematite yields darker brown or red. Oxidation of iron-bearing minerals upon exposure may cause some stones to change color after installation.

2.3 Since most Quartz-based stones are formed in layers through centuries, each layer may have considerable color variations. It is not uncommon that some may have a color range of possibly up to 12 shade variations. If a minimal amount of shade variation is desired, then additional quarrying time will be required, as well as special, hand-selection costs.

3.0 TEXTURE

3.1 The term "texture," as applied to Quartz-based stone, means size, degree of uniformity, and arrangement of constituent minerals. Quartz-based stones are essentially quartz; some are nearly pure quartz.

3.2 Grains of quartz may be well-rounded or angular, depending upon the degree to which they were water-worn before consolidation. Some deposits show remarkable uniformity in size of grains. This grain composition can affect the texture.

3.3 Texture of Quartz-based stone is also affected by the way that the grains of silica fracture. Sandstone fractures around the constituent grains. Quartzitic sandstone fractures around or through the constituent grains. Quartzite fractures conchoidally through the grains.

3.4 Quartz-based stones are the most variable type of dimension stone due to wide variety in degree of cementation and type of cementing material between the grains. There are four common cementing materials: iron oxides, clay, calcite, and quartz. All stages of cementation are found in nature, from incoherent sandstones that may be crumbled between the fingers, to the most hardened quartzites. All types between these extremes are used commercially.

3.5 Sandstones may be relatively high porosity stones. Quartzites, on the other hand, can have as little pore space as granites.

4.0 FINISHES

4.1 A common finish for Quartz-based stone is natural cleft finish. It should be noted that the face of natural-cleft stone is not necessarily a true flat surface. This surface may vary from flat to variations up to ¼" from true flat. This could result in a surface that is concave or convex, or could also be warped or "propellered" (corners tipping either down or up).

4.2 Many of the standard finishes can be applied to Quartz-based stones.

4.3 Some stone finishes can affect strength and durability. Examples are bush-hammered and thermal finishes, which reduce a stone's thickness, making it more vulnerable to weakening from exposure to freeze and thaw cycles.

5.0 THICKNESS

5.1 As these are split stones, standard thicknesses are highly variable, e.g., ¾", 1½", 2", 4", or 8" (20 mm, 40 mm, 50 mm, 100 mm, or 200 mm).

Note: As Quartz-based stone is cut thinner, its tensile strength is diminished.

6.0 SIZES

6.1 Quartz-based stone is a product of nature with many varieties available, each possessing varying characteristics. Little can be done to alter the condition in which nature presents these varieties to us. Therefore, size may become a limiting factor to consider in the selection of a particular Quartz-based stone.

6.2 A jointing scheme which permits the use of appropriate sizes of Quartz-based stone yielded by the particular quarry will greatly facilitate selection and delivery.

7.0 PRODUCT SAMPLING

7.1 Quartz-based stones are formed by nature; thus, there are variations in the tonal qualities of the stones. However, it is these natural variations that make Quartz-based stone unique, valuable, and highly desirable. Because of these variations, selection of a stone should never be made on the basis of one sample only. It is recommended that selection be based on viewing sufficient samples to show the complete range of color of the desired stone. (See "2.0 Color and Veining" in this chapter section for additional information.)

8.0 PROPER USAGE TIPS

8.1 Recommendation for commercial floors:

8.1.1 Minimum ¾" (20 mm) thickness.

8.1.2 A honed finish.

8.1.3 A minimum hardness value of 2 (Sandstone), 8 (Quartzitic Sandstone), and 8 (Quartzite) as measured by ASTM C241/C1353.

8.2 Avoid the use of gypsum or molding plaster setting spots for the installation of exterior stone.

9.0 TOLERANCES

9.1 Because of the many variances in cementation and porosity, it is recommended that the Quartz-based Stone Quarrier or

Fabricator be contacted regarding size and thickness tolerances.

10.0 FABRICATION

10.1 One process after quarrying Quartz-based stone is to guillotine the slabs to the desired length and thickness, thus the thick slabs can be split to the desired thicknesses of 2", 3", or 4" (50 mm, 75 mm, 100 mm).

TECHNICAL DATA – Quartz-based Stone

1.0 PROPERTIES OF QUARTZ-BASED DIMENSION STONE

1.1 In centuries past, relatively little importance was attached to the ultimate physical capabilities of most building materials. Rule of thumb was a common structural design criterion. As a result, the widely used materials of the day, for the most part natural rather than man-made materials, were seldom stressed to their ultimate limits.

1.2 In present-day construction, this is far from being true. Performance requirements are daily become more demanding. In striving for taller structures, greater spans, firmer foundations, thinner walls and floors, stronger frames, and generally more efficient buildings with more usable space, today's Architects and Engineers must get the most out of the materials with which they work.

1.3 Quartz-based stone is a product of nature and not always subject to the rules of consistent behavior that may apply to manufactured building materials. Physical property values of Quartz-based stone may, however, be measured using the standard test methods approved by the Dimension Stone Committee C-18 of ASTM International. The NSI and Member companies are represented on the ASTM committee and are active in its technical work of establishing proper test methods and specifications consistent with the latest technology.

1.4 Final design should always be based on specific values for the stone variety ultimately to be installed. These values may be obtained from the Stone Supplier. All materials are not suitable for all uses. In order to avoid mistaken selections, tests for material values should be made prior to final material selection.

1.5 Physical Properties of Quartz-based Stone
(These historical data and information are provided only as a guideline. Recommended minimums or maximums are established and provided by ASTM International.)*

Property — **Range of Values**

Compressive Strength (C170)
lbs/in² 2,000-37,000
Recommended (min):
4,000 (sandstone),
10,000 (quartzitic sandstone),
20,000 (quartzite)

Flexural Strength (C880)
lbs/in² 700-2,300

Modulus of Elasticity** (in millions)
lbs/in² 1.0-1.75

Density, lb/ft³ (C97) 135-170
Recommended (min):
125 (sandstone),
150 (quartzitic sandstone),
160 (quartzite)

Modulus of Rupture (C99) lbs/in².300-2,500
Recommended (min):
350 (sandstone),
1,000 (quartzitic sandstone),
2,000 (quartzite)

Absorption (by weight) % (C97) 1.0-20.0
Recommended (max):
8.0 (sandstone),
3.0 (quartzitic sandstone),
1.0 (quartzite)

* Test methods described in current ASTM standards. ** Also known as Young's Modulus.

2.0 STRENGTH (ASTM C99, C170, C880)

2.1 Values for modulus of rupture, compressive strength, and flexural strength are ascertained by testing specimens of Quartz-based stone under laboratory conditions until they fail.

2.2 Size and finish of test samples required by the standard ASTM test methods may not reflect the actual performance of stone when used in lesser thicknesses or with other finishes that affect strength. For this reason, the Modulus of Rupture (C99) test is recommended when the stone to be used will be two or more inches thick. The Flexural Strength (C880) test is recommended when the stone thickness will be less than two inches.

2.3 The strength of a Quartz-based stone is a measure of its ability to resist stresses. This strength depends on several factors: the amount of free silica, degree of cementation, porosity, and whether the stone is metamorphosed.

3.0 FIRE RESISTANCE

3.1 Stone is not combustible according to underwriters' ratings, and therefore is considered a fire-resistant material. Because of its thermal conductivity, heat transfer is fairly rapid. Most stone is not considered a highly rated thermal insulator.

3.2 Underwriters' fire-resistance ratings evaluate whether or not a material will burn, as well as how long it will keep surrounding combustible materials from reaching temperatures which will cause them to ignite. Methods of estimating fire-resistance periods of masonry walls and partitions utilizing component laminae are given in "Fire Resistance Classifications of Building Construction," BMS92, National Bureau of Standards.

4.0 ABRASION RESISTANCE (ASTM C241/C1353)

4.1 Abrasion resistance is a property of stone that should be tested per ASTM C241/C1353 to provide an indication of the stone's wearing qualities when exposed to foot traffic.

4.2 The hardness and uniform wearing qualities of most Quartz-based stones make them extremely desirable and economically practical for floors and stairs. Varieties with an abrasive hardness (H_a/I_w) of 8 or more, as measured by ASTM C241/C1353 tests, are recommended for use as flooring exposed to normal foot traffic. A minimum abrasive hardness of 12 is recommended for commercial floors, stair treads, and platforms subject to heavy foot traffic. If floors are constructed with two or more stone varieties, the H_a/I_w values of the stones must not differ by more than 5, or the floor surface will not wear evenly and uniformly.

5.0 FACTORS AFFECTING PROPERTIES

5.1 The ultimate test of a building material is its ability to have and maintain the necessary structural strength, as well as beauty of appearance and low cost of maintenance, over the useful life of the structure. Experience has proven that stone meets this test as few other building materials can. Studies have shown that the durability of most stones is little affected by cycles of weather. This is because most have a low rate of moisture absorption.

6.0 SAFETY FACTORS

6.1 Good engineering practice requires that allowable design stress must provide a margin of safety in any structural element. As a necessary precaution against such conditions as wind, ice, snow, impact, temperature changes, and imperfect workmanship, these allowable stresses must be smaller than those which produce failure.

6.2 Within the accepted limits of safe design practice, the closer the allowable load is to the ultimate failure load, the more efficient is the use of the material and the less the cost of the construction.

6.3 Contemporary building design does not usually employ stone as part of the structural frame, but rather as an independent unit, a curtain wall, or veneer. Therefore, the primary concern in such cases is with wind or seismic loads, and a safety factor of 8.0 is recommended. Where the stone is to be subjected to concentrated loading, such as stair treads or lintels supported only at the ends, a factor of 10.0 should be used.

6.4 These safety factors may be adjusted using sound engineering principles and judgment.

6.5 As buildings become taller and individual stone-slab veneer becomes larger in area, the lateral forces due to wind loads must be considered. Wind tunnel tests are often used on major structures to determine wind dynamics and force magnitude. Reinforcement is sometimes necessary for large dimension-slab veneer in critical areas.

7.0 SEISMIC CONSIDERATIONS

7.1 Seismic considerations generally require that low buildings be stiff, and that tall buildings be relatively flexible. Design of connections must account for seismically induced horizontal loading. Local building codes vary and must always be checked to determine specific requirements for each area. The National Bureau of Standards has published two documents on the topic: “Earthquake Resistant Masonry Construction,” NBS Science Series 106; and “Abnormal Loading on Buildings and Progressive Collapse: An Annotated Bibliography,” NBS Science Series 67. The U.S. Army Corps of Engineers has also published TM 5-809-10, “Seismic Design for Buildings.”

8.0 EFFLORESCENCE AND STAINING

8.1 Efflorescence is a salt deposit, usually white in color that appears on exterior surfaces of masonry walls. The efflorescence-producing salts found in masonry are usually sulfates of sodium, potassium, magnesium, calcium, and iron. Salts which are chlorides of sodium, calcium, and potassium will sometimes appear, but they are so highly soluble in water that they will be washed off by rain.

8.2 The water-soluble salts causing efflorescence come from other materials in the wall. The salts exist in small amounts and are leached to the surface by water percolating through the walls. The most feasible means of prevention is to stop the entrance of large amounts of water. Absorption from the face will not cause efflorescence unless there are open joints.

8.3 Quartz-based stones are seldom injured by efflorescence. However, some of the salt crystals may form in the stones' pores near the surface. Crystal growth (recrystallization) in the pores can cause stress on the walls of the pores and cause the stone to flake off. If the conditions bringing about this action persist, scaling may continue and flake off one layer after another. For this to happen, large amounts of water must enter the wall and must contain large amounts of salts.

8.4 Research indicates that staining and discoloration occurring on new buildings are caused by the action of water percolating through cement from which soluble alkali salts are leached. The salts are then carried through the stone, where partially oxidized organic matter is picked up. This is then transported to the surface of the stone, where it is deposited as a stain as evaporation of the water takes place.

8.5 This staining phenomenon is similar to efflorescence except that it involves organic material. It does not harm the stone other than leaving an objectionable appearance during or soon after erection. However, if left alone, the stain is removed naturally by the action of the elements, usually in the course of a few months.

8.6 A considerable amount of water passing through the stone is necessary to bring out conspicuous discolorations. Proper precautions taken during construction of the walls will usually prevent such troubles. A simple and helpful expedient is to provide frequent weep holes in the base course and above shelf angles. These should be placed in the vertical joints so they can be sloped upward from the front to back.

8.7 Stains sometimes appear on the base course when Quartz-based stone is in contact with soil, due to the carrying of soluble salts and some colored soil constituents up through and to the surface of the stone by capillary action. Almost all soils contain soluble salts. Therefore, this staining phenomenon should disappear when the source of moisture is eliminated.

8.8 Avoid contact between soil and stone. Damp-proofing treatments of either a bituminous or cementitious nature may be used as a barrier to the groundwater or construction moisture causing these stains.

9.0 THERMAL EXPANSION

9.1 The thermal expansion of Quartz-based stone is an important consideration when it is used with dissimilar materials to form large units which are rigidly fixed. The coefficient of thermal expansion varies from one variety to another; actual thermal characteristics of a specific Quartz-based stone should be obtained from the Quarriers or Fabricator before making a final selection.

SERPENTINE

1.0 GENERAL

1.1 Related Documents

1.1.1 Drawings and general provisions, including General and Supplementary Conditions of the Contract and Division I Specification sections, apply to this section.

1.2 Applicable Publications

1.2.1 The following publications listed here and referred to thereafter by alphanumeric code designation only, form a part of this specification to the extent indicated by the references thereto:

1.2.2 ASTM International (ASTM):

1.2.2.1 C1526, Standard Specification for Serpentine Dimension Stone

1.2.2.2 C97, Standard Test Methods for Absorption and Bulk Specific Gravity of Dimension Stone

1.2.2.3 C99, Standard Test Method for Modulus of Rupture of Dimension Stone

1.2.2.4 C170, Standard Test Method for Compressive Strength of Dimension Stone

1.2.2.5 C241, Standard Test Method for Abrasion Resistance of Stone Subjected to Foot Traffic

1.2.2.6 C880, Standard Test Method for Flexural Strength of Dimension Stone

1.2.2.7 C1353, Standard Test Method for Abrasion Resistance of Dimension Stone Subjected to Foot Traffic Using a Rotary Platform Abraser

1.2.3 Natural Stone Institute (NSI):

1.2.3.1 Membership, Products, and Services Directory

1.2.3.2 Dimension Stone Design Manual

1.2.3.3 Additional publications may be available from the NSI Bookstore. Go online at www.naturalstoneinstitute.org.

1.3 Scope of Included Work

1.3.1 The work to be completed under this contract includes all labor and materials required for the furnishing and installation of all serpentine work shown or called for on the contract drawings, specifications, and addenda.

1.4 Definition of Terms

1.4.1 The definitions of trade terms used in this specification shall be those published by the NSI or ASTM International.

1.5 Source of Supply

1.5.1 All serpentine shall be obtained from quarries having adequate capacity and facilities to meet the specified requirements, and by a firm equipped to process the material promptly on order and in strict accord with specifications. The Specifying Authority (architect, designer, engineer, contracting officer, end user, etc.) reserves the right to approve the Material Supplier prior to the award of this contract. Stone and workmanship quality shall be in accordance with Industry Standards and Practices as set forth by the NSI.

1.6 Samples

1.6.1 The Serpentine Contractor shall submit through the General Contractor, for approval by the Specifying Authority, at least two sets of samples of the various kinds of serpentine specified. The sample size shall be 1'-0" x 1'-0" (300 mm x 300 mm) and shall represent approximately the finish, texture, and anticipated range of colors to be supplied.

Where necessary to show variations in color and markings, larger samples or range sets of samples should be submitted. If serpentine is to be matched, a minimum of two sets each containing four matched samples showing proposed veining and range of colors in each set must be supplied. Samples designating finished face shall be clearly labeled on the back with the name of the serpentine, and the use for which the serpentine is intended. One set of samples shall be retained by the Specifying Authority, and one set shall be returned to the Serpentine Supplier for their record and guidance. It is noted herein that serpentine is a natural material and will have intrinsic variations in color, markings, and other characteristics. Depending on the serpentine selected and quantity required, a range mockup may be used to further define the characteristics of the material. Cost of mockup, if required, shall not be included in this section.

1.6.2 Prior to fabrication, an inspection and approval by the Specifying Authority and/or General Contractor and/or End User of the finished slabs is recommended to understand the finish and full range of the material.

1.7 Shop Drawings

1.7.1 The Serpentine Contractor shall submit through the General Contractor, for approval by the Specifying Authority, sufficient sets of shop drawings showing general layout, jointing, anchoring, stock thickness, and such other pertinent information. These drawings shall show all bedding, bonding, jointing and anchoring details along with the net piece dimensions of each serpentine unit. One copy of approved drawings shall be retained by the Specifying Authority, one copy shall be retained by the General Contractor, and one copy returned to the Serpentine Contractor for fabrication. NO FABRICATION OF SERPENTINE SHALL BE STARTED UNTIL SUCH DRAWINGS HAVE BEEN FULLY APPROVED AND MARKED AS SUCH. The General Contractor shall furnish all field dimensions necessary for fabrication. If measurements are not established and guaranteed in advance, the Serpentine Contractor shall obtain and verify measurements at the building. The General Contractor shall be responsible for all reasonable assistance to the Serpentine Contractor, including the services of an Engineer, if required, for the establishment of levels, benchmarks, and the like. The Serpentine Contractor shall not be responsible for determining, making, or verifying (1) design, structural, wind, seismic, or other design loads; (2) engineering estimates; (3) plans or specifications; or (4) the types, sizes, or locations of anchors, unless specifically added to the scope of work.

1.8 Defective Work

1.8.1 Any piece of serpentine showing flaws or imperfections upon receipt at the storage yard or building site shall be referred to the Specifying Authority for determination as to responsibility and decision as to whether it shall be rejected, patched, or redressed for use.

1.9 Repairing Damaged Stone

1.9.1 Patching during fabrication. Serpentines have some variation in working qualities. Veins and lines of separation are common. It is standard practice to repair these variations by use of reinforcing, liners, sticking[1] together, filling with resin or terrazzo, and doing all other work necessary to hold the stone together to yield a finished product that is usable for architectural purposes. On completion, most repair is visible, with differences in light reflection. Unlike other dimension stones, many varieties of serpentine that have been reinforced and repaired are suitable for use in exterior environments,

[1] *Sticking* describes the butt edge repair of a broken piece, now generally done with dowels, cements, or epoxies. The pieces are "stuck" together; thus "sticking."

though not in all situations. Where questions of suitability for use are encountered, NSI recommends that reliance on past performance is the best guide for making decisions as to future performance.

1.9.2 Patching during installation. Small chips at the edges and corners of serpentine may be patched, provided the structural integrity of the stone is not affected and the patch matches the color and finish of the stone so that it does not detract from the appearance.

2.0 MATERIALS

2.1 Serpentine

2.1.1 General: All serpentine shall be of kind or kinds shown on the Specifying Authority's drawing or as specified herein, conforming to or within the range of approved samples and in accordance with the characteristics and working qualities. Care shall be taken in selection to produce as harmonious effects as possible. Patching and waxing[2], where permitted under the Marble Institute of America Group Classifications, shall be carefully done to conform to the serpentine's general character and finish. Texture and finish shall be within the range of sample(s) approved by the Specifying Authority.

2.1.2 ASTM C1526 [C97] [C99] [C170] [C241/C1353] [C880] See the chart of applicable ASTM standards and tests in the Appendix.

2.1.3 Schedule: Serpentine shall be provided as follows:

2.1.3.1 For (*state location on building*) (*state name and color*) serpentine with a (*type*) finish, supplied by (*name company or list several approved suppliers*).

2.1.3.2 Provide information as in 2.1.3.1 for each different serpentine/finish combination on the project.

2.1.4 Asbestos Content. Most serpentine stone contains a minor quantity of asbestos fibers as a constituent to the white calcite veining common to the variety, and as such, should be worked "wet" only. The asbestic content has no effect on the stone's use and/or maintenance. (Refer also to the Geological Classification section within this chapter).

2.1.5 Finishes: Finishes listed in the schedule shall conform with definitions by NSI or ASTM International.

2.1.6 Polished: A mirrorlike, glossy surface which brings out the full color and character of the stone. This finish is not recommended for exterior or commercial floor use.

2.1.7 Honed: A velvety smooth surface with little or no gloss.

2.2 Setting Mortar (And Adhesives)

2.2.1 Portland cement shall conform to the requirements of the Standard Specification for Portland Cement, ASTM C150. White portland cement is recommended for white or light colored serpentine. Nonstaining cement shall conform to the requirements of the Standard Specification for Masonry Cement, ASTM C91. Molding Plaster (plaster of paris) shall conform to the requirements of the Standard Specification for Gypsum Casting Plaster and Gypsum Molding Plaster, ASTM C59/C59M.

2.2.2 Sand. All sand shall be clean, free from organic and other deleterious matter likely to stain the finished work, and shall be screened as required for the desired results.

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[2] *Waxing* refers to the practice of filling minor surface imperfections such as voids or sand holds with melted shellac, cabinetmaker's wax or certain polyester compounds. It does not refer to the application of past wax to make surfaces shinier.

2.2.3 Portland cement shrinkage-reducing accelerator used with portland cement to give it the quick-setting characteristics of plaster of paris, shall be a nonstaining admixture that will not corrode anchors or dowels.

2.2.4 Nonstaining adhesive shall be of a type that will not stain the serpentine, is not affected by temperature changes or moisture, and adheres firmly to all clean surfaces.

2.3 Pointing Mortar

2.3.1 Mortar for pointing shall be Type N, as defined in ASTM C270 (Standard Specification for Mortar for Unit Masonry). All mixing, handling, and pacing procedures shall be in accordance with ASTM C270.

2.4 Sealants and Backup Material (if Applicable)

2.4.1 Where specified (state type or name of sealant) shall be used for the pointing of joints. The backup material used with the sealant shall be (identify material).

2.4.2 Sealants used for pointing to exclude moisture and to provide a joint that will remain plastic for many years, shall be nonstaining.

2.5 Anchors, Cramps, and Dowels

2.5.1 Anchors, cramps, and dowels shall be made of corrosion-resistant metals. Special cramps, dowels, and the like shall be used where shown on shop drawings, but elsewhere, #8 copper or stainless steel wire anchors shall be used. It shall be the responsibility of the Serpentine Contractor to anchor all serpentine securely. For standing serpentine, the following practices usually prevail:

2.5.1.2 A minimum of four anchors should be provided for pieces up to 12 square feet (1 m^2), with two additional anchors for each additional 8 square feet (0.75 m^2) surface area. Shims used to maintain joints shall be plastic.

2.5.1.3 Use of copper wire for anchors to be installed over 12' (3.5 m) off the ground is not recommended.

3.0 FABRICATION

3.1 Beds and Joints

3.1.1 Bed and joint width shall be determined by analysis of anticipated building movements and designed to accommodate such movements without inducing undue stresses in the stone panels or joint filler materials. Expansion joints shall be designed and located to accommodate larger movements.

3.2 Backs of Pieces

3.2.1 Backs of pieces shall be sawn or roughly dressed to approximately true planes. Back surfaces shall be free of any matter that may create staining.

3.3 Moldings, Washes, and Drips

3.3.1 Moldings, washes, and drips shall be constant in profile throughout their entire length, in strict conformity with details shown on approved shop drawings. The finish quality on these surfaces shall match the finish quality of the flat surfaces on the building.

3.4 Back-Checking and Fitting to Structure or Frame

3.4.1 Stone coming in contact with structural work shall be back-checked as indicated on the approved shop drawings. Stones resting on structural work shall have beds shaped to fit the supports as required.

3.4.2 Maintain a minimum of 1" (25 mm) between stone backs and adjacent structure. Note: many bolted connections will require more space than this; 2" (50 mm) space may be more desirable. Large-scale details should illustrate and control these conditions.

3.5 Cutting for Anchoring, Supporting, and Lifting Devices

3.5.1 Holes and sinkages shall be cut in stones for all anchors, cramps, dowels, and other tieback and support devices per industry standard practice or approved shop drawings. However, additional anchor holes shall be drilled at job site by Serpentine Contractor to facilitate alignment.

3.5.2 No holes or sinkages will be provided for Serpentine Contractor's handling devices unless arrangement for this service is made by the Serpentine Contractor with the Serpentine Fabricator.

[NOTE: It is not recommended that lewis pins be used for stones less than 3½" (90 mm) thick.]

3.6 Cutting and Drilling for Other Trades

3.6.1 Any miscellaneous cutting and drilling of stone necessary to accommodate other trades will be done by the Serpentine Fabricator only when necessary information is furnished in time to be shown on the shop drawings and details, and when work can be executed before fabrication. Cutting and fitting, due to job site conditions, will be the responsibility of the Serpentine Contractor.

3.6.2 Incidental cutting such as for window frame clips, etc., which is normally not considered to be the responsibility of the stone supplier, will be provided only by arrangement by the General Contractor and Serpentine Contractor with the Serpentine Fabricator.

3.7 Carving and Models

All carving shall be done by skilled Stone Carvers in a correct and artistic manner, in strict accordance with the spirit and intent of the approved shop drawing, or from models furnished or approved by the Specifying Authority.

4.0 SHIPPING AND HANDLING

4.1 Packing and Loading

Finished serpentine shall be carefully packed and loaded for shipment using all reasonable and customary precautions against damage in transit. No material which may cause staining or discoloration shall be used for blocking or packing.

4.2 Site Storage

It shall be the responsibility of the Serpentine Contractor to receive, store, and protect the serpentine from damage by others after it is delivered to the job site and prior to its erection in the building. All serpentine shall be received and unloaded at the site with care in handling to avoid damage or soiling. If serpentine is stored outside, it shall be covered with non-staining waterproof paper, clean canvas, or polyethylene.

5.0 INSTALLATION

5.1 General Installation

5.1.1 Installation shall be accomplished with competent, experienced Stone Setters, in accordance with the approved shop drawings.

5.1.2 All serpentine pieces shall be identified with a unique piece number corresponding with the number on the shop drawings. Interchanging of numbered pieces is not permitted.

5.1.3 Serpentine shall be free of any ice or frost at time of installation. Salt shall not be used for the purpose of melting ice, frost, or snow on the stone pieces.

5.1.4 Adequate protection measures shall be taken to ensure that exposed surfaces of the stone shall be kept free of mortar at all times.

5.2 Mortar Setting

5.2.1 Caution with Serpentine Setting Beds. Water expands the intercrystalline space in serpentine dimension stone. When it is being installed in a mortar bed, techniques should be employed that minimize the amount of water at the back face of the stone, and/or employment of fogging on the face (to increase the intercrystalline space at both surfaces uniformly) should be considered. Absent of this, the stone could expand at the back face temporarily to a larger dimension than the top face, causing warping and/or twisting. The warped stone is difficult, if not impossible, to return to its original dimensions.

5.2.2 Other methodologies suggest employment of installation material that is not water-soluble to avoid this potential problem.

5.2.3 This is an installation condition, and should not be construed as a limitation of the stone's range of application. Most serpentine varieties perform well in wet work applications.

5.3 Floor Serpentine

5.3.1 Floor Preparation. It is the General Contractor's responsibility to clean all subfloor surfaces to remove dirt, dust, debris, and loose particles immediately prior to setting serpentine floor and to ensure that the area to receive the stone flooring meets the deflection standards of the industry.

5.3.2 Curing compounds of any kind shall not be used on the slab on which floor serpentine is to be directly set. If a curing compound is present, it is the General Contractor's responsibility to remove it by scarifying the slab.

5.3.3 Before being set, all serpentine shall be clean and free of foreign matter of any kind.

5.3.4 Cement Bed. The cement bed to receive the serpentine tile shall consist of 1 part portland cement to not more than 3 to 5 parts of clean, sharp sand mixed quite dry for tamping. White Portland cement is recommended for light-colored serpentines.

5.3.5 Serpentine Tamped. The serpentine shall be tamped with a suitable mallet until firmly bedded to the proper level of the floor.

5.3.6 Serpentine Removed. The serpentine shall then be removed and the back parged with wet cement or the bed sprinkled with water and cement. In the latter procedure, the back of the serpentine shall be wet. The method of fully buttering edges of the serpentine as it is laid is equally approved.

5.3.7 Joints between the serpentine pieces shall show an even width when laid and finished.

5.3.8 Traffic after Installation. The floor shall be roped off for 24 hours after installation and then grouted with water and white portland cement grout or non-staining dry set portland cement grout.

5.3.9 Timeline for Additional Cleaning. Cleaning or additional surfacing, if required, shall not be undertaken until the new floor is at least seven days old.

5.3.10 Thin-Set Method. The thin set method of installing serpentine tile employing the use of dry set portland cement mortars is recommended for thin serpentine tiles [nominal 3/8" (9.5 mm) thick] where optimum setting space is not available. Subfloor shall be clean, smooth finished, and level.

5.3.11 Stone dust must be washed off the back face of stone pavers prior to installation. Apply mortar with flat side of trowel over an area that can be covered with tile while mortar remains plastic. Within ten minutes, and using a notched trowel sized to facilitate the proper coverage, comb mortar to obtain an even-setting bed without scraping the backing material. Key the mortar into the substrate with the flat side of the trowel. Comb with the notched side of the trowel in one direction. Firmly press stone tiles into the mortar and move them perpendicularly across the ridges, forward and back approximately 1/8" to ¼" (3 mm to 6.5 mm) to flatten the ridges and fill the valleys. Ensure a maximum mortar thickness of 3/32" (2.5 mm) between stone tile and backing after stone tile has been tamped into place. Stone tile shall not be applied to skinned-over mortar. Or alternatively, back butter the stone tiles to ensure 100% contact. In either method, ensure 100% contact on 3/8" (9.5) tile; not less than 80% contact on ¾" (20 mm) or thicker material, excepting that all corners and edges of stone tiles must always be fully supported, and contact shall always be 100% in exterior and/or water-susceptible conditions.

5.4 Interior Veneer Serpentine

5.4.1 The serpentine shall be set by spotting with gypsum molding plaster or cement mortar and the use of concealed anchors secured in the wall backing.

5.5 Serpentine Wall Tile

5.5.1 Individually set thin tile [nominal 3/8" (9.5 mm) thick] on vertical surfaces exceeding 8' (2.5 m) is not recommended. Where thin serpentine tile is installed, non-staining adhesives or dry set mortars may be used as setting beds.

5.6 Toilet and Shower Compartments

5.6.1 Stiles and partitions shall be assembled with concealed dowel fastenings or corrosion resistant angles, three in height of stall.

5.6.2 For ceiling-hung units, metal supporting members in ceiling are to be furnished and installed by the General Contractor.

5.7 Mortar Joints

5.7.1 Mortar joints shall be raked out to a depth of ½" to ¾" (12.5 mm to 20 mm). Apply pointing mortar in layers not exceeding 3/8" (9.5 mm) and allow each layer to get hard to the touch before the next layer is applied. Tool finished joints with a concave tool having a diameter approximately 1/8" (3 mm) greater than the joint width.

5.7.2 Care shall be taken to keep expansion joints free of mortar, which would compromise their function.

5.8 Anchorage

5.8.1 All serpentine shall be anchored or doweled in accordance with the approved shop drawings.

5.8.2 To the furthest extent possible, all anchor preparations in the serpentine units shall be shop-applied.

5.8.3 All anchorage devices and anchor hole/slot fillers shall be in accordance with ASTM C1242. Care must be taken to ensure that any holes capable of retaining water are filled after use to prevent water collection and freezing.

5.9 Sealant Joints

5.9.1 Where so specified, joints requiring sealant shall be first filled with a closed-cell ethafoam rope backer rod. The backer rod shall be installed to a depth that provides optimum sealant profile after tooling.

5.9.2 If recommended by the Sealant Manufacturer, primers shall be applied to the substrate surfaces according to the manufacturer's directions prior to application of the joint sealant.

5.10 Expansion Joints

5.10.1 It is not the intent of this specification to make control and expansion-joint recommendations for a specific project. The Specifying Authority must specify control and expansion joints and show locations and details on drawings.

5.11 Caulking

5.11.1 Where so specified, joints shall be pointed with the sealant(s) specified in Section 2.4 after first installing the specified backup material and applying a primer if required, all in strict accordance with the printed instructions of the Sealant Manufacturer.

5.11.2 All sealants shall be tooled to ensure maximum adhesion to the contact surfaces.

5.12 Weep Tubes

5.12.1 Plastic or other weep tubes shall be placed in joints where moisture may accumulate within the wall, such as at base of cavity, continuous angles, flashing, etc., or as shown on architectural drawings.

6.0 CLEANING AND PROTECTION

6.1 Cleaning

6.1.1 Serpentine shall be shop-cleaned at the time of final fabrication. It shall also be cleaned after installation and all pointing or caulking is completed. All dirt, excess mortar, weld splatter, stains, and other defacements shall be removed.

6.1.2 All cleaning methods shall be in accordance with ASTM C1515.

6.1.3 Stiff bristle fiber brushes may be used, but the use of wire brushes or of acid type cleaning agents and other solutions that may cause discoloration is expressly prohibited. Fabricator should be contacted before cleaners other than neutral detergents are used.

6.2 Protection of Finished Work

6.2.1 After the serpentine work is installed, it shall be the responsibility of the General Contractor to see that it is properly and adequately protected from damage and stains until all trades are finished. This responsibility includes the stone cleaning costs prior to the final inspection. The Serpentine Contractor will outline the needs for protection, in writing, to the General Contractor. For the protection of projecting members, corners, window stools and saddles, wood guards using lumber that will not stain or deface serpentine shall be supplied, installed, and maintained by the General Contractor. All nails used shall be galvanized or nonrusting. Damage to finished serpentine by other trades shall be repaired or replaced at the expense of the General Contractor. Serpentine flooring shall be adequately protected by the General Contractor against traffic and other damage with non-staining materials, without cost to the Serpentine Contractor.

6.2.2 All serpentine work in progress shall be protected at all times during construction by use of a suitably strong, impervious film or fabric securely held in place.

PRODUCT DESCRIPTION – Serpentine

1.0 GEOLOGICAL CLASSIFICATION

1.1 Serpentine. These beautiful and elegant green stones traditionally have been grouped in the commercial marble category. However, they are not true marbles. Marble is by geologic definition metamorphic limestone, calcium carbonate ($CaCO_3$), and dolomite

$CaMg(CO_3)_2$. Geologically, the "green marbles," as they are informally known, are the low-level metamorphic stone "serpentinite," of which the dominant mineral is serpentine. When the mineral name is altered to end with the suffix "-ite," it becomes the name of the stone in which it is the main chemical constituent. Serpentinite is sometimes confused with "green schist," an entirely different rock generally not suitable as dimension stone and rarely seen in the market in part because large, nonfractured blocks are difficult to obtain and loose mineral grains often preclude achieving suitably polished and durable surfaces.

1.2 The major parent rock of the serpentine mineral is dark, iron- and magnesium-rich igneous rock of the oceanic type, with a lesser amount of lighter, continental-type rock admixed. When these are intruded with hot, chemical-rich fluids, the mineral serpentine is formed in belt-like rinds around larger blocks of oceanic-type, seafloor rock bodies. This action takes place when two large segments of Earth's crust crash together, causing regional scale metamorphism with injection of chemical-rich fluids[3]. Serpentines are thought to be formed very deep, at temperatures up to around 500°C at a depth called the "Moho," [4] the border marking the transition between the outer crust of the Earth and the underlying upper mantle, at depths of less than 10 to more than 60 km (6 to 40 miles).

1.3 Slight variations of parent rock mineral content, the condition of the parent rock, variations in chemistry of the invading fluids, and changes in temperature, pressure, and time plus subsequent geologic history, all influence the formation of serpentine stone. Frequently asked questions are: Why the great differences between different shades of green? Why does one fade and others do not? Why is one very dark green and others light- or yellowish-green? Why is one provided with reinforcing net epoxied to the back and another is not? The complex differences are all in the chemistry of rocks, fluids, and variations in parameters of the metamorphic process.

1.4 A wide range in apparent quality and performance of these beautiful stones reflects the diversity of mineral content and consequent variations in the physical properties and durability between the many "green marbles" or serpentinites on today's market. This clearly points up the exceptional value of the experience and knowledge attained by skilled stone technicians.

1.5 The geochemistry involved with these rocks is complex; however, knowing something about a few of the important chemical components of serpentine and their properties greatly aids understanding this often perplexing stone group.

1.6 **Serpentine** ($Mg_3Si_2O_5(OH)_4$) is only formed as a metamorphic mineral. It has the sheeting habit of mica in that it is composed of thin sheets loosely bound together like pages in a poorly manufactured book. Unlike the well-known micas, biotite and muscovite, serpentine sheets are not elastic, but they are flexible. Large chunks of the mineral have a "soapy" appearance and luster, and feel slippery or "greasy." The slippery surfaces act as a lubricant in faulting of the stone. Serpentinites often occur in contorted and complex shapes because of the flexibility of the sheets, and that is part of the attraction of the stone. Serpentine hardness varies from about H=2.5 to 5 on the Mohs Scale[5], depending on specific parameters of its geologic history and other admixed minerals. Serpentine does not react to cold, dilute acid.

1.7 **Asbestos**. The normal, sheet-like "habit" or occurrence of serpentine has been

[3] Skinner, B. J. and S. C. Porter, 1992, *The Dynamic Earth*, 2nd ed., John Wiley & Sons, New York, p. 455.
[4] *Moho* is the accepted slang term for Mohorovičić Discontinuity, or the crust/mantle boundary identified by a contrast in the velocity of sound through the two chemically different rock compositions.
[5] See Appendix for the Mohs Scale of mineral hardness.

described, but another form of serpentine is fibrous, and when found in this form it is the potentially dangerous mineral asbestos. Properly known as chrysotile serpentine or chrysotile asbestos, it has a slightly different chemistry than normal serpentine. Additional meta-morphism, and again slight changes in chemistry, produce the familiar mineral talc. Since the three forms of serpentine often occur together, avoid cutting serpentinites dry and maintain absolutely meticulous dust control in the shop.

1.8 Chrysotile and Talc. The transformation of serpentine to chrysotile (asbestos) to talc is a continuously variable chemical series and the members are chemically quite similar, but have differing molecular geometry. Since they form in response to slight differences in metamorphic pressures and chemistry, all three minerals may be found together. Talc is the softest of minerals and used as the example for H=1 on the Mohs Scale. Talc does not polish. Chrysotile may polish if highly compacted and cut normal to the fibers. Sometimes chrysotile may become highly siliceous; that is, the mineral is replaced by silica but retains a "ghost" of its fibrous structure. This altered variant is known in the semiprecious gem trade as "tiger's eye" for its striking optical characteristics. Since both talc and asbestos can be considered undesirable admixtures to a commercial-grade "green marble," they are not generally found in more than small or trace amounts in the better-known serpentines used for decades. Their occurrence tends to weaken the stone, allows moisture penetration, weathers faster, and should be considered detrimental in some exterior applications where moisture control is difficult. White veins in serpentine indicate the presence of talc or asbestos; consequently, the use of such stone should be minimized in external applications.

1.9 Calcite and magnesite (calcium and magnesium carbonates, ($CaCO_3$) and ($MgCo_3$) occur in serpentinites, usually as white to off-white discrete masses or veins of varying thickness in the figure of the stone. Both carbonate minerals have several properties in common: they are both H=3 (soft), break in perfect little rhombohedrons due to inherent weakness in molecular structure, and both are generally white or sometimes slightly iron-stained.

1.10 The only characteristic that can be used to differentiate the two is their reaction to cold, dilute acid: calcite will effervesce vigorously while magnesite does not. Is this important in dimension stone? Yes, if used as a tabletop, one of the traditional uses of highly figured "green marbles." It will not be easily etched by salad vinegar or wine if the carbonate mineral is magnesite. The simple dilute acid test can be done by anyone; however, if a surface-masking sealer is used, the acid may not reach the calcite and produce the typical reaction. If the sealing agent is trustworthy over an extended time, the occurrence of one or the other of these carbonates stones should not matter. Consulting with Sealing Professionals is recommended.

1.11 Carbonate minerals soluble in dilute acids should be used with extreme care in exterior applications where an acid-polluted atmosphere exists. Likewise, magnesite-rich "green marbles" should not be used in exterior applications where atmospheric sulfate pollution occurs. Magnesite will react to very dilute sulfuric acid in the moisture and recrystallize to water-soluble magnesium sulfate (milk of magnesia).

1.12 Note: Thin-set, cementitious compounds will probably react with any carbonate mineral in the serpentinite stones yielding a failure in attaching thin sheets of some green marble.

1.13 Siderite ($FeCO_3$) is a semi-hard iron carbonate (H=3.5 to 4.5 on the Mohs Scale) not uncommon in serpentinites as pale- to dark-brown masses or veins. It breaks easily into parallelogram-shaped fragments, as do other carbonates, and does not react with cold, dilute acids. It will effervesce in hot, dilute acids, but trying to perform that test is strongly discouraged due to the danger of eye damage when attempting to heat any acid.

1.14 Brucite (magnesium hydroxide or $Mg(OH)_2$) commonly occurs with serpentine, greenschists, chlorite schists, and with talc and other low-grade metamorphic stone formed from dark, high iron- and magnesium-rich igneous rock. Brucite is very soft, about H=2.5 – the same hardness as a human fingernail – thus it is not desirable to have large accumulations or veins of brucite in "green marbles." Brucite is very soluble in cold, dilute acids, but will not effervesce, becoming instead a mud-like slurry.

1.15 Note that since serpentine is formed in part from iron- and magnesium-rich parent rock, the occurrence of other high-Mg minerals such as brucite or magnesite and the carbonates of iron, Fe, Ca, and Mg are to be expected as minor constituents in serpentinites.

1.16 Chlorite $[(Mg,Fe)_5(Al,Fe)_2Si_3O_{10}(OH)_8]$ is another green, very soft, sheet-like, metamorphic mineral. Chlorite, like serpentine, brucite, and magnesite, has flexible but not elastic sheets loosely bound together. It has a greasy-feeling surface that facilitates internal slippage in the serpentinite and greenstone belts. Its color ranges from medium green to a light, yellowish-green, and light to medium yellow. Chlorite hardness is H=2 to 2.5, or very soft. Although chlorite may polish, it does not retain polish and is prone to rapid surface dulling. Veins of chlorite weaken the stone when sliced thin and may be a likely reason to reinforce some slabs with backup netting and epoxy. Chlorite's sheeting habit acts as a plane of weakness along which faulting, slippage, and fracturing will occur, further weakening a thinly sawn piece.

1.17 Chlorite may be almost impossible to distinguish from serpentine except by hardness, a very difficult distinction to make, and these two minerals do occur together. Rapid weathering or loss of the well-polished surface of some "green marbles" may in fact be due to undetected chlorite that occurs as finely disseminated or small pockets in the serpentine that are obscure except to close inspection by experienced Stone Technicians.

1.18 Albite ($NaAlSi_3O_8$). This plagioclase feldspar composed of sodium aluminum silicate is found in some serpentinites, an expectation given the dark, oceanic-type parent of serpentine. Albite is hard (H=6) and durable, thus a vein of albite is in no way a detriment unless incipient fractures accompany the vein – probably when the vein happens to be bordered by a very thin chlorite rind.

1.19 Magnetite (Fe_3O_4) iron oxide is often present in serpentinites due to mineral segregation that occurs in metamorphic processes. Magnetite is very hard (H=5.5 to 6.5), harder than common glass. It is magnetic, black, and when polished, has a metallic luster.

1.20 Limitations. As a final note to this section regarding the use of serpentine in building applications, remember that failures with the "green marbles" can occur in some projects from the physical limitations of accessory minerals in the stone's chemical composition. In addition, serpentine's sheet-like, crystalline habits and slippery texture can sometimes cause weakness in slabs, or allow accelerated surface oxidation in exterior uses where water, temperature extremes, and sunlight will rapidly degrade some minerals. The degree of compaction should always be examined in any stone selection.

2.0 COLOR AND VEINING

2.1 The color, veining, clouds, mottlings, and shadings in serpentine are caused by minor inclusions during the formation or some prior degradation or weathering of the stone to release staining color. Iron oxides make the pinks, yellows, browns, and reds. Most grays, blue grays, and blacks are of bituminous origin.

Greens are caused by micas, chlorites, and silicates.

3.0 TEXTURE

3.1 The term “texture,” as applied to serpentine, means size, degree of uniformity, and arrangement of constituent minerals. Grains of calcite and other carbonates, the chief accessory mineral of most serpentines, are crystalline and have definite rhombohedral cleavage which shows bright, reflecting faces on a broken surface. In most serpentines, however, the grains are elongated in one direction by the plication (folding) of the beds.

4.0 FINISHES

4.1 Serpentine’s surface may be finished in a number of ways. In general, smooth finishes tend to emphasize color and veining, whereas rough finishes tend to subdue the veining or markings.

4.2 Typical Finishes for Serpentine Are:

4.2.1 Polished: A glossy surface that brings out the full color and character of the serpentine. It is not generally recommended for exterior use or commercial floors.

4.2.2 Honed: A satin-smooth surface with little or no gloss, recommended for commercial floors.

5.0 THICKNESS

5.1 Standard nominal thicknesses for serpentine veneer are ¾", 7/8", 1¼", 1½", and 2" (20 mm, 22 mm, 30 mm, 40 mm, and 50 mm). When a serpentine thinner than ¾" (20 mm) is specified, the ratio between thickness and overall size and the use of reinforcing backup materials must be considered. Serpentine thicker than 2" (50 mm) is usually regarded as cubic stock.

6.0 SIZES

6.1 Serpentine is a product of nature with hundreds of varieties available, each possessing distinct characteristics. Little can be done to alter the condition in which nature presents these varieties to us. Therefore, size may become a limiting factor to consider in the selection of serpentine. Check with the Stone Supplier as to the sizes that are available for the specific serpentine.

6.2 Selection and delivery can be greatly facilitated by a jointing scheme which permits the use of smaller sizes. A final jointing scheme should be agreed upon after the serpentine has been selected and the Serpentine Contractor has been consulted.

7.0 PRODUCT SAMPLING

7.1 Serpentine is formed by nature; thus, there are variations in the tonal qualities of the stones. However, it is these natural variations that make serpentines unique, valuable, and highly desirable. Because of these variations, selection of serpentine should never be made on the basis of one sample only. It is recommended that selection be based on viewing sufficient samples to show the complete range of colors of the desired stone.

8.0 PROPER USAGE TIPS

Recommendation for commercial floors:
1) Minimum ¾"(20 mm) thickness.
2) A honed finish.
3) A minimum hardness value of 10 as measured by ASTM C241/C1353.

Avoid the use of gypsum or molding plaster setting spots for the installation of exterior stone.

9.0 VENEER CUTTING

9.1 Quarry blocks are reduced to slabs by a gang saw. The gang saw consists of a series of steel blades set parallel in a frame that moves forward and backward. The most productive and precision gang saws have diamond-tipped blades with individual hydraulic blade tensioners.

9.2 Serpentine blocks can be sawn either perpendicular or parallel to the bedding plane. The perpendicular cut is referred to as an across-the-bed or vein cut. The parallel cut is with-the-bed or fleuri cut. Some serpentines produce a pleasing surface when sawed in either direction, and are available as either vein or fleuri. Other serpentines produce a pleasing surface only when sawed in one direction, and are generally available only in that variety.

TECHNICAL DATA - Serpentine

1.0 PROPERTIES OF SERPENTINE DIMENSION STONE

1.1 In centuries past, relatively little importance was attached to the ultimate physical capabilities of most building materials. Rule of thumb was a common structural design criterion. As a result, the widely used materials of the day, for the most part natural rather than manmade materials, were seldom stressed to their ultimate limits.
In present-day construction, however, this is far from being true. Performance requirements are daily becoming more demanding. In striving for taller structures, greater spans, firmer foundations, thinner walls and floors, stronger frames, and generally more efficient buildings with more usable space, today's Architects and Engineers must get the most out of the materials with which they work.

1.2 Serpentine is a product of nature and not always subject to the rules of consistent behavior that may apply to manufactured building materials. It may not be proper for certain applications.

1.3 Physical property values of serpentine may, however, be measured using the standard test methods approved by the Dimension Stone Committee C 18 of ASTM International. The values found when stone is tested for absorption, density, compressive strength, abrasion resistance, and flexural strength should be useful for the Designer and Engineer when preliminary construction calculations are being made. However, these tests should be made before the project specifications are written, not after. Member companies of the Marble Institute of America are represented on this committee and are active in its technical work of establishing proper test methods and specifications consistent with the latest technology.

1.4 Physical Properties of Serpentine (This historical data and information is provided only as a guideline. Recommended minimums or maximums are established and provided by ASTM International.)*

Property — **Range of Values**

Compressive Strength (C170)
lbs/in²...........................9,000 27,000
Recommended (min): 10,000

Flexural Strength (C880)
lbs/in²................................. 900-5,000
Recommended (min): 1,000

Modulus of Elasticity** (in millions)
lbs/in².................................... 2.0-15.0

Density, lb/ft³ (C97) 155-180
Recommended (min): 168

Modulus of Rupture (C99) lbs/in².500-2,500
Recommended (min): 1,000

Absorption, by weight % (C97)...... 0.09-1.2
Recommended (max): 0.20 exterior, 0.60 interior

Abrasion Resistance (H_a) (C241)..... 25-110
Recommended (min): 10

* Test methods described in current ASTM standards. ** Also known as Young's Modulus.

2.0 STRENGTH (ASTM C170, ASTM C880)

2.1 The strength of a serpentine is a measure of its ability to resist stresses. This strength depends on several factors: the rift and cleavage of the crystals, the degree of cohesion, the interlocking of the crystals, and the nature of any cementing materials present.

3.0 FIRE RESISTANCE

3.1 Serpentine is not combustible according to underwriters' ratings, and so is considered a fire-resistant material. Because of its thermal conductivity, however, the heat transfer through serpentine is fairly rapid. Serpentine is not considered a highly rated thermal insulator.

3.2 Underwriters' fire-resistance ratings evaluate whether or not a material will burn, as well as how long it will keep surrounding combustible materials from reaching temperatures which will cause them to ignite. Pilot plant tests at The Ohio State University Pyrotechnics Laboratory indicate that a 10 minute rating could be expected from 7/8" (22 mm) thick serpentine.

3.3 The use of an insulating material with serpentine substantially improves the fire rating, as shown in the following:

7/8" (22 mm) serpentine with 1" (25 mm) core of:
Paper Honeycomb.....................½ hour
Cement-Bonded Wood Excelsior......1 hour
Autoclaved Cellular Concrete........1½ hour

3.4 Methods of estimating fire-resistance periods of masonry walls and partitions utilizing component laminae are given in "Fire Resistance Classifications of Building Construction," BMS92, National Bureau of Standards.

4.0 ABRASION RESISTANCE (ASTM C241/C1353)

4.1 Abrasion resistance is a property of stone that should be tested per ASTM C241/C1353 to provide an indication of the stone's wearing qualities when exposed to foot traffic.

4.2 The hardness and uniform wearing qualities of most serpentine varieties make them extremely desirable and economically practical for floors and stairs. Varieties with an ASTM C241/1353 abrasive hardness rating (H_a/I_w) of 10 or more are recommended for use as flooring. A minimum abrasive hardness of 12.0 is recommended for commercial floors, stair treads, and platforms subject to heavy foot traffic. Surfaces of floors constructed with two or more varieties, with H_a/I_w differences more than 5, will not wear evenly and uniformly.

5.0 FACTORS AFFECTING PHYSICAL PROPERTIES

5.1 The ultimate test of a building material is its ability to have and maintain the necessary structural strength, as well as beauty of appearance and low cost of maintenance, over the useful life of the structure. Experience has proven that serpentine meets this test as few other building materials can.

5.2 Illinois Institute of Technology Research Institute's studies have shown that the durability of serpentine is little affected by cycles of weather. This is because of serpentine's low rate of absorption. The rates of moisture absorption of all the serpentines studied were less than 1 percent by weight. Other masonry materials range upward from 4 to 12 percent.

6.0 SAFETY FACTORS

6.1 Good engineering practice requires that allowable design stress must provide a margin of safety in any structural element. As a necessary precaution against such conditions as wind, ice, snow, impact, temperature changes, and imperfect workmanship, these allowable stresses must be smaller than those which produce failure.

6.2 Within the accepted limits of safe design practice, the closer the allowable load is to the ultimate failure load in a structure, the more efficient is the use of the material and the less the cost of the construction.

6.3 Contemporary design of buildings, exclusive of the monumental type, does not usually employ serpentine as part of the structural frame, but rather as an independent unit, a curtain wall, or veneer. Therefore, the primary concern in such cases is with wind load, and a safety factor of 5.0 is recommended. Where the serpentine is to be subjected to concentrated loading, such as stair treads or lintels supported only at the ends, a factor of 10.0 should be used.

6.4 As buildings become taller and individual stone slab veneer becomes larger in area, the lateral forces due to wind loads must be considered. Wind tunnel tests are often used on major structures to determine wind dynamics and force magnitude. Reinforcement is sometimes necessary for large-dimension slab veneer in critical areas.

6.5 To determine the thickness and size of panel required:

6.5.1 Determine the design and wind load.

6.5.2 Obtain the flexural strength of the serpentine under consideration using the ASTM C880 test method. This information may be available from the Serpentine Supplier.

6.5.3 Select the unsupported span for each thickness for which the stress is below the flexural strength of the serpentine from the appropriate table.

6.6 This span for each thickness is the maximum for panels that are supported on two sides only.

6.7 If the panel is supported on all four sides and the long side of the panel exceeds twice the short side, use the short span from the table.

7.0 SEISMIC CONSIDERATIONS

7.1 Seismic considerations generally require that low buildings be stiff, and that tall buildings be relatively flexible. Design of connections must account for seismically induced horizontal loading. Local building codes vary and must always be checked to determine specific requirements for each area.

7.2 Additional Readings:

7.2.1 The National Bureau of Standards has published two documents on the topic: "Earthquake Resistant Masonry Construction," NBS Science Series 106; and "Abnormal Loading on Buildings and Progressive Collapse: An Annotated Bibliography," NBS Science Series 67.

7.2.2 The U.S. Army Corps of Engineers has also published TM 5-809-10, "Seismic Design for Buildings."

8.0 EFFLORESCENCE AND STAINING

8.1 Efflorescence is a salt deposit, usually white in color that appears on exterior surfaces of masonry walls. The efflorescence producing salts found in masonry are usually sulfates of sodium, potassium, magnesium, calcium, and iron. Salts which are chlorides of sodium, calcium, and potassium will sometimes appear, but are so highly soluble in water that they will be washed off by rain.

8.2 The water-soluble salts causing efflorescence come from other materials in the wall. The salts exist in small amounts and are leached to the surface by water percolating through the walls. The most feasible means of prevention is to stop the entrance of large amounts of water. Absorption from the face will not cause efflorescence unless there are open joints.

8.3 Serpentine is not injured by efflorescence. However, some of the salt crystals may form in the pores near the surface. Crystal growth (recrystallization) in the pores can cause stress on the walls of the pores and cause the stone to flake off. If the conditions bringing about this action persist, scaling may continue and flake off one layer after another. For this to happen, large amounts of water must enter the wall and must contain large amounts of salts.

8.4 Research indicates that staining or discoloration occurring on new buildings is caused by the action of water percolating through cement from which soluble alkali salts are leached. The salts are then carried by the water through the serpentine, where partially oxidized organic matter is picked up. This is then transported to the surface of the stone, where it is deposited as a stain as the water evaporates.

8.5 This staining phenomenon is similar to efflorescence, except that it involves organic material. It does not harm the stone other than leaving an objectionable appearance during or soon after erection. However, if left alone, the stain is removed naturally by the action of the elements, usually in the course of a few months.

8.6 A considerable amount of water passing through the stone is necessary to bring out conspicuous discolorations. Proper precautions taken during construction of the walls will usually prevent such troubles. A simple and helpful expedient is to provide frequent weep holes in the base course and above shelf angles. These should be placed in the vertical joints so they can be sloped upward from the front to the back.

8.7 Stains sometimes appear on the base course when serpentine is in contact with soil, or on interior and exterior horizontal surfaces, due to the carrying of soluble salts and some colored soil constituents up through and to the surface of the stone by capillary action. Almost all soils and most of the veining in serpentine contain soluble salts. Therefore, this staining phenomenon is similar to the discoloration described previously, and will disappear when the source of moisture is eliminated. However, materials from the veining may remain on the stone's surface. In walls, provide venting so that moisture can escape through the vents rather than through the stone. On horizontal surfaces, the use of a vapor barrier between the setting bed and the concrete slab, or between the setting bed and the ground, is recommended.

Additional Resources: Refer to Veneer Cutting and Veneer Patterns drawings at the close of Chapter 7 (Marble and Onyx).

SLATE

1.0 GENERAL

1.1 Related Documents

1.1.1 Drawings and general provisions, including General and Supplementary Conditions of the Contract and Division I Specification sections, apply to this section.

1.2 Applicable Publications

1.2.1 The following publications listed here and referred to thereafter by alphanumeric code designation only, form a part of this specification to the extent indicated by the references thereto:

1.2.2 ASTM International (ASTM):

1.2.2.1 C629, Standard Specification for Slate Dimension Stone

1.2.2.2 C120, Standard Test Methods of Flexure Testing of Slate (Modulus of Rupture, Modulus of Elasticity)

1.2.2.3 C121, Standard Test Method for Water Absorption of Slate

1.2.2.4 C217, Standard Test Method for Weather Resistance of Slate

1.2.2.5 C241, Standard Test Method for Abrasion Resistance of Stone Subjected to Foot Traffic

1.2.2.6 C880, Standard Test Method for Flexural Strength of Dimension Stone

1.2.2.7 C1353, Standard Test Method Using the Taber Abraser for Abrasion Resistance of Dimension Stone Subjected to Foot Traffic

1.2.3 Natural Stone Institute (NSI):

1.2.3.1 Membership, Products, and Services Directory

1.2.3.2 Dimension Stone Design Manual

1.2.3.3 Additional publications may be available from the NSI Bookstore. Go online at www.naturalstoneinstitute.org.

1.3 Scope of Included Work

1.3.1 The work to be completed under this contract includes all labor and materials required for the furnishing and installation of all slate work shown or called for on the contract drawings, specifications, and addenda.

1.4 Definition of Terms

1.4.1 The definitions of trade terms used in this specification shall be those published by the NSI or ASTM International.

1.5 Source of Supply

1.5.1 All slate shall be obtained from quarries having adequate capacity and facilities to meet the specified requirements, and by a firm equipped to process the material promptly on order and in strict accord with specifications. The Specifying Authority (architect, designer, engineer, contracting officer, end user, etc.) reserves the right to approve the Material Supplier for slate prior to the award of this contract. Stone and workmanship quality shall be in accordance with Industry Standards and Practices as set forth by the NSI.

1.6 Samples

1.6.1 The Slate Contractor shall submit through the General Contractor, for approval by the Specifying Authority, at least two sets of samples of the various kinds of slate specified. The sample size shall be 1'-0" x 1'-0" and shall represent approximately the finish, texture, and anticipated range of color to be supplied.

One set of samples shall be retained by the Specifying Authority, and one set shall be returned to the Slate Supplier for his/her record and guidance. It is noted herein that slate is a natural material and will have intrinsic variations in color, markings, and other characteristics. Color variation range is to be only from natural markings in the slate or from the reflective sheen and shadow value of the graining of the natural-cleft textures and cleavage planes. Depending on slate selected and quantity required, a range mockup may be used to further define the characteristics of the material. Cost of mockup, if required, shall not be included in this section.

1.6.2 Prior to fabrication, an inspection and approval by the Specifying Authority and/or General Contractor and/or End User of the finished slabs is recommended to understand the finish and full range of the material.

1.7 Shop Drawings

1.7.1 The Slate Contractor shall submit through the General Contractor, for approval by the Specifying Authority, sufficient sets of shop drawings showing general layout, jointing, anchoring, stock thickness, and other pertinent information. These drawings shall show all bedding, bonding, jointing, and anchoring details along with the net piece dimensions of each slate unit. One copy of the approved shop drawings shall be retained by the Specifying Authority, one copy shall be retained by the General Contractor, and one copy returned to the Slate Contractor for fabrication. NO FABRICATION OF SLATE SHALL BE STARTED UNTIL SUCH DRAWINGS HAVE BEEN FULLY APPROVED AND MARKED AS SUCH. The Slate Contractor shall not be responsible for determining, making, or verifying (1) design, structural, wind, seismic, or other design loads; (2) engineering estimates; (3) plans or specifications; (4) the types, sizes, or locations of anchors; or (5) verification of field dimensions, unless specifically added to the scope of work.

1.8 Defective Work

1.8.1 Any piece of slate showing flaws or imperfections upon receipt at the storage yard or building site shall be referred to the Specifying Authority for determination as to responsibility and decision as to whether it shall be rejected, patched, or redressed for use. Any material in question should not be installed prior to inspection and approval.

1.9 Repairing Damaged Stone

1.9.1 Chips at the edges or corners may be patched, provided the structural integrity of the stone is not affected and the patch matches the color and finish of the natural stone so that it does not detract from the stone's appearance.

2.0 MATERIALS

2.1 Slate

2.1.1 General: All slate shall be of standard architectural grade, free of cracks, seams, starts, or other traits which may impair its structural integrity or function. Inherent color variations characteristic of the quarry from which it is obtained will be acceptable. Texture and finish shall be as shown in the sample(s) approved by the Specifying Authority.

2.1.2 ASTM C629 [C120] [C121] [C217] [C241/1353] See the chart of applicable ASTM standards and tests in the Appendix.

2.1.3 Schedule: Slate shall be provided as follows:

2.1.3.1 For (*state location on building*) (*state name and color*) slate with a (*type*) finish, supplied by (*name company or list several approved suppliers*).

2.1.3.2 Provide information as in 2.1.3.1 for each different slate/finish combination in the project.

2.1.4 Finishes: Face finish of all exterior panels should be natural cleft. Sand-rubbed, honed and other finishes are available, depending on the Slate Supplier. All exposed edges should be honed to remove saw marks and darken the edge color.

2.1.4.1 Finishes listed in the schedule shall conform with definitions by NSI or ASTM International.

2.2 Setting Mortar

2.2.1 Mortar for setting and pointing shall be one part portland cement and one part plastic lime hydrate to three to five parts of clean, nonstaining sand. It shall be mixed in small batches, using potable, non-alkaline water with a pH of 7, until it is thoroughly homogeneous, stiff, and plastic. After mixing, the mortar shall set for not less than one hour or more than two hours before being used.

2.3 Pointing Mortar

2.3.1 Mortar for pointing shall be Type N, as defined in ASTM C270 (Standard Specification for Mortar for Unit Masonry). All mixing, handling, and placing procedures shall be in accordance with ASTM C270.

2.4 Sealants and Backup Material (if Applicable)

2.4.1 Where specified, (*state type or name of sealant*) shall be used for the pointing of joints. The backup material used with the sealant shall be (*identify material*)

2.5 Anchors, Cramps, and Dowels

2.5.1 All wire anchors, cramps, dowels, and other anchoring devices shall be nonferrous metal of the types and sizes shown on approved shop drawings. Doweling natural-cleft slate to slate is not acceptable.

3.0 FABRICATION

3.1 Dimensional Limitations

3.1.1 Slate spandrels, panels, and wall facings are recommended in thicknesses of 1", 1¼", and sometimes 1½" (25, 30, and 40 mm). Standard economical lengths are up to 6'-6" (2 m) and widths up to 4'-0" (1.2 m). Special larger sizes are available to meet design and job conditions on special request. No single piece is recommended to be over 9'-6" ((3 m) in length or 5'-0" 1.5 m) in width. Larger sizes may be available only under special conditions and limited production.

3.2 Beds and Joints

3.2.1 Bed and joint width shall be determined by analysis of anticipated building movements and designed to accommodate such movements without inducing undue stresses in the stone panels or joint filler materials. Expansion joints shall be designed and located to accommodate larger movements.

3.2.2 Some slight lippage and variation is natural and unavoidable where the natural-cleft face comes together at the sawed joints.

3.2.3 Joints 3/8" or ½" (9.5 or 12.5 mm) are recommended between standard size panels, and ¼" and 3/8" (6.5 and 9.5 mm) joints at abutting masonry. All joints are to be water- and moisture-tight and caulked with a proper sealant.

3.3 Backs of Pieces

3.3.1 Backs of pieces shall be sawn or roughly dressed to approximately true planes. Back surfaces shall be free of any matter that may create staining.

3.4 Moldings, Washes, and Drips

3.4.1 Moldings, washes, and drips shall be constant in profile throughout their entire length, in strict conformity with details shown on approved shop drawings. The finish quality on these surfaces shall match the finish quality of the flat surfaces on the building.

3.5 Back-checking and Fitting to Structure or Frame

3.5.1 Stone coming in contact with structural work shall be back-checked as indicated on the approved shop drawings. Stones resting on structural work shall have beds shaped to fit the supports as required.

3.5.2 Maintain a minimum of 1" (25 mm) between stone backs and adjacent structure. Note: many bolted connections will require more space than this; 2" (50 mm) space may be more desirable. Large-scale details should illustrate and control these conditions.

3.6 Cutting for Anchoring, Supporting, and Lifting Devices

3.6.1 Holes and sinkages shall be cut in stones for all anchors, cramps, dowels, and other tieback and support devices per industry standard practice or approved shop drawings. However, additional anchor holes shall be drilled at job site by Slate Contractor to facilitate alignment.

3.6.2 No holes or sinkages will be provided for Slate Contractor's handling devices unless arrangement for this service is made by the Slate Contractor with the Slate Fabricator.

[NOTE: It is not recommended that lewis pins be used for stones less than 3½" (90 mm) thick.]

3.7 Cutting and Drilling for Other Trades

3.7.1 Any miscellaneous cutting and drilling of stone necessary to accommodate other trades will be done by the Slate Fabricator only when necessary information is furnished in time to be shown on the shop drawings and details, and when work can be executed before fabrication. Cutting and fitting, due to job site conditions, will be the responsibility of the Slate Contractor.

3.7.2 Incidental cutting such as for window frame clips, etc., which is normally not considered to be the responsibility of the Stone Supplier, will be provided only by arrangement by the General Contractor and Slate Contractor with the Slate Fabricator.

4.0 SHIPPING AND HANDLING

4.1 Packing and Loading

4.1.1 Finished slate shall be carefully packed and loaded for shipment using all reasonable and customary precautions against damage in transit. No material which may cause staining or discoloration shall be used for blocking or packing.

4.2 Site Storage

4.2.1 Upon receipt at the building site, the slate shall remain in the factory-prepared bundles until beginning of the installation. Bundles shall be staged in an area which is least susceptible to damage from ongoing construction activity. Once unbundled, the slate shall be stacked on timber or platforms at least 2" (50 mm) above the ground, and the utmost care shall be taken to prevent staining or impact damage of the slate. If storage is to be prolonged, polyethylene or other suitable, nonstaining film shall be placed between any wood and finished surfaces of the slate. Polyethylene or other suitable, nonstaining film may also be required as protective covering.

5.0 INSTALLATION

5.1 General Installation

5.1.1 Installation shall be accomplished with competent, experienced Stone Setters, in accordance with the approved shop drawings.

5.1.2 All slate stone pieces shall be identified with a unique piece number corresponding with the number on the shop drawings. Interchanging of numbered pieces is not permitted.

5.1.3 Slate stone shall be free of any ice or frost at time of installation. Salt shall not be used for the purpose of melting ice, frost, or snow on the stone pieces.

5.1.4 Adequate protection measures shall be taken to ensure that exposed surfaces of the stone shall be kept free of mortar at all times.

5.2 Mortar Setting and Anchorage

5.2.1 All setting shall be done by competent Stone Setters, in accordance with approved shop drawings.

5.2.2 Exterior panels shall be anchored to the masonry wall or framing by at least four bronze wire or other nonferrous metal anchors for each piece. Standard size anchor is 1/8" to ¼" (3 to 6.5 mm)wire (depending on the thickness of the stone) turned down 1" (25 mm) into a 3/8" (9.5 mm) round, 1½" (40 mm) deep hole in the edge of the slate. Each piece must be anchored individually for proper adjustment. Slabs over 12 square feet (1 m^2) in surface area shall have at least two additional anchors every 6 square feet (0.5 m^2). Relief angles and liners may be required at normal floor-line distances.

5.2.3 The larger the panel, the more pronounced and rustic will be the textured face. Generous tolerance allowances of this natural-textured material will give more speed and ease in installation and a better general appearance. Anchoring and setting methods should allow for slight adjustments of each individual panel. Careful piece-to-piece selection should be exercised by the Slate Contractor at the job. Individual anchoring allows proper adjustment and alignment of each piece in relation to surrounding pieces. Round anchor holes in the edge of the slate to receive nonferrous wire anchors are the least expensive and the strongest system. Slots for strap anchors are sometimes acceptable.

5.2.4 Rear face of slabs should be at least 1" (25 mm) from the face of the backup wall. Gauged backs are frequently required where fitting is tight. Space between back of slate and wall should not be filled in completely, but instead spotted with approved nonstick mastic compound or portland cement in spots approximately 6" x 6" (150 x 150 mm) located every 18" (450 mm) apart. All shims and blocks must be removed.
Interior panels are set and anchored similarly to exterior work.

5.2.5 Panels set in metal frames shall have rabbeted edges and a sealant for all joints to prevent moisture seepage. Hairpin-spring anchors in the back of the panels make slate easily adaptable to slate-faced precast units and systems.

5.2.6 In some selected interior work, small 1'-0" x 1'-0" (300 x 300 mm) or less ¼" (6.5 mm) thick gauged panels can be applied with a proper adhesive without anchors. Some interior work may be set with narrow joints without grout.

5.2.7 Individually set thin slate tile [¼" or 3/8" (6.5 or 9.5 mm)] on vertical surfaces exceeding 15'-0" (4.5 m) is not recommended.

5.3 Mortar Joints

5.3.1 Mortar joints shall be raked out to a depth of ½" to ¾" (12.5 to 20 mm). Apply pointing mortar in layers not exceeding 3/8" (9.5 mm) and allow each layer to get hard to the touch before the next layer is applied. Tool finished joints with a concave tool having a diameter approximately 1/8" (3 mm) greater than the joint width.

5.3.2 Care shall be taken to keep expansion joints free of mortar, which would compromise their function.

5.4 Anchorage

5.4.1 All slate shall be anchored or doweled in accordance with the approved shop drawings.

5.4.2 To the furthest extent possible, all anchor preparations in the slate units shall be shop-applied.

5.4.3 All anchorage devices and anchor hole/slot fillers shall be in accordance with ASTM C1242. Care must be taken to ensure that any holes capable of retaining water are filled after use to prevent water collection and freezing.

5.5 Sealant Joints

5.5.1 Where so specified, joints requiring sealant shall be first filled with a closed-cell ethafoam rope backer rod. The backer rod shall be installed to a depth that provides optimum sealant profile after tooling.

5.5.2 If recommended by the Sealant Manufacturer, primers shall be applied to the substrate surfaces according to the manufacturer's directions prior to application of the joint sealant.

5.6 Expansion Joints

5.6.1 It is not the intent of this specification to make control or expansion joint recommendations for a specific project. The Specifying Authority must specify control or expansion joints and show location and details on drawings.

5.7 Caulking

5.7.1 Where so specified, joints shall be pointed with the sealant(s) specified in Section 2.4, after first installing the specified backup material and applying a primer if required, all in strict accordance with the printed instructions of the Sealant Manufacturer.

5.7.2 All sealants shall be tooled to ensure maximum adhesion to the contact surfaces.

5.8 Weep Tubes

5.8.1 Plastic or other weep tubes shall be placed in joints where moisture may accumulate within the wall, such as at base of cavity, continuous angles, flashing, etc., or as shown on architectural drawings.

6.0 CLEANING AND PROTECTION

6.1 Cleaning

6.1.1 The Slate Contractor shall keep the slate clean with a sponge and clean water. No mortar drippings shall be allowed to dry on the face of the slate. Upon completion of various portions of work, all mortar stains, grease marks, and dirt should be removed by washing with a good grade of cleaner. Flush and clean with clear water.

6.2 Protection of Finished Work

6.2.1 After the slate work has been installed, it shall be the responsibility of the General Contractor to see that it is properly and adequately protected from damage or stains until all trades are finished. This responsibility includes the stone cleaning costs prior to final inspection. The Slate Contractor will outline the needs for protection, in writing, to the General Contractor.

PRODUCT DESCRIPTION - Slate

1.0 GEOLOGICAL CLASSIFICATION

1.1 Slate is a fine-grained, metamorphic rock exhibiting "slaty" cleavage, which allows it to be split into thin sheets.[1] It is a low-grade metamorphic rock formed from shale, which is a thin-bedded, fine-grained, clastic sedimentary rock compacted from mud of clay-sized silicate clay minerals.[2]

1.2 How Slate Is Formed. Clay minerals are often suspended in the turbid waters of rivers, lakes, and ponds following heavy rains and their consequent flooding. When turbidity ceases, clay particles settle to the bottom of the still water, descending with a rocking, back-and-forth motion, like falling leaves. Over time, the clay accumulates in thin, flat layers on the bottom. Additional layers are deposited with each heavy rain or flood event until gradually many thin layers build up multiple beds of clay sequences with a water saturation of about 60%. If undisturbed through continual sedimentation, compaction occurs, squeezing out ±95% of the water. With increased burial to thousands of feet, additional compaction and cementation occurs, and shale is formed. Shale readily splits apart at bedding planes, sometimes into very thin sheets or thick units.

1.3 If the resulting shale sequence, a clastic sedimentary stone, is subjected to regional compression at a high enough pressure-temperature-time cycle, then metamorphism occurs. Regional pressure at this level usually folds the entire sedimentary sequence, thus the bedding surfaces will generally, but not always, be at some angle to the pressure. Pressure causes the small, flat sheets of clay minerals in the shale to always realign normal (perpendicular to the direction of pressure). The metamorphic pressure can be from any direction and may have no relation to former bedding, only coinciding with bedding as an accident of fold geometry.

1.4 This realignment and added compression develops the "slaty" cleavage or cleavability, one of the defining and most useful properties of slate. Because of the realignment of the microscopic sheets of clay minerals, the new cleavage is independent of the former bedding, which can no longer function as a parting plane even though it may still be perfectly visible as a color demarcation. A fresh cleavage surface on slate has a silvery sheen from the microscopic sheets of muscovite and chlorite mica that typically develop on cleavage surfaces in low-grade metamorphism. Time, oxidation, freezing and thawing, rain, and hail ultimately fade colors and degrade the stone's sheen. This is not a fault–just the normal consequence of weathering and not detrimental in most cases unless water penetrates to allow frost heaving.

1.5 Slate colors are caused by small amounts of iron (red-brown), organic carbon (black), and other additives, minerals, or mixtures that yield violet, green, gray, and other colors.

1.6 Slate quality has been commonly related to how long it lasts on a roof. Some slates from northern New England are known to endure at least 250 years. Slate roofs from Vermont dwellings constructed circa 1740 have been recycled to new homes and remain in good condition, exhibiting only some fading from surface oxidation of carbonaceous matter that once gave the slate its dark gray hue. Slate from areas of less intense metamorphism or slightly less optimal parent rock composition

[1] Ref: American Geological Institute. *The Glossary of Geology*, 2nd ed., 1980, Bates and Jackson, eds.

[2] *Clay*, the word, has two distinct meanings: *Clay minerals* are complex silicates, the products of chemical weathering of feldspar and other silicate minerals. Clay minerals have a sheet-like molecular structure, the same structure as mica. Clay mineral sheets are carried in suspension by water, and deposition from suspension when turbidity ends. *Clay* is also a size term defined as particles less than 1/256 mm or 0.00016" in size. Particles can also be ground-up mineral crystals, rock fragments, and colloidal lithic material, as well as clay minerals.

several states to the south of Vermont are reported to be good for 75 to 100 years.

1.7 Phyllite. If the metamorphic pressures are more intense, the time under pressure is longer, or the parent shale composition is silty, sandy, or contains other foreign matter and entrained chemicals, the resulting metamorphic stone may develop into phyllite, the next higher metamorphic grade. Phyllite tends to have nonuniform, undulating cleavage surfaces and often large cubes or crystals of pyrite (FeS_2) that quickly oxidize and bleed ugly iron stain, or superhard garnet "knots" that occur as lumps and bumps on the wavy cleavage. Phyllite develops more muscovite mica (a hydrous potassium aluminum silicate) and sericite (iron carbonate or $FeCO_3$) on the cleavages than slate, thus phyllite has an even more silky silver sheen than ordinary slate.

1.8 Schist. If the variables in metamorphism already mentioned are carried to the next step, then schist is developed. In schist, secondarily developed minerals from intense metamorphism such as muscovite or biotite mica occur in compact masses and usually do not have the well-defined, flat cleavage characteristic of slate, thus schist is unsuitable for most traditional uses of slate. The mica flakes do not lie in flat planes and are loose enough to easily flake off. Schist is named for the major, flat mineral in its composition; for example, muscovite schist, biotite schist, hornblende schist, etc.

1.9 Unfortunately, some schists and phyllites are sold as slate and when used in exterior applications result in sheets sloughing off, iron stains bleeding out of the stone, or actual disintegration of tiles and slabs. Some of these "marginal slates" are highly colored and have interesting textures, but are best reserved for interior, decorative applications and not in places where there is potential moisture or where falling stone is a safety hazard.

1.10 Because the metamorphic process and resulting stone is so dependent on the right combination of parent stone composition, location, and the pressure-temperature-time cycle, the products are a continuum from one extreme to another–from insufficiently metamorphosed to highly metamorphosed–both extremes being unsuitable for building purposes. A stone that cannot be used isn't "bad," but there is simply a lot of stone unsatisfactory for commercial applications.

2.0 COLOR AND VEINING

2.1 The color of a slate is determined by its chemical and mineralogical composition. The gray and bluish-gray colors are due chiefly to the presence of carbonaceous material; many other colors are due to iron compounds. Slates containing large proportions of finely divided carbonaceous matter are black. Other colors that are found are blue-black, red, green, purple, mottled, yellow, brown, and buff.

2.2 Permanence of color has considerable importance, for although some slates maintain their original color for many years, others change to new shades within a comparatively short time.

2.3 Some slates tend to fade under the influences of the elements. Such changes may be due to the presence of small quantities of iron-lime-magnesia carbonates which decompose readily and form a yellow hydrous iron oxide, limonite. Therefore, slates are of two types: unfading and fading. Unfading color is not a quality verifiable by any current ASTM or other test method.

3.0 TEXTURE

3.1 Differences in conditions of deposition often result in variations in texture of successive strata, and such variations make it possible to trace folds and contortions within the quarry. "Ribbons" are dark bands, a fraction of an inch to several inches in width, intersecting blocks of slate at various angles. Cleavage and grain are other characteristics of slate that can affect its texture. Cleavage is the tendency for stone split with ease in one direction. However, many slates have a second direction of splitting that is less pronounced called the grain.

4.0 FINISHES

4.1 Slate's surface may be finished in a number of ways. Typical finishes for slate are:

4.1.1 Natural Cleft: A cleavage face formed when the slate is split into any thickness.

4.1.2 Honed: A satin smooth surface with no gloss.

4.1.3 Sand Rubbed: A flat, nonreflective surface.

4.1.4 Tumbled: A weathered, aging finish.

4.1.5 Machine Gauged (Diamond Gauged): Surface is a level plane with swirl marks noticeable.

4.2 The type of finish desired bears some relationship to final cost, as the smoother surfaces require more finishing, and consequently, more time. The most economical finish is the natural cleft.

4.3 Other finishes, such as **bush-hammered**, **sandblasted**, and **planed**, may also be available. Some stone finishes can affect strength and durability. For example, bush-hammered and thermal finishes reduce a stone's thickness, making it more vulnerable to weakening from exposure to freeze and thaw cycles.

5.0 THICKNESS

5.1 Standard thicknesses for slate veneers are ¾", 1", 1¼", 1½", and 2" (20 mm, 25 mm, 30 mm, 40 mm, and 50 mm). Slate tiles are available in a variety of thicknesses ranging from ¼" to 1" (6.5 mm to 25 mm). The following table represents approximate recommended thicknesses for selected slate applications:

Use	**Thickness**	
	Residential Foot Traffic	Commercial Foot Traffic
Flagging (exterior)	¾"	1"
Thresholds	¾" –7/8"	1" – 1 ¼"
Tile	¼" – 5/8"	¾" – 1"
Treads	1" – 1 ¼"	1 ½" – 2"

6.0 SIZES

6.1 Slate is a product of nature with many varieties available, each possessing varying characteristics. Little can be done to alter the condition in which nature presents these varieties to us. Therefore, size may become a limiting factor to consider in the selection of a particular slate. The following table represents approximate recommended sizes for selected slate applications.

Use	**Length (max)**	**Width (max)**
Flagging (exterior)	1"-6"	2'-0"
Thresholds	4'-0"	8"
Tile	2'-0"	1'-6"
Treads	5'-6"	1'-6"

6.2 A jointing scheme which permits the use of smaller sizes of slate will greatly facilitate selection and delivery. The NSI Member/Supplier can assist with approval of the final scheme.

7.0 PRODUCT SAMPLING

7.1 Slate is formed by nature; thus, there are variations in the tonal qualities of the stones. However, it is these natural variations that make slate unique, valuable, and highly desirable. Because of these variations, selection of a particular slate should never be made on the basis of one sample only. It is recommended that selection be based on viewing sufficient samples to show the complete range of colors of the desired stone. NSI Members can provide these range samples.

8.0 PROPER USAGE TIPS

8.1 Recommendation for commercial floors:

8.1.1 Minimum ¾" (20 mm) thickness.

8.1.2 A honed or cleft finish.

8.1.3 A minimum hardness value of 8 as measured by ASTM C241/C1353.

8.2 Avoid the use of gypsum or molding plaster setting spots for the installation of stone.

9.0 TOLERANCES

9.1 Because of the variances in natural cleft or cleavage, it is recommended that the Slate Quarrier or Fabricator be contacted regarding size and thickness tolerances.

10.0 SOUNDNESS

10.1 Slate, consisting as it does chiefly of very small overlapping flakes consolidated under pressure, is a strong rock. Most mica slates of good commercial quality are highly impervious to moisture.

TECHNICAL DATA - Slate

1.0 PROPERTIES OF SLATE DIMENSION STONE

1.1 In centuries past, relatively little importance was attached to the ultimate physical capabilities of most building materials. Rule of thumb was a common structural design criterion. As a result, the widely used materials of the day, for the most part natural rather than manmade materials, were seldom stressed to their ultimate limits.

1.2 In present-day construction, however, this is far from being true. Performance requirements are daily becoming more demanding. In striving for taller structures, greater spans, firmer foundations, thinner walls and floors, stronger frames, and generally more efficient buildings with more usable space, today's Architects and Engineers must get the most out of the materials with which they work.

1.3 Slate is a product of nature and not always subject to the rules of consistent behavior that may apply to manufactured building materials.

1.4 Physical property values of slate may, however, be measured using the standard test methods approved by the Dimension Stone Committee C-18 of ASTM International. The NSI and Member companies are represented on the ASTM committee and are active in its technical work of establishing proper test methods and specifications consistent with the latest technology.

1.5 Final design should always be based on specific values for the slate variety ultimately to be installed. These values may be obtained from the Slate Supplier. All materials are not suitable for all uses. In order to avoid mistaken selections, tests for material values should be made prior to final material selection.

1.6 Physical Properties of Slate.
(This historical data and information is provided only as a guideline. Recommended minimums or maximums are established and provided by ASTM International.)*

Property	Range of Values
Compressive Strength (C170) lbs/in²	10,000-15,000
Flexural Strength (C880) lbs/in²	6,000-5,000
Density, lb/ft³ (C97)	170-190

Property	Range of Values
Modulus of Rupture (C120) lbs/in²	5,500-9,000
Recommended (min): 7,200 along grain, 9,000 across grain	
Absorption, by Weight % (C121)	0.1-0.45
Recommended (max): 0.25 interior, 0.45 exterior	
Abrasion Resistance (C241/C1353) (H_a) 6.0-10	6.0-10.0
Recommended (min): 8	

* Test methods described in current ASTM standards.

2.0 STRENGTH (ASTM C120, C880)

2.1 Values for modulus of rupture and flexural strength are determined by testing specimens of slate under laboratory conditions until they fail.

2.2 The strength of slate is a measure of its ability to resist stresses. This strength depends on several factors: the amount of mica flakes and quartz grains present, the degree of cohesion, and the nature of any cementing materials present.

3.0 FIRE RESISTANCE

3.1 Slate is not combustible according to underwriters' ratings, and therefore is considered a fire-resistant material. Because of its thermal conductivity, heat transfer is fairly rapid. Most slate is not considered a highly rated thermal insulator.

3.2 Underwriters' fire-resistance ratings evaluate whether or not a material will burn, as well as how long it will keep surrounding combustible materials from reaching temperatures which will cause them to ignite. Methods of estimating fire-resistance periods of masonry walls and partitions utilizing component laminae are given in "Fire Resistance Classifications of Building Construction," BMS92, National Bureau of Standards.

4.0 ABRASION RESISTANCE (ASTM C241/C1353)

4.1 Abrasion resistance is a property of slate that should be tested per ASTM C241/C1353 to provide an indication of the slate's wearing qualities when exposed to foot traffic.

4.2 The hardness and uniform wearing qualities of most slate makes it extremely desirable and economically practical for floors and stairs. Varieties with an abrasive hardness (H_a) of 8 or more as measured by ASTM C241/C1353 tests are recommended for use as flooring exposed to normal foot traffic. A minimum abrasive hardness of 10 is recommended for commercial floors, stair treads, and platforms subject to heavy foot traffic. The abrasion resistance hardness values pertain to foot traffic only. If floors are constructed with two or more stone varieties, the H_a values of the stones must not differ by more than 5 or the floor surface will not wear evenly and uniformly.

5.0 FACTORS AFFECTING PROPERTIES (ASTM C121, C217)

5.1 The ultimate test of a building material is its ability to have and maintain the necessary structural strength, as well as beauty of appearance and low cost of maintenance, over the useful life of the structure. Experience has proven that slate meets this test as few other building materials can. Studies have shown that the durability of most slates is little affected by cycles of weather. This is because of slate's low rate of water absorption.

5.2 Currently, two ASTM test methods are unique to slate. ASTM C217 "Standard Test Method for Weather Resistance of Slate," is a method that is useful in indicating the differences in weather resistance between various slates, and should be used to correlate their durability. ASTM C121 "Standard Test Method for Water Absorption of Slate," provides another element in the comparison of slates. Water absorption testing can be helpful in determining the porosity of a particular slate.

6.0 SAFETY FACTORS

6.1 Good engineering practice requires that allowable design stress must provide a margin of safety in any structural element. As a necessary precaution against such conditions as wind, ice, snow, impact, temperature changes, and imperfect workmanship, these allowable stresses must be smaller than those which produce failure.

6.2 Within the accepted limits of safe design practice, the closer the allowable load is to the ultimate failure load, the more efficient is the use of the material and the less the cost of the construction.

6.3 Contemporary building design does not usually employ slate as part of the structural frame, but rather as an independent unit, a curtain wall, or veneer. Therefore, the primary concern in such cases is with wind or seismic loads, and a safety factor of 5.0 is recommended. Where the slate is to be subjected to concentrated loading, such as stair treads or lintels supported only at the ends, a factor of 10.0 should be used. These safety factors may be adjusted using sound engineering principles and judgment.

6.4 As buildings become taller and individual slate slab veneer becomes larger in area, the lateral forces due to wind loads must be considered. Wind tunnel tests are often used on major structures to determine wind dynamics and force magnitude. Reinforcement is sometimes necessary for large-dimension slab veneer in critical areas.

7.0 SEISMIC CONSIDERATIONS

7.1 Seismic considerations generally require that low buildings be stiff, and that tall buildings be relatively flexible. Design of connections must account for seismically induced horizontal loading. Local building codes vary and must always be checked to determine specific requirements for each area. The National Bureau of Standards has published two documents on the topic: "Earthquake Resistant Masonry Construction," NBS Science Series 106; and "Abnormal Loading on Buildings and Progressive Collapse: An Annotated Bibliography," NBS Science Series 67. The U.S. Army Corps of Engineers has also published TM 5-809-10, "Seismic Design for Buildings."

8.0 EFFLORESCENCE AND STAINING

8.1 Efflorescence is a salt deposit, usually white in color that appears on exterior surfaces of masonry walls. The efflorescence-producing salts found in masonry are usually sulfates of sodium, potassium, magnesium, calcium, and iron. Salts which are chlorides of sodium, calcium, and potassium will sometimes appear, but they are so highly soluble in water that they will be washed off by rain.

8.2 The water-soluble salts causing efflorescence come from other materials in the wall. The salts exist in small amounts and are leached to the surface by water percolating through the walls. The most feasible means of prevention is to stop the entrance of large amounts of water. Absorption from the face will not cause efflorescence unless there are open joints.

8.3 Slate is seldom injured by efflorescence. However, some of the salt crystals may form in the pores near the surface. Crystal growth (recrystallization) in the pores can cause stress on the walls of the pores and cause the stone to flake off. If the conditions bringing about this action persist, scaling may continue and flake off one layer after another. For this to happen, large amounts of water must enter the wall and must contain large amounts of salts.

8.4 Calcium carbonate is the least resistant constituent of slates to long weather exposure, especially to sulfur fumes, for sulfur trioxide acting on calcium carbonate forms calcium sulfate, or gypsum, a mineral which expands greatly with disruptive effects during crystallization. Iron carbonate is sometimes present, and its decomposition not only affects the slate, but the resulting iron oxides may cause stains. Iron sulfides may oxidize and form spots and stains. The oxidation of iron-bearing minerals, especially ferrous carbonate, often causes color changes.

NOTES:

SOAPSTONE

1.0 GENERAL

1.1 Related Documents

1.1.1 Drawings and general provisions, including General and Supplementary Conditions of the Contract and Division I Specification sections, apply to this section.

1.2 Applicable Publications

1.2.1 The following publications listed here and referred to thereafter by alphanumeric code designation only, form a part of this specification to the extent indicated by the references thereto:

1.2.2 ASTM International (ASTM):

1.2.2.1 There currently is no ASTM Standard Specification for Soapstone Dimension Stone.

1.2.2.2 C97, Standard Test Methods for Absorption and Bulk Specific Gravity of Dimension Stone

1.2.2.3 C99, Standard Test Method for Modulus of Rupture of Dimension Stone

1.2.2.4 C170, Standard Test Method for Compressive Strength of Dimension Stone

1.2.2.5 C241, Standard Test Method for Abrasion Resistance of Stone Subjected to Foot Traffic

1.2.2.6 C880, Standard Test Method for Flexural Strength of Dimension Stone

1.2.2.7 C1353, Standard Test Method Using the Taber Abraser for Abrasion Resistance of Dimension Stone Subjected to Foot Traffic

1.2.3 Natural Stone Institute (NSI):

1.2.3.1 Membership, Products, and Services Directory

1.2.3.2 Dimension Stone Design Manual

1.2.3.3 Additional publications may be available from the NSI Bookstore. Go online at www.naturalstoneinstitute.org.

1.3 Scope of Included Work

1.3.1 The work to be completed under this contract includes all labor and materials required for the furnishing and installation of all slate work shown or called for on the contract drawings, specifications, and addenda.

1.4 Definition of Terms

1.4.1 The definitions of trade terms used in this specification shall be those published by NSI or ASTM International.

1.5 Source of Supply

1.5.1 All soapstone shall be obtained from quarries having adequate capacity and facilities to meet the specified requirements, and by a firm equipped to process the material promptly on order and in strict accord with specifications. The Specifying Authority (architect, designer, engineer, contracting officer, end user, etc.) reserves the right to approve the Material Supplier for slate prior to the award of this contract. Stone and workmanship quality shall be in accordance with Industry Standards and Practices as set forth by NSI.

1.6 Samples

1.6.1 The Soapstone Contractor shall submit through the General Contractor, for approval by the Specifying Authority, at least two sets of samples of the various kinds of Soapstone specified. The sample size shall be 1'-0" x 1'-0" (300 x 300 mm) and shall represent approximately the finish, texture, and anticipated range of color to be supplied. One set of samples shall be retained by the Specifying Authority, and one set shall be returned to the Soapstone Supplier for his/her record and guidance. It is noted herein that Soapstone is a natural material and will have intrinsic variations in color, markings, and other characteristics. Color variation range is to be only from natural markings in the Soapstone or from the reflective sheen and shadow value of the graining of the natural-cleft textures and cleavage planes. Depending on Soapstone selected and quantity required, a range mockup may be used to further define the characteristics of the material. Cost of mockup, if required, shall not be included in this section.

1.6.2 Prior to fabrication, an inspection and approval by the Specifying Authority and/or General Contractor and/or End User of the finished slabs is recommended to understand the finish and full range of the material.

1.7 Shop Drawings

1.7.1 The Soapstone Contractor shall submit through the General Contractor, for approval by the Specifying Authority, sufficient sets of shop drawings showing general layout, jointing, anchoring, stock thickness, and other pertinent information. These drawings shall show all bedding, bonding, jointing, and anchoring details along with the net piece dimensions of each Soapstone unit. One copy of the approved shop drawings shall be retained by the Specifying Authority, one copy shall be retained by the General Contractor, and one copy returned to the Soapstone Contractor for fabrication. NO FABRICATION OF SOAPSTONE SHALL BE STARTED UNTIL SUCH DRAWINGS HAVE BEEN FULLY APPROVED AND MARKED AS SUCH. The Soapstone Contractor shall not be responsible for determining, making, or verifying (1) design, structural, wind, seismic, or other design loads; (2) engineering estimates; (3) plans or specifications; (4) the types, sizes, or locations of anchors; or (5) verification of field dimensions, unless specifically added to the scope of work.

1.8 Defective Work

1.8.1 Any piece of Soapstone showing flaws or imperfections upon receipt at the storage yard or building site shall be referred to the Specifying Authority for determination as to responsibility and decision as to whether it shall be rejected, patched, or redressed for use. Any material in question should not be installed prior to inspection and approval.

1.9 Repairing Damaged Stone

1.9.1 Chips at the edges or corners may be patched, provided the structural integrity of the stone is not affected and the patch matches the color and finish of the natural stone so that it does not detract from the stone's appearance. Scratches may be hand-sanded after which mineral oil shall be re-applied to achieve uniform color.

2.0 MATERIALS

2.1 Soapstone

2.1.1 General: All Soapstone shall be of standard architectural grade, free of cracks, seams, starts, or other traits which may impair its structural integrity or function. Inherent color variations characteristic of the quarry from which it is obtained will be acceptable. Texture and finish shall be as shown in the sample(s) approved by the Specifying Authority.

2.1.2 Currently there is no ASTM Standard Specification for Soapstone Dimension Stone.

2.1.3 Schedule: Soapstone shall be provided as follows:

2.1.3.1 For (*state location on building*) (*state name and color*) Soapstone with a (*type*) finish, supplied by (*name company or list several approved suppliers*).

2.1.3.2 Provide information as in 2.1.3.1 for each different Soapstone/finish combination in the project.

2.1.4 Finishes: Face finish of exterior panels should be a fine honed finish. All exposed edges should be honed to remove saw marks and darken the edge color. Finished surfaces should be treated with mineral oil to achieve a uniform, dark, rich color.

2.1.5 Finishes listed in the schedule shall conform with definitions by the NSI or ASTM International.

3.0 FABRICATION

3.1 Moldings, Washes, and Drips

3.1.1 Moldings, washes, and drips shall be constant in profile throughout their entire length, in strict conformity with details shown on approved shop drawings. The finish quality on these surfaces shall match the finish quality of the flat surfaces on the project.

3.2 Cutting and Drilling For Other Trades

3.2.1 Any miscellaneous cutting and drilling of stone necessary to accommodate other trades will be done by the Soapstone Fabricator only when necessary information is furnished in time to be shown on the shop drawings and details, and when work can be executed before fabrication. Cutting and fitting, due to job site conditions, will be the responsibility of the Soapstone Contractor.

3.2.2 Incidental cutting, such as for window frame clips, etc., which is normally not considered to be the responsibility of the Stone Supplier, will be provided only by arrangement by the General Contractor and Soapstone Contractor with the Soapstone Fabricator.

4.0 SHIPPING AND HANDLING

4.1 Packing and Loading

4.1.1 Finished Soapstone shall be carefully packed and loaded for shipment using all reasonable and customary precautions against damage in transit. No material which may cause staining or discoloration shall be used for blocking or packing.

5.0 INSTALLATION

5.1 General Installation

5.1.1 Installation shall be accomplished with competent, experienced Stone Setters, in accordance with the approved shop drawings.

5.1.2 All Soapstone stone pieces shall be identified with a unique piece number corresponding with the number on the shop drawings. Interchanging of numbered pieces is not permitted.

5.1.3 Soapstone stone shall be free of any ice or frost at time of installation. Salt shall not be used for the purpose of melting ice, frost, or snow on the stone pieces.

5.1.4 Adequate protection measures shall be taken to ensure that exposed surfaces of the stone shall be kept free of mortar at all times.

5.2 Expansion Joints

5.2.1 It is not the intent of this specification to make control or expansion joint recommendations for a specific project. The Specifying Authority must specify control or expansion joints and show location and details on drawings.

5.3 Caulking

5.3.1 Where so specified, joints shall be pointed with the sealant(s) after first installing the specified backup material and applying a primer if required, all in strict accordance with the printed instructions of the Sealant Manufacturer.

5.3.2 All sealants shall be tooled to ensure maximum adhesion to the contact surfaces.

6.0 CLEANING AND PROTECTION

6.1 Cleaning

6.1.1 The Soapstone Contractor shall keep the Soapstone clean with a sponge and clean water, utilizing a neutral detergent if necessary.

6.2 Protection of Finished Work

6.2.1 After the Soapstone work has been installed, it shall be the responsibility of the General Contractor to see that it is properly and adequately protected from damage or stains until all trades are finished. This responsibility includes the stone cleaning costs prior to final inspection. The Soapstone Contractor will outline the needs for protection, in writing, to the General Contractor.

PRODUCT DESCRIPTION – Soapstone

1.0 GEOLOGICAL CLASSIFICATION

1.1 Soapstone currently enjoys a resurgence of popularity for surfaces, kitchenware, traditional decorative uses, industrial applications and artistic carvings. The long-known, unique physical properties and wide range of colors are once again driving forces in this recent interest.

1.2 Soapstone is a *metamorphic*[1] stone or rock composed of one or more minerals; however, in most industrial applications it is almost always a mixture of minerals because the mixture is somewhat harder than single-mineral soapstone and mineral mixtures in nature are common, while single mineral purity is much less common.

1.3 Soapstone texture can vary from massive[2] to fibrous or flaky. The best commercial grades are highly compacted and are not absorbent. It commonly has a "soapy" to slippery and soft feel when the surface is unaltered by long use or treated with chemicals or oils.

1.4 Soapstone of commercial value is quarried in many places around the world: in far Arctic areas of Canada, Scandinavia, Siberia and Russia, as well as in Brazil and northeastern United States.

1.5 Soapstone has been used for thousands of years by the Inuit people ("Eskimo") and others as a medium for carving highly valued sculpture.

[1] Soapstone is always of metamorphic origin, formed by very high pressures and generally from light-colored, low specific gravity, highly silicic (> 60% SiO_2; or quartz) igneous rock.

[2] *Massive* in metamorphic stone means a stone whose constituents are neither oriented in parallel position nor arranged in layers; that is, a stone that does not have layering, schistosity, foliation or similar structure.

2.0 MINERALOGY

2.1 Minerals commonly found in soapstone - in general order of abundance:

2.1.1 Talc: Hydrous magnesium silicate $Mg_3Si_4O_{10}(OH)_2$ is the most abundant mineral component and thus dictates some of the stone's characteristic properties like hardness and feel. Since talc defines the Mohs hardness of 1, the softest level of the Mohs scale, soapstone dominantly composed of talc may be a bit soft for use as a surface material since it could easily be scratched by even a fingernail. Soapstone is somewhat harder if its composition includes one or more of the minerals below.

2.1.2 Magnesite: Magnesium carbonate ($MgCO_3$) moderately hard Mohs 3.5 – 4.5, not soluble in cold, dilute hydrochloric acid, generally the second most abundant soapstone mineral. Exhibits excellent rhombohedral cleavage that is microscopic and not detrimental in massive soapstone. Is generally the white mineral filling "veins" in soapstone and may be responsible for much of the mottled appearance.

2.1.3 Dolomite: A calcium and magnesium carbonate ($CaMg(CO_3)$), Mohs hardness of ~3.5, does not react with dilute hydrochloric acid.

2.1.4 Micas: Muscovite is inert, colorless, elastic and flaky mica. Less common in soapstone is the dark mica biotite which contains iron and magnesium, H=2.5 - 4.

2.1.5 Chlorite is a metamorphic greenish mica that is soft, non-flexible; and non-reactive. It is responsible for the greenish color of some soapstone.

2.1.6 Rare Accessory Minerals: minor to trace amounts of pyroxene (augite, etc.) and amphibole (hornblende etc.) derived from the alteration of ferromagnesian silicates in igneous rock that, because of the Fe and Mg, may yield "disfiguring" coloration or blemishes.

2.2 **Steatite** (a.k.a. "steatite talc"): A nearly obsolete term for soapstone or very pure talc-rich rock used for talcum powder and formerly for electrical insulators. Since the term is used in some older definitions of soapstone, it has found its way into the literature of some quarries and distributors of soapstone. It is recommended the use of this term be discontinued as it demands a definition that at best is often vague and confusing. Almost everyone is familiar with talcum powder (talc), its softness and feel.

3.0 PHYSICAL PROPERTIES OF SOAPSTONE

3.1 **Hardness**: Soapstone used for surfaces is a soft dimension stone. Mohs hardness 1-4, depending on mineral content. The softness is a plus: It can be worked with ordinary tooling, scratches and dings can be eliminated or minimized with ordinary sandpaper, and it is forgiving of china–much more so than granite. It does not have a bothersome preferential breakage or fracture direction.

3.2 **Chemical reactivity**: Soapstone is very inert. It does not react with strong acids or alkali (basic) solutions. It is non-poisonous and safe to cook in or use around food.

3.3 Heat retention is very high. Soapstone is unaffected by temperatures from well below zero to above ±2,000°F (±1,100°C). Thus it is very useful as refractory material and is frequently used for wood burning stoves that use both of these properties. It is dimensionally very stable through a wide range of temperature. The ancient Nordic Vikings used flat soapstone pebbles for pocket hand warmers.

3.4 Absorbency: Since soapstone is a metamorphic stone formed under high pressure, it is highly compacted and dense; thus absorbency is zero or so close to zero that it is inconsequential, making this stone exceedingly sanitary as a food preparation surface, as well-maintained surfaces resist harboring bacterial growth.

3.5 Color: Usually in the gray to gray-bluish ranges to mottled white or lighter gray and greenish hues and/or streaked with irregular veins of white that may be talc, magnesite, chlorite, dolomite or again, a mixture.

3.6 Electrical: Soapstone is non-conductive and thus is ultra safe for kitchen counter surfaces. Formerly used for high voltage electrical insulation.

4.0 FIRE RESISTANCE

4.1 Soapstone is not combustible according to underwriters' ratings, and therefore is considered a fire-resistant material. Because of its thermal conductivity, heat transfer is fairly rapid. Most soapstone is not considered a highly rated thermal insulator.

4.2 Underwriters' fire-resistance ratings evaluate whether or not a material will burn, as well as how long it will keep surrounding combustible materials from reaching temperatures which will cause them to ignite. Methods of estimating fire-resistance periods of masonry walls and partitions utilizing component laminae are given in "Fire Resistance Classifications of Building Construction," BMS92, National Bureau of Standards.

TRAVERTINE

1.0 GENERAL

1.1 Related Documents

1.1.1 Drawings and general provisions, including General and Supplementary Conditions of the Contract and Division I Specification sections, apply to this section.

1.2 Applicable Publications

1.2.1 The following publications listed here and referred to thereafter by alphanumeric code designation only, form a part of this specification to the extent indicated by the references thereto:

1.2.2 ASTM International (ASTM):

1.2.2.1 C1527, Standard Specification for Travertine Dimension Stone

1.2.2.2 C97, Standard Test Methods for Absorption and Bulk Specific Gravity of Dimension Stone

1.2.3.3 C99, Standard Test Method for Modulus of Rupture of Dimension Stone

1.2.2.4 C170, Standard Test Method for Compressive Strength of Dimension Stone

1.2.2.5 C241, Standard Test Method for Abrasion Resistance of Stone Subjected to Foot Traffic

1.2.2.6 C880, Standard Test Method for Flexural Strength of Dimension Stone

1.2.2.7 C1353, Standard Test Method for Abrasion Resistance of Dimension Stone Subjected to Foot Traffic Using a Rotary Platform Abraser

1.2.3 Natural Stone Institute (NSI):

1.2.3.1 Membership, Products, and Services Directory

1.2.3.2 Dimension Stone Design Manual

1.2.3.3 Additional publications may be available from the NSI Bookstore. Go online at www.naturalstoneinstitute.org.

1.3 Scope of Included Work

The work to be completed under this contract includes all labor and materials required for the furnishing and installation of all travertine work shown or called for on the contract drawings, specifications, and addenda.

1.4 Definition of Terms

1.4.1 The definitions of trade terms used in this specification shall be those published by NSI or ASTM International.

1.5 Source of Supply

1.5.1 All travertine shall be obtained from quarries having adequate capacity and facilities to meet the specified requirements, and from a firm equipped to process the material promptly on order and in strict accord with specifications.

1.5.2 The Specifying Authority (architect, designer, engineer, contracting officer, end user, etc.) reserves the right to approve the Material Supplier for travertine prior to the award of this contract.

1.6 Samples

1.6.1 The Travertine Contractor shall submit through the General Contractor, for approval by the Specifying Authority, at least two sets of samples of the various kinds of travertine specified. The sample size shall be 1'-0" x 1'-0" (300 x 300 mm) and shall represent approximately the vein trend, finish, texture, direction of cut (vein or fleuri), incidence of holes, color of fill (if applicable), and anticipated range of color to be supplied. One set of samples shall be retained by the

Specifying Authority, and one set shall be returned to the Travertine Supplier for his/her record and guidance. It is noted herein that travertine is a natural material and will have intrinsic variations in color, markings, and other characteristics. Depending on travertine selected and quantity required, a range mockup may be used to further define the characteristics of the material. (NSI recommends the use of mockups.) Wherever possible, mockups should remain as a completed portion of the project. Where that is not possible, cost of mockup shall not be included in this section.

1.6.2 Prior to fabrication, an inspection and approval by the Specifying Authority and/or General Contractor and/or End User of the finished slabs is recommended to understand the finish and full range of the material

1.7 Shop Drawings

1.7.1 The Travertine Contractor shall submit through the General Contractor, for approval by the Specifying Authority, sufficient sets of shop drawings showing general layout, jointing, anchoring, stock thickness, and other pertinent information. These drawings shall show all bedding, bonding, jointing, and anchoring details along with the net piece dimensions of each travertine unit. One copy of the approved shop drawings shall be retained by the Specifying Authority, one copy shall be retained by the General Contractor, and one copy returned to the Travertine Contractor for fabrication. All jointing as shown by the Specifying Authority on the contract drawings shall be followed, unless modifications are agreed upon in writing, or indicated upon the approved shop drawings. If the contract drawings do not show the intent of the jointing, it will be the Travertine Contractor's responsibility to establish the jointing to meet the Specifying Authority's design intent within the limitations of the material selected.

1.7.2 The cutting and setting drawings shall be based upon and follow the drawings and full size details prepared by the Specifying Authority, except where it is agreed in writing or shown on the approved shop drawings that changes be made. Each stone indicated on the setting drawings shall bear the corresponding number marked on an unexposed surface. Provisions for the anchoring, doweling, and handling of the material, and for the support of stone by shelf angles and mechanical anchors, when required, shall be clearly indicated on the shop drawings. NO FABRICATION OF TRAVERTINE SHALL BE STARTED UNTIL SUCH DRAWINGS HAVE BEEN FULLY APPROVED AND MARKED AS SUCH. The Travertine Contractor, unless specifically directed to do so, shall not be responsible for determining, making, or verifying (1) design, structural, wind, seismic, or other design loads; (2) engineering estimates; (3) plans or specifications; or (4) the types, sizes, or locations of anchors, unless specifically added to the scope of work.

1.8 Defective Work

1.8.1 Any piece of travertine showing flaws or imperfections upon receipt at the storage yard or building site shall be referred to the Specifying Authority for determination as to responsibility and decision as to whether it shall be rejected, patched, or redressed for use.

1.9 Repairing Damaged Travertine

1.9.1 Repair of travertine is an accepted practice and will be permitted. Some chipping is expected; repair of small chips is not required if it does not detract from the overall appearance of the work, or impair the effectiveness of the mortar or sealant. The criteria for acceptance of chips and repairs will be per the Natural Stone Institute Dimension Stone Design Manual standards unless other criteria are mutually agreed upon in writing by the Travertine Contractor and the Specifying Authority.

2.0 MATERIALS

2.1 Travertine

2.1.1 General: All travertine shall be of standard architectural grade, free from cracks, seams, starts, or other traits which may impair its structural integrity or function. Inherent color variations characteristic of the quarry from which it is obtained will be acceptable, providing such is demonstrated in the approved samples. Texture and finish shall be approved by the Specifying Authority as shown in the samples.

2.1.1.1 If travertine is supplied unfilled, careful attention must be made to the size of any holes present. Holes larger than 2 cm in diameter and/or holes that go through the stone should be filled with a travertine chip cemented below the surface of the stone.

2.1.1.2 ASTM C1527 [C97] [C99] [C170] [C241/C1353] [C880] See the chart of applicable ASTM standards and tests in the Appendix.

2.1.2 Schedule: Travertine shall be provided as follows:

2.1.2.1 For (*state location on building*) (*state name and color*) travertine with a (*type*) finish, supplied by (*name company or list several approved suppliers*).

2.1.2.2 Provide information as in 2.1.2.1 for each different travertine/finish combination in the project.

2.1.3 Finishes: Finishes listed in the schedule shall conform with definitions by NSI or ASTM International.

2.2 Setting Mortar

2.2.1 Cement used with travertine shall be white portland cement, ASTM C150, or white masonry cement, ASTM C91.

2.2.2 Travertine should be installed with white cement. Hydrated lime should conform to ASTM C207 Type S.

2.2.3 Sand should comply with ASTM C144.

2.2.4 Mixing water must be potable quality.

2.2.5 Mortar mixes vary in proportions from a hard mixture (1:1:4) to a flexible mixture (1:1:9). Hard mixes can be expected to set up stress conditions between the stone and mortar in joints because the thermal coefficient of mortar expansion is greater than that of stone. In paving installations, stress is often sufficient to break the bond between the stone and the substrate. Flexible mortars are not suitable for exterior work.

2.3 Pointing Mortar

2.3.1 Pointing mortar shall be composed of one part white portland cement, one part hydrated lime, and six parts white sand passing a #16 sieve.

2.4 Sealants and Backup Material (if Applicable)

2.4.1 Where specified (*state type or name of sealant*) shall be used for the pointing of joints. The backup material used with the sealant shall be (*identify material*).

2.5 Anchors, Dowels, Fastenings

2.5.1 The Travertine Contractor shall furnish and set all anchors shown on approved shop drawings unless otherwise specified. All anchors shall be fabricated from Type 304 or 316 stainless steel or other suitable nonferrous metal. Multipart anchors may contain metal other than stainless steel, provided such metal is not embedded in linkages in the travertine.

2.6 Stain Prevention

2.6.1 Where necessary, specify one or both of the following systems:

2.6.1.1 Damp-proof unexposed stone surfaces. Joint surfaces should be damp-proofed only to 1" (25 mm) of finished surface when using non-staining emulsion.

2.6.1.2 Damp-proof all concrete surfaces on which travertine will rest. Damp-proof adjacent concrete structure, haunches, etc.

2.7 Adjacent To Water

2.7.1 Travertine used in areas adjacent to water that is chemically purified should be tested to ensure that there is no reaction between the stone and the purification chemicals (see Exterior Horizontal Surfaces chapter for more information).

3.0 FABRICATION

3.1 Beds and Joints

3.1.1 Bed and joint width shall be determined by analysis of anticipated building movements and designed to accommodate such movements without inducing undue stresses in the stone panels or joint filler materials. Expansion joints shall be designed and located to accommodate larger movements.

3.2 Backs of Pieces

3.2.1 Backs of pieces shall be sawn or roughly dressed to approximately true planes. Back surfaces shall be free of any matter that may create staining

3.3 Moldings, Washes, and Drips

3.3.1 Moldings, washes, and drips shall be constant in profile throughout their entire length, in strict conformity with details shown on approved shop drawings. The finish quality on these surfaces shall match the finish quality of the flat surfaces on the building.

3.4 Back-Checking and Fitting to Structure or Frame

3.4.1 Stone coming in contact with structural work shall be back-checked as indicated on the approved shop drawings. Stones resting on structural work shall have beds shaped to fit the supports as required.

3.4.2 Maintain a minimum of 1" (25 mm) between stone backs and adjacent structure; however, many bolted connections will require more space – 2" (50 mm) may be preferable. Large-scale details should illustrate and determine these conditions.

3.5 Cutting for Anchoring, Supporting, and Lifting Devices

3.5.1 Holes and sinkages shall be cut in stones for all anchors, cramps, dowels, and other tieback and support devices per industry standard practice or approved shop drawings. However, additional anchor holes shall be drilled at job site by Travertine Contractor to facilitate alignment.

3.5.2 No holes or sinkages will be provided for Travertine Contractor's handling devices unless arrangement for this service is made by the Travertine Contractor with the Travertine Fabricator.

[NOTE: It is not recommended that lewis pins be used for stones less than 3½" (90 mm) thick.]

3.6 Cutting and Drilling for Other Trades

3.6.1 Any miscellaneous cutting and drilling of stone necessary to accommodate other trades will be done by the Travertine Fabricator only when necessary information is furnished in time to be shown on the shop drawings and details, and when work can be executed before fabrication. Cutting and fitting, due to job site conditions, will be the responsibility of the Travertine Contractor.

3.6.2 Incidental cutting such as for window frame clips, etc., which is normally not considered to be the responsibility of the Stone Supplier, will be provided only by arrangement by the General Contractor and Travertine Contractor with the Travertine Fabricator.

3.7 Carving and Models

3.7.1 All carving shall be done by skilled Stone Carvers in a correct and artistic manner, in strict accordance with the spirit and intent of the approved shop drawing, or from models furnished or approved by the Specifying Authority.

4.0 SHIPPING AND HANDLING

4.1 Packing and Loading

4.1.1 The cut travertine shall be carefully packed for transportation with exercise of all customary and reasonable precautions against damage in transit. All travertine under this contract shall be loaded and shipped in the sequence and quantities mutually agreed upon by the General Contractor, Travertine Contractor, and the Travertine Fabricator.

4.2 Site Storage

4.2.1 Receipt, storage, and protection of travertine prior to and during installation shall be the responsibility of the Travertine Contractor.

4.2.2 All travertine shall be received and unloaded at the site with all necessary care in handling to avoid damaging and soiling.

4.2.3 Stones shall be stored above the ground on non-staining skids made of cypress, white pine, poplar, or yellow pine without an excessive amount of resin. Chemically treated wood should not be used. DO NOT USE CHESTNUT, WALNUT, OAK, FIR, AND OTHER WOODS CONTAINING TANNIN. Completely dry travertine shall be covered with non-staining waterproof paper, clean canvas, or polyethylene.

5.0 INSTALLATION

5.1 General Installation

5.1.1 Installation shall be accomplished with competent, experienced Stone Setters, in accordance with the approved shop drawings.

5.1.2 All travertine pieces shall be identified with a unique piece number corresponding with the number on the shop drawings. Interchanging of numbered pieces is not permitted.

5.1.3 Travertine shall be free of any ice or frost at time of installation. Salt shall not be used for the purpose of melting ice, frost, or snow on the stone pieces.

5.1.4 Adequate protection measures shall be taken to ensure that exposed surfaces of the stone shall be kept free of mortar at all times.

5.2 Setting Mortar

5.2.1 All travertine shall be set accurately in strict accordance with the contract, approved shop drawings, and specifications. White portland cement with a low-alkali content is recommended.

5.2.2 When necessary, before setting in the wall, all stones shall be thoroughly cleaned on all exposed surfaces by washing with a fiber brush and soap powder, followed by a thorough rinsing with clear water.

5.2.3 All stone joint surfaces not thoroughly wet shall be saturated with clear water just prior to setting.

5.2.4 Except as otherwise specially noted, paving stone shall be set in full beds of mortar with all vertical joints flushed full. For vertical panels, completely fill all anchor, dowel, and similar holes, as well as first-course panels in traffic areas up to 36" (900 mm) of finished floor. All bed and vertical joints shall be 3/8" (9.5 mm) unless otherwise noted.

5.2.5 Plastic setting pads shall be placed under heavy stones, column drums, etc., in the same thickness as the joint, and in sufficient quantity to avoid squeezing mortar out. If anchor system requires lower stones to carry the weight of upper stone, then any heavy stones or projecting courses shall not be set until mortar in courses below has hardened sufficiently to avoid squeezing.

5.2.6 Joints can be tooled when initial set has occurred, or raked out 1" (25 mm) and pointed later. If pointed with sealant, the raked depth and sealant applications shall conform to manufacturer's instructions.

5.2.7 Projecting stones shall be securely propped or anchored until the wall above is set.

5.2.8 Only the ends of lugged sills and steps shall be embedded in mortar. Balance of joint shall be left open until finally pointed.

5.2.9 All cornice, copings, projecting belt courses, other projecting courses, steps, and platforms (in general, all stone areas either partially or totally horizontal) should be set with unfilled vertical joints. After setting, insert properly sized backup material or backer rod to proper depth, and gun in sealant.

5.2.10 In cold weather, International Masonry Industry All Weather Council recommendations for setting from 40ºF to 20ºF (4ºC to -6ºC) shall be followed, except that no additives shall be used in the setting mortar, and below 20ºF (-6ºC), all work shall be done in heated enclosures.

5.2.11 Individually set thin tile [nominal 3/8" (9.5 mm)] on vertical surfaces exceeding 8' (2.5 m) is not recommended.

5.3 Mortar Joints

5.3.1 Mortar joints shall be raked out to a depth of ½" to ¾" (12.5 to 20 mm). Apply pointing mortar in layers not exceeding 3/8" (9.5 mm) and allow each layer to get hard to the touch before the next layer is applied. Tool finished joints with a concave tool having a diameter approximately 1/8" (3 mm) greater than the joint width.

Care shall be taken to keep expansion joints free of mortar, which would compromise their function.

5.4 Anchorage

5.4.1 All travertine shall be anchored or doweled in accordance with the approved shop drawings.

5.4.2 To the furthest extent possible, all anchor preparations in the travertine units shall be shop-applied.

5.4.3 All anchorage devices and anchor hole/slot fillers shall be in accordance with ASTM C1242. Care must be taken to ensure that any holes capable of retaining water are filled after use to prevent water collection and freezing.

5.5 Sealant Joints

5.5.1 Where so specified, joints requiring sealant shall be first filled with a closed-cell ethafoam rope backer rod. The backer rod shall be installed to a depth that provides optimum sealant profile after tooling.

5.5.2 If recommended by the Sealant Manufacturer, primers shall be applied to the substrate surfaces according to the manufacturer's directions prior to application of the joint sealant.

5.6 Expansion Joints

5.6.1 Joints shall be adequate to allow for thermal and structural differential movement. Filler material for these joints shall be non-staining.

5.6.2 It is not the intent of this specification to make control or expansion-joint recommendations for a specific project. The Specifying Authority must specify expansion and control joints and show locations and details on the drawings.

5.7 Caulking

5.7.1 Where so specified, joints shall be pointed with the sealant(s) specified in Section 2.4, after first installing the specified backup material and applying a primer if required, all in strict accordance with the printed instructions of the Sealant Manufacturer.

5.7.2 All sealants shall be tooled to ensure maximum adhesion to the contact surfaces.

5.8 Weep Tubes

5.8.1 Plastic or other types of weep tubes shall be placed in joints where moisture may accumulate within the wall, such as at the base of a cavity, continuous angles, flashing, etc., or as shown on architectural drawings.

6.0 CLEANING AND PROTECTION

6.1 Cleaning

6.1.1 The stone shall be washed with fiber brushes, mild soap powder or detergent, and clean water, or approved mechanical cleaning process.

6.1.2 Special consideration and protection shall be provided when brickwork or other masonry is cleaned above the travertine. Strong acid compounds used for cleaning brick will burn and discolor the travertine.

6.1.3 Use of sandblasting, wire brushes, or acids will only be permitted under special circumstances approved by Specifying Authority (architect, engineer, contracting officer, etc.).

6.2 Protection of Finished Work

6.2.1 During construction, tops of walls shall be carefully covered at night and especially during any precipitation or other inclement weather.

6.2.2 At all times, walls shall be adequately protected from droppings.

6.2.3 Whenever necessary, substantial wooden covering shall be placed to protect the stonework. Non-staining building paper or membrane shall be used under the wood. Maintain all covering until removed to permit the final cleaning of the stonework.

6.2.4 The Travertine Contractor will outline the needs for protection in writing to the General Contractor. The General Contractor shall be responsible for protection of the finished work until all trades are finished. This responsibility includes the stone cleaning costs prior to the final inspection.

6.2.5 Finishes commonly available are defined as follows:

6.2.5.1 Polished: Glossy.

6.2.5.2 Honed: Dull sheen.

6.2.5.3 Smooth: Smooth with minimum of surface interruption.

6.2.5.4 Plucked: Rough texture.

6.2.5.5 Machine Tooled: Parallel grooves cut in the stone. Available with 4, 6, or 8 grooves to the inch.

6.2.5.6 Tumbled: A weathered, aging finish.

6.2.5.7 Diamond Gang Sawn: Comparatively smooth surface with some parallel markings and scratches.

PRODUCT DESCRIPTION – Travertine

1.0 GEOLOGICAL CLASSIFICATION

1.1 Travertine is a varietal name for a kind limestone formed under special conditions of deposition. It is classed as chemical sedimentary rock and is deposited as precipitates in terrestrial (land) environments, as opposed to limestone, which is the cemented or recrystallized accumulation of calcareous organic debris deposited on the sea bottom, then compacted and later cemented. Some marine limestone textures are altered to have travertine-like voids before or after deposition and cementation. Marine limestone may or may not have fossils visible to the unaided eye. If not, then fossil marine microorganisms are probably present in great abundance together with some spores and pollen from terrestrial plants, algae, and fungi. Because marine limestone fossils are chitinous (the material of fingernails), they are preserved even if the limestone is recrystallized, which obliterates calcareous fossils.

1.2 Travertine is valuable in the dimension stone industry because of its striking textural character—very porous, often cavernous on a scale of inches, with a diverse palette of light hues and soft earth tones. In part because it is soft and easily worked, travertine has been a favorite building and decorative stone from preclassical times to the present. While void spaces are distinctive features of travertine, so too is the character of the stone itself. Void spaces are sometimes filled with waterproof materials, especially if used on floors to avoid snagging high heel shoes.

1.3 The etymology of its name is from the Italian word "travertino," derived from the ancient Roman name Tibur (now Tivoli), a town near Rome where travertine forms an extensive deposit that has been worked for many centuries. At Tivoli, travertine formed around hot springs heated by volcanic activity associated with Mt. Vesuvius.

1.4 In a strict sense, travertine is most often[1] considered a precipitate of calcium carbonate[2] from saturated, generally warm or hot, fresh, mineral-laden waters in and around the mouth of conducting fractures or conduits. One of several alternative modes of formation can be wind-agitated pools or ponds saturated with calcium carbonate, thus causing precipitates to form in concretionary deposits found with true, Tivoli-type travertine. Although travertine often contains plant fragments or fossils of land animals such as rodents or deer, it will not have marine fossils as do other travertine-like limestones or marine limestone.

1.5 Limestone is developed by compaction and cementation of debris from sea shells, algae, and other marine organisms that extract calcium carbonate from seawater. Subsequent geologic forces can act upon these formations to produce travertine-like limestone with abundant voids and high porosity that mimics travertine texture. These are marketed as travertine, although they are not the chemical precipitate, Tivoli-type travertine formed around springs. Postdepositional and post-cementation dissolution, mineral replacement, and other chemical changes[3] are called "diagenesis," and include weathering effects or

[1] The American Geological Institute definition of travertine allows inclusion of onyx and other travertine-like limestone.

[2] The mineral calcite ($CaCO_3$) has several *metastable* relatives, minerals that exist for only a short time and then revert to the most stable form of $CaCO_3$, which is calcite. One such example is *aragonite,* still $CaCO_3$, but with a slightly different physical geometry of atoms in its molecules than the more stable molecular geometry of calcite.

[3] Diagenetic chemical changes can include introduction of other minerals by invading solutions. Some of these minerals are chert (hydrous silica), the sulfide minerals of iron, lead, zinc, and strontium; pyrite (FeS_2), galena (PbS), sphalerite (ZnS), and celestite ($SrSO_4$).

metamorphic changes caused by pressure, heat, or time at depth together with regional crustal movement.

1.6 Diagenetically altered limestone may have high porosity, often up to 40% or more. The stone itself may have been formed in very shallow waters like tidal flats or near-shore reefs where deposits are exposed at low tide to dry in hot sunlight. That drying tends to preserve and enhance high porosity, or at least provide a well-cemented framework that persists even though the void space may be filled with carbonate muds (from tidal flats) or land-derived mud. Fillings may be washed out later or dissolved, leaving voids. This kind of limestone is sometimes included in the travertine category because its texture having voids resembles that of travertine. However, the mode and environment of formation is entirely different than the terrestrial, Tivoli-type travertine.

1.7 Other limestone that ends up with an open travertine texture may be formed by secondary solution of the calcium carbonate at great depth—even in formerly dense limestone of low porosity. In this case, void space is again developed by dissolution due to the influx of slightly acidic water that differentially dissolves some of the calcium carbonate.

1.8 A good example is Upper Cretaceous-age (≈70-100 million years old) travertine limestone from central Texas. This limestone was a shallow-water deposit containing abundant large marine clams and coiled snails. The shells filled with carbonate mud from marine grasses, and the surrounding matrix and filling was then cemented; later and at depth, the calcium carbonate shell was dissolved, leaving a "*steinkern*" (derived from the German, literally meaning "stone nut") or casting of the internal shape of the shell cavity plus void space formerly occupied by shells. Differential solution occurs because these large, heavy mollusk shells are composed of the mineral aragonite, a reactive, unstable form of calcite easily dissolved or converted to calcite over time. Other voids can also be traced to dissolution of aragonite shell debris in central Texas travertine.

1.9 Clay Balls. Not uncommon, and usually undesirable, clay balls are occasionally found in travertine. These are lumps of clay tumbled by currents until more or less round, and deposited in the sedimentation of the limestone. Clay balls are generally not cemented, will not polish, are soft, and wash out.

1.10 Tufa. A stone often mistaken for travertine is calcareous tufa. Tufa is a very porous, punky stone that precipitates around the vents of freshwater springs saturated with calcium carbonate that occur on the bottoms of salty, landlocked lakes such as Mono Lake in California and the Dead Sea in Israel.

1.10.1 Calcareous precipitation from fresh-water occurs when CO_3-laden springwater mixes with the saturated salt water of the lake. Often precipitation is aided by the presence of algal and fungal activity in or around the lake bottom springs. Tufa deposits can take the form of mounds or spires, giving them, if the lake level is low enough that they can be seen, a crenellated, castle-like appearance with multiple hollow spires that springwater flowed up through. Spires can be 10 feet high. Tufa is usually so soft, spongy, irregular, and badly colored that it generally does not make a usable dimension stone. When occasional, rare deposits are usable, they are marketed as travertine.

1.11 Tuff. Another stone, tuff, is frequently confused with tufa. Tuff is a pyroclastic deposit (volcanic ash) is not the same as, nor related to, Tufa.

1.11.1 The primary composition of travertine-type stones, except the volcanic tuff, is calcite or calcium carbonate ($CaCO_3$), with a few having the mineralogical variation of aragonite. When water precipitates one soluble mineral, it may also precipitate other minerals or even replace calcium carbonate if the chemical building blocks are available. Thus most travertine may contain some hydrous silica (chert or flint) or any other soluble salt, other minerals, and occasional terrigenous grains of clastic sediments—clays, quartz silt, or even a few grains of quartz sand.

2.0 COLOR AND VEINING

2.1 As with most sedimentary rocks, travertine colors range from light buff through tan to brown and into shades of red, due to varying amounts of iron oxides in the stone. Many rocks are colored by iron staining that leached out of rock units above or superimposed on top of the travertine or limestone deposit.

2.2 Other colors are due to inclusion of minerals other than iron and variations in colors of banding that reflect changes in the volume or chemistry of invading fluids, changes in conduits, and alternating wet and dry climatic cycles.

3.0 TEXTURE

3.1 The term "texture," as applied to travertine, means size, degree of uniformity, and arrangement of constituent materials.

4.0 FINISHES

4.1 Travertine surfaces may be finished in a number of ways. Typical finishes are:

4.1.1 Polished: A glossy surface which brings out the full color and character of the travertine.

4.1.2 Honed: A satin smooth surface with little or no gloss.

4.1.3 Smooth: An even, flat, level finish, with no surface bumps or roughness.

4.1.4 Sawn: A comparatively rough surface; can be chat, shot, sand, or diamond sawn.

4.1.5 Filled or Unfilled. Travertine for horizontal applications is usually filled with a cementitious fill or an epoxy fill similar in color to the background color of the travertine.

5.0 THICKNESS

5.1 Standard thicknesses for travertine are generally ¾", 1¼", 2", and 2-3/8" (20, 30, 50, and 60 mm). The recommended thicknesses vary depending on the type of travertine used.

5.2 Cutting can be made to exact metric measurements through conversion of U.S. Conventional System values to SI International System equivalents. Note that as travertine, like all other natural stone, is cut thinner, its tensile strength diminishes.

6.0 SIZES

6.1 Travertine is a product of nature with many varieties available, each possessing varying characteristics. Little can be done to alter the condition in which nature presents these varieties to us. Therefore, size may become a limiting factor to consider in the selection of a particular travertine.

6.2 NSI Members should be consulted for specific size information for a particular stone and its desired use. A jointing scheme that permits the use of smaller sizes of travertine may greatly facilitate selection and delivery. NSI Member/Supplier should assist in the final scheme approval.

7.0 PRODUCT SAMPLING

7.1 Travertine is formed by nature; thus, there are variations in the tonal qualities of the stones. However, it is these natural variations that make travertine unique, valuable, and highly desirable. Because of these variations, selection of a travertine should never be made on the basis of one sample only. It is recommended that selection be based on viewing sufficient samples to show the general range of color of the desired stone. NSI Members can provide these range samples.

8.0 PROPER USAGE TIPS

8.1 Recommendation for commercial floors:

8.1.1 Minimum ¾" (20 mm) thickness.

8.1.2 A honed finish.

8.1.3 A minimum hardness value of 10 as measured by ASTM C241/C1353.

8.2 Avoid the use of gypsum or molding plaster setting spots for the installation of exterior stone.

9.0 TOLERANCES

9.1 Because of the many variations in types of travertine, it is recommended that the Travertine Quarrier or Fabricator be contacted regarding size and thickness availability. Tolerances for fabrication and installation are the same as for marble dimension stones.

10.0 CUT TYPES

10.1 Due to the bedding planes inherent in most travertine, there are two ways to cut the material that will give dramatically different patterns and color ranges:

10.1.1 Vein Cut: Vein-cut travertine is cut against the bedding planes, exposing the edge of the formation and giving a very linear pattern.

10.1.2 Fleuri Cut: Sometimes called "cross cut," the fleuri cut is parallel to the bedding plane, exposing a "flowery," random pattern. Although the stone is strong when cut in this method, use in high-traffic paving areas may be problematic. Holes may appear after installation due to thin wall cavities at or near the exposed surface of the stone. These cavity holes may open because of heavy foot traffic. It is acceptable practice to fill holes that appear after installation.

11.0 FILLING OF TRAVERTINE

11.1 Travertine may be obtained with its normal voids unfilled or filled. Although some finish travertine floors by grinding in place after installation, this practice is less desirable than filling by a Stone Finisher in his shop under controlled conditions.

11.2 Filler. Common materials used for filling are natural (gray colored) or tinted portland cement, and clear or colored epoxy or polyester resins. Unless otherwise specified, matching colored portland cement is used as filler.

TECHNICAL DATA – Travertine

1.0 PROPERTIES OF TRAVERTINE DIMENSION STONE

1.1 In centuries past, relatively little importance was attached to the ultimate physical capabilities of most building materials. Rule of thumb was a common structural design criterion. As a result, the widely used materials of the day, for the most part natural rather than manmade materials, were seldom stressed to their ultimate limits.

1.2 In present-day construction, this is far from being true. Performance requirements are daily becoming more demanding. In striving for taller structures, greater spans, firmer foundations, thinner walls and floors, stronger frames, and generally more efficient buildings with more usable space, today's

Architects and Engineers must get the most out of the materials with which they work.

1.3 Travertine is a product of nature and not always subject to the rules of consistent behavior that may apply to manufactured building materials.

1.4 Physical property values of travertine may, however, be measured using the standard test methods approved by the Dimension Stone Committee C18 of the ASTM International. The NSI and Member companies are represented on the ASTM committee and are active in its technical work of establishing proper test methods and specifications consistent with the latest technology.

1.5 Final design should always be based on specific values for the stone variety ultimately to be installed. These values may be obtained from the Stone Supplier. All materials are not suitable for all uses. In order to avoid mistaken selections, tests for material values should be made prior to final material selection.

1.6 Physical Properties of Travertine
(This historical data and information is provided only as a guideline. Recommended minimums or maximums are established and provided by ASTM International.)*

Property	Range of Values
Compressive Strength (C170) lbs/in²	5,000 -10,500
Recommended (min): 5,000 (interior), 7,500 (exterior)	
Flexural Strength (C880) lbs/in²	600-1,500
Recommended (min): 500 (interior), 500 (exterior)	
Modulus of Elasticity (in millions) lbs/in²	2.0-15.0
Density, lb/ft^3 (C97)	140-165
Recommended (min): 144	
Modulus of Rupture (C99) lbs/in²	500-1,500
Recommended (min): 700 (interior), 700 (exterior)	
Absorption, by weight % (C97)	0.10-2.5
Recommended (max): 2.5	
Abrasion Resistance (C241) (H_a)	7-25
Recommended (min): 10	

* Test methods described in current ASTM standards.

2.0 STRENGTH (ASTM C99, C170, C880)

2.1 Values for modulus of rupture, compressive strength, and flexural strength are ascertained by testing specimens of travertine under laboratory conditions until they fail.

2.2 Size and finish of test samples required by the standard ASTM test methods may not reflect the actual performance of stone when used in lesser thicknesses or with other finishes that affect strength. For this reason, the Modulus of Rupture (C99) test is recommended when the stone to be used will be two or more inches thick. The Flexural Strength (C880) test is recommended when the stone thickness will be less than two inches.

2.3 The strength of a travertine is a measure of its ability to resist stresses. The two "cuts" of travertine will exhibit different strength characteristics and must be tested for the type of cut being used on the project. Travertine's strength depends on several factors, such as the rift and cleavage of the calcite crystals, the degree of cementation, the interlocking of the calcite crystals, and the nature of any cementing materials present.

3.0 FIRE RESISTANCE

3.1 Stone is not combustible according to underwriters' ratings, and therefore is considered a fire-resistant material. Because of its thermal conductivity, heat transfer is fairly rapid. Most stone is not considered a highly rated thermal insulator.

3.2 Underwriters' fire-resistance ratings evaluate whether or not a material will burn, as well as how long it will keep surrounding combustible materials from reaching temperatures which will cause them to ignite. Methods of estimating fire-resistance periods of masonry walls and partitions utilizing component laminae are given in "Fire Resistance Classifications of Building Construction," BMS92, National Bureau of Standards.

4.0 ABRASION RESISTANCE (ASTM C241/C1353)

4.1 Abrasion resistance is a property of stone that should be tested per ASTM C241/C1353 to provide an indication of the stone's wearing qualities when exposed to foot traffic.

4.2 The hardness and uniform wearing qualities of most varieties of travertine make them extremely desirable and economically practical for floors and stairs. Varieties with an abrasive hardness (H_a/I_w) of 10 or more as measured by ASTM C241/C1353 tests are recommended for use as flooring exposed to normal foot traffic. A minimum abrasive hardness of 12 is recommended for commercial floors, stair treads, and platforms subject to heavy foot traffic. If floors are constructed with two or more stone varieties, the H_a/I_w values of the stones must not differ by more than 5 or the floor surface will not wear evenly and uniformly.

5.0 FACTORS AFFECTING PROPERTIES

5.1 The ultimate test of a building material is its ability to have and maintain the necessary structural strength, as well as beauty of appearance and low cost of maintenance, over the useful life of the structure. Experience has proven that stone meets this test as few other building materials can. Studies have shown that the durability of most stones is little affected by cycles of weather. This is because most have a low rate of moisture absorption.

5.2 Exterior travertine paving is not recommended for environments where deicing chemicals may be used to melt ice and snow, because these chemicals will damage most travertine.

6.0 SAFETY FACTORS

6.1 Good engineering practice requires that allowable design stress must provide a margin of safety in any structural element. As a necessary precaution against such conditions as wind, ice, snow, impact, temperature changes, and imperfect workmanship, these allowable stresses must be smaller than those which produce failure.

6.2 Within the accepted limits of safe design practice, the closer the allowable load is to the ultimate failure load, the more efficient is the use of the material and the less the cost of the construction.

6.3 Contemporary building design does not usually employ stone as part of the structural frame, but rather as an independent unit, a curtain wall, or veneer. Therefore, the primary concern in such cases is with wind or seismic loads, and a safety factor of 8.0 is recommended. Where the stone is to be subjected to concentrated loading, such as stair treads or lintels supported only at the ends, a factor of 10.0 should be used. These safety factors may be adjusted using sound engineering principles and judgment.

6.4 As buildings become taller and individual stone slab veneers becomes larger in area, the lateral forces due to wind loads must be considered. Wind tunnel tests are often used on major structures to determine wind dynamics and force magnitude. Reinforcement is sometimes necessary for large-dimension slab veneer in critical areas.

7.0 SEISMIC CONSIDERATIONS

7.1 Seismic considerations generally require that low buildings be stiff, and that tall buildings be relatively flexible. Design of connections must account for seismically induced horizontal loading. Local building codes vary and must always be checked to determine specific requirements for each area. The National Bureau of Standards has published two documents on the topic: "Earthquake Resistant Masonry Construction," NBS Science Series 106; and "Abnormal Loading on Buildings and Progressive Collapse: An Annotated Bibliography," NBS Science Series 67. The U.S. Army Corps of Engineers has also published TM 5-809-10, "Seismic Design for Buildings."

8.0 EFFLORESCENCE AND STAINING

8.1 Efflorescence is a salt deposit, usually white in color that occasionally appears on exterior surfaces of masonry walls. The efflorescence-producing salts found in masonry are usually sulfates of sodium, potassium, magnesium, calcium, and iron. Salts which are chlorides of sodium, calcium, and potassium will sometimes appear, but they are so highly soluble in water that they will be washed off by rain.

8.2 The water-soluble salts causing efflorescence come from other materials in the wall. The salts exist in small amounts and are leached to the surface by water percolating through the walls.

8.3 The most feasible means of prevention is to stop the entrance of large amounts of water. Absorption from the face will not cause efflorescence unless there are open joints.

8.4 However, some of the salt crystals may form in the pores near the surface. Crystal growth (recrystallization) in the pores can put stress on the walls of the pores and cause the stone to flake off. If the conditions bringing about this action persist, scaling may continue and flake off one layer after another. For this to happen, large amounts of water must enter the wall and must contain large amounts of salts.

8.5 Avoid contact between soil and stone. Damp-proofing treatments of either a bituminous or cementitious nature may be used as a barrier to the ground water or construction moisture causing these stains.

HORIZONTAL SURFACES

1. DESIGN CRITERIA

1.1. STONE SELECTION

1.1.1. STONE PRODUCT DEFINITIONS

1.1.1.1. TILE: A stone tile is a thin, flat piece of natural stone used as finishing material, with a thickness ranging from ¼" to ⅝" (6 to 16 mm) inclusive and having no dimension greater than 2' 0" (610 mm). Tiles are normally supplied in typical sizes, with atypical pieces being field cut to fit, although in some cases when detailed shop drawings are prepared, factory cutting of atypical pieces can occur.

1.1.1.2. CUT-TO SIZE: Cut-to-size stone products, also referred to as "slab stock" stone products, are custom fabricated pieces of natural stone. Fabrication of these products normally occurs in a factory setting, where each piece is custom fabricated to fit, but partial fabrication may also occur in the field at the time of installation.

1.1.1.3. Natural stone tiles and cut-to-size products may have different fabrication tolerances due to their different methods of fabrication. Refer to the specific stone description chapter for fabrication tolerances.

1.1.1.4. LABOR ASSIGNMENT: The successful installation of both dimension stone and stone tile is dependent upon the experience and craft knowledge of the firm contracted to install the stone. The Natural Stone Institute endorses the use of NSI Accredited Natural Stone companies. See www.naturalstoneinstitute.org for a directory of installation companies accredited by the NSI.

1.1.2. SAMPLES: The Dimension Stone Contractor shall furnish samples of the various dimension stones to be used. Samples shall indicate the extremes of color, veining, texture, and marking that the stone supplied to the project will have. Samples must be reviewed as a complete set and approved or rejected in their entirety, without stipulation.

1.1.2.1. Pending the scope of the installation and the variability of the stone product, a mockup of a specified size and extent, may be required to adequately demonstrate the range of the material's color and character. Mockups are intended to demonstrate the full range of color tones and natural characteristics of the stone to be expected across the entire project yet condensed into the much smaller surface area of the mockup. Therefore, the effects of the variation and characteristics of the stone will be more concentrated, and appear more extreme, than the actual project since the actual project will have less frequent occurrences of these elements.

1.1.2.2. Pending the scope of the installation and the variability of the stone product, a "dry-lay" may be required to adequately demonstrate the range of the material's color character, and finish, with the advantage of predetermining the actual position and orientation of each stone panel. The dry-lay allows the design professional to see the actual blend of the finished floor, and also allows the arrangement of pieces to be adjusted per his/her desires. Since each stone panel is dedicated to a specific location, crating and handling must be skillfully executed to prevent damage as there may or may not be a suitable replacement available for a given stone. A dry lay is generally considered to be a wise investment for decorative interior office lobby, floor and wall projects. It provides a beneficial team building experience and the formal approval of all stone prior to shipment helps eliminate jobsite anxiety and rejections.

1.1.2.3. Inspection of supplied material to evaluate compliance with approved samples/mockups/dry-lays shall be done at a viewing distance of not less than 6'-0" (2 m), with natural lighting, and an angle perpendicular to the face of the stone.

1.1.3. THICKNESS Suggested minimum thicknesses for Horizontal stone surfaces:

1.1.3.1. Exterior Stone Pavers, Pedestrian Traffic: 1¼" (30 mm).

1.1.3.2. Exterior Stone Pavers, Vehicular Traffic: Is best determined by engineering analysis, but is generally 3" (75 mm) or thicker.

1.1.3.3. Interior Residential Stone Flooring: ⅜" (10 mm).

1.1.3.4. Interior Commercial Flooring, light duty (e.g., retail shops, tenant areas of office buildings): ⅜" (10 mm).

1.1.3.5. Interior Commercial Flooring, Heavy Duty/High Traffic: ¾", or 1¼" (20 or 30 mm) pending stone variety selection and level of traffic loading.

1.1.3.6. Note: Large stone unit sizes and/or specific loading/traffic requirements may dictate the use of greater thicknesses than those listed above.

1.1.3.7. Note: Regardless of the stone thickness, loading as a result of building maintenance equipment oftentimes requires protection of the stonework to prevent damage from the equipment.

1.1.4. SHOP DRAWINGS: Detailed, scale shop drawings which include elevations, plan views and section details shall be provided by the stone contractor. Shop drawings shall address:

1.1.4.1. Stone Type and Finish
1.1.4.2. Stone sizes, thicknesses, joinery and patterning
1.1.4.3. Reference to building column grid lines
1.1.4.4. Vein and Rift directions, if appropriate
1.1.4.5. Joint sizes and treatments
1.1.4.5.1. Typical Joints
1.1.4.5.2. Expansion Joints
1.1.4.5.3. Movement Joints

1.1.4.6. Identification of mortar, adhesive, and grout types.

1.1.4.7. Relationship to adjacent building materials, cavities, and placement tolerances of support systems.

1.1.4.8. Details of mechanical anchorage, including anchor devices and metallurgy of same.

1.1.5. FABRICATION: Stone paving units are precut and prefinished to dimensions specified on shop drawings and are usually delivered to the job site ready to install.

1.1.6. CARVING: All carving shall be performed by stone carvers in strict accordance with approved full-size details or models, with allowance for documented industry tolerances. Architectural drawings shall show approximate depth and relief of carving. Carving shall be left as it comes from the tool, unless otherwise specified.

1.1.7. FIELD REPAIR: Shop fabrication is generally preferred over field fabrication as quality control is more easily monitored in the controlled environment of a shop setting. When field fabrication is necessary, it shall be accomplished by skilled, experienced mechanics. Conditions or occurrences that may exist which would necessitate field fabrication:

1.1.7.1. Inability to verify field dimensions or conditions prior to stone being in transit to the installation site.

1.1.7.2. Requirement to coordinate with related components that are being installed concurrently with the stone.

1.1.7.3. Changes in the scope or design of the installation.

1.1.7.4. Repair or patching is sometimes necessary due to damage of material either on-site or in transit. By allowing these repairs to be made on-site, progress of the job can be maintained, thus aiding the successful completion of the work. Repairs should not detract from the desired appearance or strength of the completed installation. The means and methods or examples should be discussed and/or demonstrated for approval prior to performing the repair.

1.1.8. STONE COLORS and VARIETIES: Pending the material successfully meeting the specified performance requirements, most of the commercially available varieties are suitable provided they meet or exceed the necessary performance specifications of the project.

1.1.9. SIZES and THICKNESSES may need to be determined by engineering analyses. The following properties should be considered when determining size and thickness of stone paving units:

1.1.9.1. Flexural Strength (Ref: ASTM C880) of the stone

1.1.9.2. The unsupported span or anticipated deformation of the bedding system.

1.1.9.3. The anticipated loads.

1.1.9.4. Stone thickness tolerances.

1.1.9.5. Size and availability limitations of stone blocks and/or slabs

1.1.9.6. Compatibility of the chemical composition of setting bed and the stone material's reaction to the chosen setting bed materials. (Pre-construction testing for compatibility is recommended).

1.1.9.7. Factors of Safety

1.1.10. STONE FINISHES

1.1.10.1. Exterior stone pavements shall have textured surfaces such as flamed (a.k.a. "thermal"), sanded, bush-hammered, cleft, or other suitably textured finishes.

1.1.10.2. Interior stone flooring finishes may include honed, polished, sanded, flamed (a.k.a. "thermal"), sawn, sanded, and natural cleft, and other finishes.

1.1.10.3. Many proprietary finishes are offered from suppliers which may be suitable but are not included in the above, generic lists.

1.2. TECHNICAL DATA

1.2.1. PHYSICAL PROPERTY VALUES. Final design should always be based on the specific property values of the stone to be used. These values may be obtained from the Stone Supplier. When current (≤3 years, per ASTM C1799) reliable physical property data is not available from the supplier, re-testing of the stone should be considered.

1.2.2. Each stone variety used for exterior stone paving should conform to the applicable ASTM standard specification and the physical requirements contained therein. The specification for each stone type follows:

1.2.2.1. Granite: ASTM C615, Standard Specification for Granite Dimension Stone

1.2.2.2. Limestone: ASTM C568, Standard Specification for Limestone Dimension Stone

1.2.2.3. Marble: ASTM C503, Standard Specification for Marble Dimension Stone

1.2.2.4. Onyx: No ASTM Standard exists at this time

1.2.2.5. Quartz-Based Stone: ASTM C616, Standard Specification for Quartz-Based Dimension Stone

1.2.2.6. Serpentine: ASTM C1526, Standard Specification for Serpentine Dimension Stone

1.2.2.7. Slate: ASTM C629, Standard Specification for Slate Dimension Stone

1.2.2.8. Soapstone: No ASTM Standard exists at this time

1.2.2.9. Travertine: ASTM C1527, Standard Specification for Travertine Dimension Stone

1.3. ABRASION RESISTANCE

Class of usage establishes the minimum abrasion resistance that a stone requires to withstand the foot traffic requirements of the project. This is determined according to the ASTM C241 or C1353 test methods for abrasion resistance and is reported as H_a when tested per ASTM C241 or I_w when tested per ASTM C1353. The two scales correlate well in the range of values contained within this section and are considered to be interchangeable. Extremely hard stone varieties will produce vastly different values between the two test methods, but this is insignificant since the requirements of this section will easily be satisfied. There are three recognized classes of usage for interior stone flooring, plus additional classifications for thresholds, steps, and exterior surfaces:

1.3.1. Light Traffic class is reserved for interior residential use where there is relatively little traffic and/or shoes are not always worn. Stone must have a minimum H_a or I_w of 6.0.

1.3.2. Moderate Traffic class is reserved for residential entranceways and small commercial installations where pedestrian traffic is less than 50 persons per minute. Stone must have a minimum H_a or I_w of 7.0

1.3.3. Heavy Traffic class is reserved for commercial installations (banks, shopping malls, train or bus stations, etc.) where pedestrian traffic is greater than 50 persons per minute. Minimum H_a or I_w is 10.0 for general areas, increasing to 12.0 for elevator lobbies, halls, and other areas of traffic concentration.

1.3.3.1. Consider higher abrasion resistance than listed above for those areas immediately accessible from outdoors. Solid contaminants (grit) that collects on the shoes of pedestrians will be carried into the interior walking surface and act as an abrasive.

1.3.4. Exterior paving should have a minimum H_a or I_w of 12.0.

1.3.5. Thresholds: H_a or I_w of the varieties selected should be a minimum of 12.0.

1.3.6. Stairs: Thresholds: H_a or I_w of the varieties selected should be a minimum of 12.0. Higher abrasion resistance should be considered for stairs that experience abrasive grits from streets or snowmelting applications.

1.3.7. These classifications are for the stone's abrasion resistance only. The stone's finish (polished, honed, thermal, etc.) will wear with traffic. Polished finish on stones with low abrasion indices (generally ≤ 20.0, although exceptions exist) are not suitable for most moderate and any heavy-traffic areas as the gloss will be reduced by the abrasion of the foot traffic. Stone with high abrasion resistance will generally maintain a polished surface in foot traffic areas. Stones with lesser abrasive indices are likely to abrade in service, and generally perform better if supplied in honed finish. While a polished finish in softer stone varieties will be dulled by foot traffic, a honed finish on a soft stone will oftentimes become glossier due to foot traffic.

1.3.8. Limitations. If several varieties of stone are used together, the abrasive resistance (H_a or I_w) of the stones should be similar. Proper testing (ASTM C241 or ASTM C1353) should be performed on each stone variety. If the abrasion resistance of either stone is <20.0, then the difference in abrasion resistance between the stones shall be ≤5.0. This can be ignored when using stones with higher abrasion resistance indices (generally ≥20.0, although exceptions exist), since the resultant wear will generally be minimal.

1.4. FRICTION

Slips and falls may be caused by inadequate available friction or due to a sudden change in available friction. For example, a spilled beverage or other contaminant may reduce available friction in a given area. Because of this, the maintenance of a floor is an important factor in its ability to provide a safe walking surface. Local building codes normally take precedence over other regulatory agencies. Natural stone used for paving provides an adequate available static coefficient of friction for human ambulation when supplied with an appropriate finish and properly maintained. Proper maintenance includes prompt cleanup of spills and correcting other conditions that can cause a sudden reduction in a floor's static or dynamic coefficient of friction. Aftermarket products are available for application on natural stones to increase available friction if required. Such products must be applied and maintained according to the manufacturer's recommendations.

1.4.1. Testing of frictional properties to ascertain appropriate traction levels per ANSI 326.3 (American National Standard Test Method for Measuring Dynamic Coefficient of Friction of Hard Surface Flooring Materials) is recommended.

1.5. SUBSTRATES

1.5.1. DEFLECTION. Deflection must be limited in the substrate for installation of stone finishes. Stone thickness of less than ¾" (20 mm) is considered to contribute no flexural strength to the assembly, providing decorative and abrasion resistance properties only. Stone of ¾" (20 mm) or greater thickness may be considered to be part of the structural assembly provided its suitability has been verified by comprehensive engineering analysis.

1.5.2. CAST-IN-PLACE CONCRETE FLOORS. The substrate shall be designed for a total load deflection not exceeding L/360, as measured between control or expansion joints.

1.5.3. FRAME CONSTRUCTION. The subfloor areas over which stone finishes are to be installed must be designed to have a total load deflection not exceeding L/720.

1.5.3.1. The use of strongbacks, cross-bridging or other means of reinforcement is recommended to limit differential deflection between adjacent framing members.

1.5.4. Impact loading and rolling loads shall be considered when designing substrate floor assemblies.

1.5.5. Preloading the floor prior to installation may be required to lessen the effects of the deformation due to the dead load of the stone and other components.

1.5.6. MATERIAL WEIGHTS: For estimating purposes, mortar bed weight can be approximated as 0.75 lb per square foot per each 1/16" of thickness (2.3 kg/m² per each mm of thickness). Stone weight can be approximated as 1 lb per square foot per each 1/16" of thickness (3 kg/m² per each mm of thickness).

1.5.7. SELF-LEVELING UNDERLAYMENTS. Gypsum-based and self-leveling underlayments are not recommended for use with stone paving, except in conjunction with an approved primer and waterproofing or crack isolation membrane (See ANSI A118.10-118.12). If using this method, careful adherence to the manufacturer's recommended procedure is required.

1.6. JOINTS

Width of Joints between Stones. Joints between stones should be of sufficient width to ensure that the grout being used can be placed throughout the full depth of the stone and properly compacted within the joint.

1.6.1. Typical joint widths for stone installation:

1.6.1.1. EXTERIOR STONE PAVEMENT: Minimum ¼" (6 mm), preferably ⅜" (10 mm). Joints of ½" (12 mm) or larger are frequently required for large unit size installation.

1.6.1.2. INTERIOR STONE FLOORING INSTALLATION: Minimum 1/16"

(1.5 mm), preferably ⅛" (3 mm). Joints of ¼" (6 mm) or larger are frequently required for large unit size installation.

1.6.2. Joints of ½" to 1" (12 to 25 mm) are frequently required for installing stones with split, or "snapped" edges.

1.6.3. Stone units with "cleft" or other non-planar surface finishes generally require larger joints to minimize perceived lippage. Joint widths of ¾" or 1" (20 to 25 mm) are not uncommon with these material finishes.

1.6.4. An arris, or chamfer is commonly used on stone edges to reduce the vulnerability of chipping during handling and transport. Joints between stone units having an arris or chamfer will appear wider than the actual dimension when filled.

Installation of natural stone with tight joints is not recommended.

1.6.5. Where vertical surfaces meet horizontal paving, the joint should be filled with an elastomeric sealant in lieu of grout. These joints should be at least ⅜" (10 mm) in width and continue through the stone assembly to the substrate or backing (membranes may remain continuous). Follow the sealant manufacturer's recommendation to determine if primer or backer rod is required.

1.6.5.1. Installation sequencing is generally easier if the walls are installed first and the floor material abuts the wall face, although some designers prefer to have the horizontal surface extend under the vertical surface, for aesthetic reasons. In either case, protection of completed work must be provided.

1.6.6. EXPANSION AND MOVEMENT JOINTS: Expansion and/or movement joints are essential for the success of stone installations. Various methods require proper design and location of expansion joints as shown in "Method EJ171," from the Tile Council of North America Installation Handbook. Because of the limitless conditions and structural systems in which stone can be installed, the Specifying Authority shall show locations and details of expansion joints on project drawings.

1.6.6.1. FINAL DESIGN. It is not the intent of this manual to make movement and expansion joint recommendations for a specific project. The Architect must specify expansion and movement joints and show location and details on drawings.

1.6.6.2. Movement Joints are also required in fields of paving. Movement joints extend through the finish layer only and provide an interruption to the accumulation of shear stress resulting from differential in expansion between the finish layer and substrate layers of the paving assembly. Reference ANSI A108.01 section 3.7 and ANSI A108.02 section 4.4 for guidance on movement joint location and design.

1.6.6.3. Expansion, isolation, or construction joints in the substrate must continue through the entire stone installation assembly.

1.7. LIPPAGE

1.7.1. Tolerances for allowable lippage can be found in Chapter 22 on Tolerances.

1.7.2. Allowable lippage is an installation tolerance and is additive to the inherent warpage of the stone unit.

1.7.3. Industry lippage tolerances will not be attainable in heavily textured surfaces, including flamed coarse-grained stones, cleft, or water-jet finishes. In those installations, joint width should be increased to limit perceived lippage, and in some cases joints as wide as ¾" (20 mm) may be required.

1.7.4. Industry lippage tolerances may not be achievable with extremely large format stone pavers, in which case larger than typical joint widths are recommended to minimize perceived lippage.

2. RELATED MATERIALS

2.1. MEMBRANES

2.1.1. The use of membranes to improve system performance is common in the design of stone walking surface installations.

2.1.2. Comply with the membrane manufacturer's written instructions regarding the applicability and installation of the membrane product.

2.1.3. Common types of membranes and their intended contribution to the system performance are discussed below:

2.1.3.1. CLEAVAGE MEMBRANES: Cleavage membranes are used in thick-bed installations below a reinforced mortar bed to intentionally prevent the bond between the stone setting system and the substrate slab, allowing independent movement (free floating) of the stone and setting system.

2.1.3.2. CRACK ISOLATION MEMBRANES: Crack Isolation membranes are used to isolate the stone from minor in-plane cracking of the substrate surface in thin-set applications. Crack Isolation membranes are used in thin-set applications and can be sheet applied, trowel applied, or liquid applied.

2.1.3.3. UNCOUPLING MEMBRANES: Uncoupling membranes are sheet applied, and geometrically configured to provide a small airspace which accommodates lateral flexibility between the tile and the substrate, reducing the transfer of stresses to thin-set stone installation systems. Uncoupling membranes are most frequently used on wood frame support systems.

2.1.3.4. WATERPROOF MEMBRANES: Waterproof membranes are used to prevent the migration of liquid water. These membranes are most commonly liquid applied, although sheet products are available. Some waterproofing membranes also function as crack isolation membranes.

2.1.3.5. SOUND ATTENUATION MEMBRANES: Sound attenuation membranes are used to reduce audible transmission from one level to the level below in multi-story construction. These membranes are most commonly used in condominium and office buildings.

2.1.3.6. MEMBRANE SPECIFICATIONS: Specifications for various membranes can be found in ANSI A118:

2.1.3.6.1. A118.10 American National Standard Specifications for Load Bearing, Bonded, Waterproof Membranes for Thin-set Ceramic Tile and Dimension Stone Installation

2.1.3.6.2. A118.12 American National Standard Specifications for Crack Isolation Membranes for Thin-Set Ceramic Tile and Dimension Stone Installation

2.1.3.6.3. A118.13 American National Standard Specification for Bonded Sound Reduction Membranes for Thin-set Ceramic tile Installation

2.2. SURFACE SEALERS

2.2.1. Sealing the Face of the Stone: This section does not imply that sealing the face of the stone is a necessary practice. Application of sealers is a common practice in certain instances, such as when extremely high porosity stone is installed or when the stone floor is installed in a food or beverage service area. If any sealer coating is specified for any natural stone material, advice should be sought in detail from qualified sealer manufacturers, stone suppliers or installers (See Ch 3, pg. 3-5, section 5.10).

2.2.1.1. While commonly referred to as "sealers" the products used to treat stone surfaces are typically an "impregnating repellent" rather than a true sealer. These products, when properly applied, are designed to preserve the ability of the stone to transmit water vapor ("breathe").

2.2.2. MORTARS AND ADHESIVES Portland Cement Mortar: Portland cement mortar is a mixture of portland cement and washed sand, roughly in proportions of 1:3 (by volume) for floors. Hydrated lime may also be added in the mortar mixture up to ⅛ of the total volume. Additional additives, typically latex or acrylic, may be included in this mortar recipe. The stone is typically set with this mortar while the mortar bed is still in a plastic state.

2.2.2.1. Portland cement mortars may be reinforced with metal lath or welded wire mesh for thick set setting bed systems, especially when a slip sheet is used

2.2.2.2. Portland cement mortars are structurally strong, generally resistant to prolonged contact with water, and can be used to plumb and square surfaces installed by others.

2.2.3. DRY-PACK MORTAR: Contrary to its name, "Dry-Pack" mortar isn't actually dry, but rather it is simply under-hydrated compared to mortar mixes that are placed in a plastic state. The mortar is a mixture of portland cement and water, typically containing 1 part portland cement to 3 to 4 parts (by volume) clean washed sand.

2.2.3.1. A simple field test for the level of hydration of the dry-pack is that one should be able compact it into a "ball" in one's hand. If the mortar can be extruded between one's fingers when squeezing the ball of mortar, it is over-hydrated.

2.2.3.2. Despite being under-hydrated at the time of installation, dry-pack mortar will eventually achieve full cure due to reaction between the portland cement and water of opportunity.

2.2.3.3. Dry-Pack mortars are commonly used in exterior or other wet exposure areas. The absence of hydrated lime in this mixture eliminates the possibility of lime solids leaching to the surface.

2.2.4. THIN-SET MORTAR: Thin-set mortar, oftentimes called "dry-set mortar", is a mixture of portland cement (although a few are not cement-based) with sand and additives providing water retention. Thin-set mortars are also frequently used as a bond coat for setting stone.

2.2.4.1. Thin-set mortar is available as a factory-sanded mortar to which only water need be added. Cured thin set mortar is generally tolerant of prolonged contact with water but does not form a water barrier.

2.2.4.2. Thin-set mortar is not intended to be used in trueing or leveling the substrate surfaces as tile is being installed.

2.2.4.3. Specifications for various thin-set mortar varieties can be found in ASNI A118 as below:

2.2.4.3.1. A118.1: American National Standard Specifications for Dry-Set Cement Mortar

2.2.4.3.2. A118.3: American National Standard Specifications for Chemical Resistant, Water Cleanable Tile-Setting and -Grouting Epoxy and Water Cleanable Tile-Setting Epoxy Adhesive

2.2.4.3.3. A118.4: American National Standard Specifications for Modified Dry-Set Cement Mortar

2.2.4.3.4. A118.5: American National Standard Specifications for Chemical Resistant Furan Mortars and Grouts for Tile Installation

2.2.4.3.5. A118.8: American National Standard Specifications for Modified Epoxy Emulsion Mortar/Grout

2.2.4.3.6. A118.11: American National Standard Specifications for EGP (Exterior Glue Plywood) Latex-Portland Cement Mortar

2.2.4.3.7. A118.15: American National Standard Specifications for Improved Modified Dry-Set Cement Mortar

2.2.5. LIMESTONE (or other light-colored stones) SETTING MORTAR. Cement used in mortars for setting limestone and other light-colored stones shall be white portland cement per ASTM C150, or white masonry cement per ASTM C91. Nonstaining cement shall not contain more than 0.03% of water-soluble alkali when determined in accordance with procedure 15, calculation 16 of ASTM C91 or Federal Specification SS-C181C. However, if a large amount of standard cement has been used in the backup material and an effective water barrier has not been provided between the stone and the backup, the use of nonstaining cement may not prevent discoloration. Discoloration will reduce or disappear as the stone dries. The Indiana Limestone Institute recommends a 1:1:6 (portland: lime: sand) or Type N mortar be used with Indiana Limestone. At the present time, there are few masonry cement mortars produced labeled "nonstaining."

2.3. GROUTS

Cementitious grouts used as joint fillers can be sanded or unsanded as required. Sanded grouts tend to have greater strength and durability than unsanded grouts but can introduce the risk of surface scratching when installed in stone varieties that are softer than the aggregate in the grout and may be difficult or impossible to install in narrow width joints.

2.3.1. Pigments used in colored grouts can be difficult to blend in an even manner. This may cause color spotting and shading in the finished product.

2.3.2. Sanded portland cement grout is normally field-mixed in proportions of one part portland cement to one part clean, fine-graded sand (per ASTM C144) used for joints up to ¼" (6 mm) wide; 1:2 for joints up to ½" (12 mm) wide; and 1:3 for joints over ½" (12 mm) wide. Hydrated lime, not exceeding 1/5 part, may be added. Damp curing is preferable.

2.3.2.1. Sanded portland cement grout should be applied with caution over softer varieties of stone with honed or polished finishes because it may scratch the stone surface. Masking of the stone may be necessary.

2.3.3. Unsanded Grout portland cement grout is a commercially available mixture of portland cement and other ingredients, producing a water-resistant, dense, uniformly colored material, and is normally available in white or gray colors. Damp curing is advantageous for this material. Unsanded grout is commonly used for narrow joint widths (≤⅛" [≤3 mm]) or with soft varieties of stones with polished finish which can be scratched by the aggregate contained in a sanded grout.

2.3.4. Polymer Modified Portland Cement Grout is a mixture of any of the preceding grouts with polymer admixtures. The common polymer types are latex and acrylic. This grout is suitable for all installations subject to ordinary use and for most commercial installations. The use of polymer additives in portland cement grout increases the flexibility and reduces the permeability of the grout. Consult the grout and polymer manufacturers for specific instructions.

2.3.4.1. Specifications for polymer modified portland cement grouts can be found in A118.7 American National Standard Specifications for High Performance Cement Grouts for Tile Installation.

2.3.5. COLORING OF GROUTS: Many manufacturers offer grouting materials in colors. Architects and Designers find them pleasing for aesthetic reasons. Since some stones are more porous than others, test to determine the stability of the relationship between the colored joint filler and the stone before proceeding. Make certain pigments contained in the colored grout do not stain the stone.

2.4. JOINT SEALANTS

2.4.1. Unlike grouting, which is commonly specified in the stone specification, building sealants are normally covered in a separate specification section.

2.4.2. Sealants should comply with the requirements documented in ASTM C920 Standard Specification for Elastomeric Joint Sealants.

2.4.3. Common joint sealant chemistries include silicone, urethane, polysulfide and latex.

2.4.3.1. Urethane sealants are commonly preferred for horizontal stone surfaces because their typically higher modulus provides greater resistance to abrasion and penetration.

2.4.3.2. Strict adherence to the written instructions of sealant manufacturer is required.

2.4.3.3. Primers may be required for some sealant/substrate combinations. Refer to the manufacturer's requirements.

2.4.3.4. Some grades of silicone sealants are not recommended by their manufacturers for application on high calcite content materials. Consult the Sealant Manufacturer's technical recommendation before applying a given sealant to calcite materials.

2.4.3.5. All sealants shall be tooled to ensure proper adhesion to the contact surfaces.

2.4.3.6. Specialty sealants exist for specific in-service conditions. For example, mildew-resistant silicone sealants formulated with fungicide are often used for sealing interior joints in showers and around tubs, sinks, and plumbing fixtures. Severe service areas (patios, decks, traffic surfaces) should be caulked with materials having sufficient abrasion resistance. Consult the Sealant Manufacturer's technical recommendations for sealants in these areas.

2.4.3.7. Oil based organic sealants should not be used in conjunction with natural stone products because they may stain the stone.

2.4.3.8. Some sealants contain plasticizers which may wick into the stone perimeter and cause staining. If exemplar applications are not available to verify that the sealant does not contain staining plasticizers, testing per ASTM C1248 or ASTM D2203 is highly recommended.

2.4.4. BACKER RODS: Proper selection of the backer rod can greatly influence the performance of the joint sealant.

2.4.4.1. The backer rod performs three functions:

2.4.4.1.1. Controls the depth and shape of the sealant profile.

2.4.4.1.2. Provides support for the sealant when it is being compressed during tooling.

2.4.4.1.3. Acts as a bond breaker for the sealant to prevent three-sided adhesion. (Three-sided adhesion can result in failure of the sealant.)

2.4.4.2. Backer rods are available as either "open cell" or "closed cell" type. Closed cell backer rods are generally preferred as they do not absorb water like an open cell rod. Caution is necessary when installing closed cell rods to avoid puncturing the rods. A punctured rod, during periods of increasing temperature, will exhaust air as the air trapped within the rod expands. This can produce bubbles in the sealant or breach of the sealant joint.

2.4.4.3. Consult the Sealant, Waterproofing, and Restoration Institute guidelines for further information on proper joint sealant design, selection, and installation.

2.4.4.4. Consult sealant manufacturer to verify warranties are compliant with project specifications.

2.5. PLYWOOD SUBFLOORS

2.5.1. Refer to APA form No. E30W for plywood installation methods.

2.5.2. Plywood subfloors, including tongue-and-groove plywood, must be installed with a gap (generally ⅛ inch [3 mm]) between the sheets to allow for expansion. Stagger all seam. All subfloor seams should occur over framing, with underlayment seams occurring approximately 25% into the span between framing members. Plywood should have the strength axis running perpendicular to the joist.

2.5.3. Plywood shall be APA underlayment, C-C plugged or plugged crossband grade.

2.5.4. Inner surfaces must be clean. Remove all sawdust and dirt before applying adhesive.

2.5.5. Use a construction adhesive in accordance with manufacturer's written directions.

2.5.6. Allow adhesive to cure per manufacturer's recommendations before beginning stone installation.

2.5.7. Place screws 6" (150 mm) on center in both directions or per manufacturer's directions, whichever is less.

2.5.8. Align strength axis of both subfloor and underlayment layers.

2.5.9. A double layer (subfloor plus underlayment) is recommended for natural stone installations depending on joist spacing.

2.5.10. A crack suppression membrane is recommended when installing stone over frame construction.

2.5.11. Follow directions of manufacturers of all system components.

2.6. CEMENTITIOUS BACKER UNITS

2.6.1. Cementitious backer units are normally considered to be a bonding layer only, without providing a significant contribution to the flexural rigidity of the floor assembly.

2.6.2. Comply with manufacturer's instructions as to installation, bedding, taping, and fastening of cementitious backer units.

2.6.3. Specifications for cementitious backer units can be found in A118.9 American National Standard Specifications for Test Methods and Specifications for Cementitious Backer Units.

2.7. METAL EDGES AND TRANSITION STRIPS

2.7.1. Metal edges and/or transition strips of a different material are recommended required wherever stone flooring abuts a dissimilar flooring material.

2.7.2. Comply with manufacturer's instructions as to installation and fastening of preformed metal edge strips.

3. PAVEMENT SYSTEMS

3.1. EXTERIOR INSTALLATION METHODS:

3.1.1. MORTAR BED BONDED TO CONCRETE SUBSURFACE

3.1.1.1. Preparatory Work. Concrete slabs to receive bonded mortar beds, shall fulfill the following requirements:

3.1.1.2. Substrate slab shall be sloped toward drains to maintain a uniform depth of the mortar bed.

3.1.1.3. Concrete Slab shall have a textured surface similar to a fine broom finish and shall be free of curing compounds, dust, or any other foreign materials that would inhibit the bond of the mortar bed to the slab.

3.1.1.4. Concrete Slabs that require additional work to achieve these requirements such as grinding, feathering, patching or scarifying are considered as non-compliant with Industry Standards for stonework until remedial work has been completed by others.

3.1.1.5. METHOD. Stone paving should be installed in a full mortar bed consisting of one part portland cement and from three to four parts clean washed sand by volume. Minimum thickness of a mortar bed is 1¼" (30 mm). The recommended thickness is 2" (50 mm). Application of a bond coat of portland cement paste or other approved material (slurry) to both the paver and the substrate slab is required.

3.1.1.6. JOINTS. The joints may be pointed with suitable mortar or grout or filled with a resilient filler strip and approved sealant.

3.1.1.6.1. REINFORCING. Reinforcing of the mortar bed is recommended for beds of 2” (50 mm) depth or greater and shall be specified by the design professional.

3.1.2. MORTAR BED SEPARATED FROM CONCRETE SLAB. This method is used where the concrete slab may be problematic such as anticipated differential movement between the slab and the stone assembly. Other factors which favor selection of this installation method include:

3.1.2.1. Cracks in the slab that may transfer through a bonded system.

3.1.2.2. Contamination of the slab that may be impractical to remove.

3.1.2.3. Capillary moisture issues exist.

3.1.2.4. Where cold or control joints in slab do not align with stone grid modules.

3.1.2.5. Where an unbondable membrane exists.

3.1.2.6. In these situations, the slab will require remedial treatment commensurate with the severity of the problem. These options usually involve a membrane of some type and as such the mortar bed cannot be bonded to the substrate. As with the bonded mortar bed systems, slope and tolerance of the slab shall be such so as to maintain an even thickness of the bed. Movement joint requirements will also remain the same; however, the membrane may remain continuous.

3.1.2.7. The mortar bed must be reinforced in any unbonded installation system as specified by the design professional.

3.1.3. DRY-PACK MORTAR SYSTEMS

3.1.3.1. Contrary to its name, “Dry-Pack” mortar isn’t actually dry, but rather it is simply under-hydrated compared to mortar mixes that are placed in a plastic state.

3.1.3.2. The rough concrete substrate below the stone paving installation shall be installed by others. The concrete elevation shall be low enough to provide a minimum bed depth of 2” (50 mm) between the stone and the concrete. The concrete shall be allowed to cure for a minimum of 28 days.

3.1.3.3. A crack isolation membrane shall be placed over the concrete slab to prevent bonding of the dry-pack mortar to the concrete. (Six mil polyethylene sheeting has been found to be effective and economical for this purpose.)

3.1.3.4. The mortar bed to receive the stone paving shall consist of dry-pack mortar, containing 1 part Portland cement to approximately three to four parts clean washed sand by volume. A simple field test for the level of hydration of the dry-pack is that one should be able to compact it into a “ball” in one’s hand. If the mortar can be extruded between one’s fingers when squeezing the ball of mortar, it is over-hydrated.

3.1.3.5. The dry-pack mortar bed shall be reinforced by 2” x 2” (50 mm x 50 mm) 16 gauge (1.5 mm) galvanized welded wire mesh or as specified by the design authority. The placement of the mesh shall be within the center one-third of the mortar bed.

3.1.3.6. The mortar should be spread evenly over the substrate and screeded flat to the desired elevation, then loosened or “fluffed up” with a shallow toothed rake to assist in compression of the dry-pack when tamping the stone paver into position.

3.1.3.7. Before positioning a stone paver onto the mortar bed, the back of the paver should be sponged clean, then dried, after which it shall be parged with either thinset, or a thick layer of neat cement paste. This process is often referred to as “back buttering”.

3.1.3.8. Immediately before placing the stone paver on the mortar bed, the dry pack mortar should be sprinkled with water using a watering can with multiple small (≤ 1/16” [1.5 mm]) perforations.

3.1.3.9. The stone paver shall be placed on the mortar bed and tamped with a non-marring mallet until firmly bedded to the proper level of the floor. Several iterations of removal and replacement of the stone paver may be required to facilitate adding or removing bedding material before the proper level is achieved.

3.1.3.10. The specified joint width shall be maintained within documented tolerances between the paver units. Expansion and movement joints shall be included per industry recommendations in the pavement design.

3.1.3.11. Traffic shall be prevented from traversing the floor for a minimum of 24 hours after which it shall be grouted with the specified grout material. Grout shall not be over-hydrated, and the stiff grout mixture is to be compacted into the joints until level with the stone surface, then tooled to a slight concave profile.

3.1.4. PEDESTAL SUPPORTED SYSTEMS

3.1.4.1. PREPARATORY WORK: Adequate slope for surface drainage must be provided in rough concrete slab. Waterproofing and drainage system must be completed by other trades prior to installation of the stone.

3.1.4.2. Stone-supporting pedestals may be cast-in-place concrete, mortar, or plastic. Careful shimming is required to maintain the plane of the stone surface at the specified elevation and to prevent rocking of the finished stone paver. Commercially available threaded plastic shims are available to efficiently accomplish the elevation adjustment. (See illustration at the close of this section).

3.1.4.2.1. FLEXURAL STRENGTH. In a pedestal supported pavement system, the stone unit is a structural member that carries the live and dead loads back to the pedestals. Required thickness and pedestal spacing should be determined by a P.E. and must consider design loads, stone properties, intended traffic and appropriate safety factors. Atypical loading, such as maintenance vehicles, emergency vehicles, or performance structures must be considered when determining the anticipated loads.

3.1.4.3. OPEN JOINTS. The joints in this system are left open, allowing water to flow below the stone units to be collected and transported by the drainage system.

3.1.4.4. Advantages of this system include the elimination of the requirement to slope the stone surface to a drain, since the drainage is accomplished below the pedestrian deck, and the ease of removal and replacement of the pavers to facilitate maintenance or repair of the drainage system and waterproofing membranes below the stone pavers. An additional advantage is that because the joints are left open, the edges of the stone pavers are ventilated which prevents moisture from wicking into the stone edges (edge wicking of moisture can produce "picture framing" staining).

3.1.5. GRANULAR (SAND) BED METHOD

3.1.5.1. PREPARATORY WORK. Excavate unsuitable, unstable, or unconsolidated subgrade material and compact the area that has been cleared. Fill and level with densely graded crushed stone aggregate suitable for subbase material, or as otherwise directed by Specifying Authority.

3.1.5.2. METHOD. Place bedding course of sharp, normal weight limestone screening or concrete sand to a depth of approximately 1½" (40 mm) leveled to grade. Compact bedding course parallel to finish grade and tamp.

3.1.5.3. Stone pavers shall be laid upon the bedding course in successive courses. Every course of pavers shall be laid true and even and brought to grade by the use of non-marring mallets or similar tools, and shall be laid parallel to the base line. After the pavers are laid, the surface shall be swept and inspected. Cover surface with a wood board approximately 3" (75 mm) thick, 12" (300 mm) wide, and 6' (2 m) long, and tamp to intended position. Do all tamping immediately after laying pavers and do not allow tamper to come in contact with pavers. Broom sand into joints, tamping sand in joints to ensure full bedding around perimeter of stone.

3.1.5.3.1. Joints in granular bedded systems are typically "hand-tight" to prevent lateral migration of stone units. Some spalling at the stone surface can be expected as grains of sand get wedged into the nearly tight joints and exert pressure at the top edge of the stone as the pavers displace vertically under load.

3.2. INTERIOR INSTALLATION METHODS

3.2.1. TCNA HANDBOOK DETAILS. Since 2012, the Handbook for Ceramic, Glass, and Stone Tile Installation" by the Tile Council of North America has included a section dedicated to stone tile installation. The Natural Stone Institute has participated in the Tile Council of North America's (TCNA) development of this handbook and continues to participate in updates to the document. This document is reprinted every year, although the handbook committee meets only biennially, so substantial revisions are likely to appear only biennially. The details are not duplicated in the Natural Stone Institute publications. Contact the TCNA (www.tcnatile.com) or the Natural Stone Institute's Book Store to obtain a copy of the handbook.

3.2.2. MORTAR BED BONDED TO CONCRETE SUBFLOOR. This method is used where the concrete sub-floor is not subject to excessive movement or deflection (Recommended for installation of larger pieces [slabs]).

3.2.2.1. Concrete to receive bonded mortar beds or direct bond of stone shall fulfill the following requirements:

3.2.2.2. Slope if required, shall occur in the concrete substrate to maintain an even depth or thickness of the mortar bed and/or bond mortar.

3.2.2.3. Concrete shall have a textured surface similar to a fine broom finish and shall be free of curing of curing compounds or any other foreign materials that would inhibit the bond of the mortar bed or bond mortar to the concrete.

3.2.2.4. Undersides and edges of concrete slabs on grade shall have a suitable vapor barrier so as to prevent moisture intrusion into concrete.

3.2.2.5. Concrete that requires additional work to achieve these requirements such as grinding, feathering, patching or scarifying are considered to be non-compliant with Industry Standards for stonework until remedial work is completed.

3.2.2.6. Limits of moisture vapor transmission shall be established by the stone supplier. Testing and certification of compliance is the responsibility of the specifying authority.

3.2.2.7. Wash and dry backs and edges of pavers or tiles prior to installation.

3.2.2.8. A mortar bed consisting of one part portland cement to three to four parts clean washed sand by volume is laid over the concrete subfloor to a nominal thickness of 1¼" (30 mm). Stone is back-buttered uniformly with a cement paste bond coat, laid over the mortar bed and tamped into a true and level plane. Joints are grouted with a portland cement based grout or other approved material. (See Detail at the close of this section).

3.2.3. MORTAR BED SEPARATED FROM CONCRETE SUBFLOOR. This method is used where the concrete slab may be problematic such as anticipated differential movement between the slab and the stone assembly. Other factors that would favor the selection of this installation system include:

3.2.3.1. Cracks in the slab that may transfer through a bonded system.

3.2.3.2. Contamination of the slab that may be impractical to remove.

3.2.3.3. Capillary moisture issues exist.

3.2.3.4. Where cold or control joints in slab do not align with stone grid modules.

3.2.3.5. Where an unbondable membrane exists.

3.2.3.6. In these situations, the slab will require remedial treatment commensurate with the severity of the problem. These options usually involve a membrane of some type and as such the mortar bed cannot be bonded to the substrate. The requirement for unbonded mortar beds is that they be reinforced as specified by the design professional; usually with wire at the approximate center of the bed. As with the bonded mortar bed systems, slope and tolerance of the slab shall be such as to maintain an even thickness of the bed. Movement joint requirements will also remain the same; however, the membrane may remain continuous.

3.2.4. MORTAR BED SEPARATED FROM WOOD SUBFLOOR. This method is used where subfloor is subject to movement and deflection.

3.2.4.1. The mortar bed floats over subfloor and minimizes possibility of stone cracking from structural movement. An isolation membrane is laid over the sub-floor. A mortar bed consisting of one part portland cement to three to four parts clean washed sand by volume with reinforcement specified by the design professional. Stone tiles are laid over the mortar bed and tamped into proper plane. Joints are later grouted with a portland cement-based grout or other approved material.

3.2.5. THIN BED OVER PLYWOOD SUBFLOOR

3.2.5.1. This method should be used only in residential construction. The subfloor must be adequately designed to carry loads without excessive deflection. Subfloor must be level with a maximum variation of ⅛" in 10'-0" (3 mm in 3 m), with a deflection not exceeding L/720. Strongbacks, cross-bridging or other reinforcement shall be used to limit differential deflection between adjacent framing members. Comply with all manufacturers' written installation instructions. Apply mortar with flat side of trowel over an area that can be covered with tile while mortar remains plastic. Within ten minutes and using a notched trowel sized to facilitate the proper coverage, comb mortar to obtain an even setting bed without scraping the backing material. Key the mortar into the substrate with the flat side of the trowel. Back butter the stone tiles to ensure 95% contact with no voids exceeding 2 in² (1300 mm²) and no voids within 2" (50 mm) of tile corners on ⅜" (10 mm) tile. Back butter the stone tiles to ensure 80% contact with no voids exceeding 4 in² (2600 mm²) and no voids within 2" (50 mm) of tile corners on ¾" (20 mm) or thicker material. All corners and edges of stone tiles must be fully supported and contact area shall always be 95% or greater in water-susceptible conditions. Joints are later grouted with a portland cement-based grout or other approved material.

3.2.6. THIN-BED PORTLAND CEMENT MORTAR OVER CONCRETE SUBSTRATE

3.2.6.1. This method is used when space for full mortar bed is not possible. Concrete subfloor should not be subject to excessive movement or excessive deflection. Subfloor must be level with maximum variation of ¼" in 10'-0" (6 mm in 3 m). Mortar bed is laid using a notched trowel over subfloor to a thickness of not greater than 3/32" (2.5 mm) . Apply mortar with flat side of trowel over an area that can be covered with tile while mortar remains plastic. Within ten minutes and using a notched trowel sized to facilitate the proper coverage, comb mortar to obtain an even setting bed without scraping the backing material. Key the mortar into the substrate with the flat side of the trowel. Back butter the stone tiles to ensure a minimum of 95% contact with no voids exceeding 2 in² (1300 mm²) and no voids within 2" (50 mm) of tile corners on ⅜" (10 mm) tile. Back butter the stone tiles to ensure a minimum of 80% contact with no voids exceeding 4 in² (2600 mm²) and no voids within 2" (50 mm) of tile corners on ¾" (20 mm) or thicker material. All corners and edges of stone tiles must be fully supported and contact shall be a minimum of 95% in water-susceptible conditions. Joints are later grouted with a portland cement-based grout or other approved material. (See Detail at the close of this section).

3.2.7. THIN-BED MORTAR OVER CEMENTITIOUS BACKER UNITS

3.2.7.1. This method should be used only in residential construction and per manufacturers' instructions. The subfloor must be adequately designed to carry loads without excessive deflection. The cementitious backer unit is considered to be a bonding layer only and provides negligible structural contribution to the flooring system. Subfloor must be level with a maximum variation of 1/16" in 3'-0" (1.5 mm in 1 m), with a deflection not exceeding L/720. Cross-bridging or other reinforcement shall be used to limit differential deflection between adjacent framing members. Apply mortar with flat side of trowel over an area that can be covered with tile while mortar remains plastic. Within ten minutes and using a notched trowel sized to facilitate the proper coverage, comb mortar to obtain an even setting bed without scraping the backing material. Key the mortar into the substrate with the flat side of the trowel. Back butter the stone tiles to ensure a minimum of 95% contact with no voids exceeding 2 in² (1300 mm²) and no voids within 2" (50 mm) of tile corners on ⅜" (10 mm) tile. Back butter the stone tiles to ensure a minimum of 80% contact with no voids exceeding 4 in² (2600 mm²) and no voids within 2" (50 mm) of tile corners on ¾" (20 mm) or thicker material. All corners and edges of stone tiles must be fully supported and contact shall always be a minimum of 95% in water-susceptible conditions. Joints are later grouted with a portland cement-based grout or other approved material.

3.3. HEATED FLOOR SYSTEMS

3.3.1. In frame construction, the plywood portion of the substrate must be a minimum of 1½" (40 mm) exterior glue plywood. Leave a gap between the plywood sheets for expansion. Install a cleavage membrane over the plywood.

3.3.2. Frame and Mortar Bed. Heated floor systems are generally proprietary in nature, and the manufacturer's installation guidelines shall be closely followed. Consider using a heat deflector on top of the membrane. The heating contractor should install the heating system per manufacturer's recommendation. Fill cavity with a wire or portland mix so that the mortar bed covers pipes and is at least ¾" (20 mm) over the top of heating pipes, with a minimum bed thickness of 2½" (65 mm). Allow to cure for at least 30 days. This mortar bed thickness is necessary to dissipate heat to avoid damaging the stone by uneven heating.

3.4. THRESHOLDS

3.4.1. Exposed edges may be eased, rounded, arrised or beveled. If instructions are not given as to type of edge required, Supplier will furnish according to industry standards.

3.4.2. Thicknesses of ½", ¾", and 1¼" (12, 20, and 30 mm), or as specified.

3.5. STAIRS

3.5.1. SIZES: Tread thicknesses of ¾", 1¼", and 1½" (20, 30, or 40 mm) are commonly used for interior stairs. Thicknesses of 1¼", 2" (30, 50 mm) and cubic (greater than 2" [50 mm]) are commonly used for exterior stairs. Risers may be ¾" or 1¼" (20 or 30 mm) thick, or in the case of cubic treads, the riser face is integral with the tread surface stone.

3.5.1.1. In residential applications, thin stone (less than ¾" [20 mm] treads and risers may be installed using a thin-set portland cement mortar bed over clean and level concrete subtreads or double layers of ¾" (20 mm) plywood installed in opposite directions with ⅛" (3 mm) gaps between sheets. These types of applications will not withstand high impact or wheel loads. Overhang is not permitted when stones of this thickness are used.

3.5.2. METHODS. Stone stair treads may be installed in a cement mortar bed, or in a thin-set cement or epoxy mortar bed, over a subtread, or supported by stringers. (See detail illustrations at the close of this section).

3.5.3. 100% coverage of mortar bed material between tread and subtread is desirable.

3.5.4. Risers ¾" (20 mm) or thicker must be anchored with wire or stainless steel strap anchors. If risers thinner than ¾" are used, they may be adhered using the thin-bed portland cement mortar method.

4. TROUBLESHOOTING AND CAUTIONS

4.1. INSTALLATION METHODS
Stone paving can be installed by several methods. Consideration should be given to the various features of each method in making a selection for a specific installation. See illustrations of installation examples at the close of this section.

4.2. GEOGRAPHIC METHODS
Some installation methods and materials are not recognized and may not be suitable in some geographic areas because of local trade practices, building codes, climatic conditions, or construction methods. Therefore, while every effort has been made to produce accurate guidelines, they should be used only with the independent approval of technically qualified persons. Some installation methods and materials are not recognized and may not be suitable in some geographical areas because of local trade practices, building codes, climatic conditions, or construction methods. Therefore, while every effort has been made to produce accurate guidelines, they should be used only with the independent approval of technically qualified persons.

4.3. PROTECTION OF FINISHED WORK
During construction, the General Contractor shall protect all stone from staining and damage. After the stone paving has been installed, the General Contractor must keep all

traffic off the floors for at least 48 hours. No rolling or heavy (greater than pedestrian) traffic should be permitted on newly installed stone surfaces for at least two weeks after the floor has been grouted or caulked.

4.4. PREPARATION OF STONE UNITS

Wash and dry backs and edges of all pavers prior to installation in any installation method other than pedestal supported pavers.

4.5. MOISTURE AND ALKALINITY SENSITIVITY

Stone suppliers shall identify stones that are adversely affected by moisture and alkalinity.

4.6. SETTING BEDS FOR LIGHT COLORED STONES

White Portland cement with low alkali content is recommended for light colored stone.

4.7. TRANSITIONS FROM STONE TO SOFT FLOORING

Where stone abuts softer flooring materials, a stone threshold or metal edge protection strip is recommended. This will help prevent edge chipping caused by impact.

4.8. HOLLOW SOUND

Because of the weight and consequent difficulties in handling large-sized pavers, it is impossible to avoid an occasional "hollow" sound found in some stone units after installation. Reasons for hollow sounds include:

4.8.1. A hollow sound may indicate that insufficient bonding of the paver exists, although it is not necessarily a reliable test. Other influences can cause a hollow sound from a properly bonded paver.

4.8.2. Hollow sounds may be acoustical effects rather than bonding problems.

4.8.3. Air may be entrapped in either the setting bed or slab, causing one part of the floor to sound differently than another.

4.8.4. Separation or crack-isolation membranes installed between a slab and the setting bed may alter the acoustical report.

4.8.5. The elevation or composition of the subsurface may be irregular, causing one part of the floor to sound differently than another.

4.9. MOISTURE PENETRATION

The performance of a properly installed stone installation is dependent upon the durability and dimensional stability of the substrate to which it is bonded. The user is cautioned that certain substrate materials used in wet areas may be subject to deterioration from moisture penetration.

4.10. WET AREAS

"Wet areas" are stone surfaces that are either soaked, saturated, or subjected to moisture or liquids (usually water), e.g., gang showers, tub enclosures, showers, laundries, saunas, steam rooms, swimming pools, hot tubs, and exterior areas.

4.11. FIBERGLASS MESH BACKING

Producers frequently apply a fiber mesh reinforcement to the back surfaces of stone tiles and slabs to reduce breakage and also to increase safety when handling large slabs. Caution should be used when using a stone that has a fiberglass mesh backing applied on the back face. The fiberglass, having been bonded to the stone with a resinous (commonly epoxy, although sometimes polyester or other adhesive chemistries) adhesive, will not bond adequately with cementitious products. Only epoxy products, or products specifically made for fiberglass by the manufacture should be used when installing stone with fiberglass mesh backing.

4.12. GREEN COLORED STONE

Avoid the use of water-based adhesive when installing certain green marbles and/or serpentines. Some of these stones may warp through absorption of water from the setting bed. (Water drawn into the stone is held to the crystals by surface energy. This force tends to widen the intercrystalline space and thereby expand the wet side.)

4.13. VOIDS IN TRAVERTINE
Travertine flooring, particularly fleuri cut (also called "cross-cut) will have voids occurring just below the finished surface of the material. Since these voids are concealed by a thin shell of stone material, they do not get filled in the factory filling process. Once in service, concentrated loads (e.g., loads from wheels or spike heels) will fracture the thin shell of stone, exposing the void below. Several iterations of re-filling travertine floors in place can be expected until these voids are all discovered. This is essentially a "break-in" process for this particular material and is not considered a defect in the stone.

4.14. SEALANT STAINING
Some elastomeric sealants contain oil-based plasticizers to reduce their modulus and increase their extension/compression capability. The plasticizers can wick into stone perimeters, causing darkening of the edge (picture framing) and accelerated dirt collection on the stone face. Caution should be used in specifying sealants to ensure compatibility with stone. It is recommended that either an exemplar project be identified using the same stone and sealant components with satisfactory results, or a testing regimen (per ASTM C1248 or ASTM D2203) be employed to verify compatibility.

4.14.1. Some sealant manufactures maintain a database of stone projects using joint sealers from that manufacturer to aid in identifying exemplar projects for evaluation.

4.15. EFFLORESCENCE
Efflorescence is a salt deposit, usually white in color that appears on exterior surfaces of stone walls and floors. The efflorescence is produced by salts leached to the surface of the stone by water percolating through the stone backup and joints. The most feasible means of prevention is to stop the entrance of large amounts of water. If the conditions bringing about the efflorescence continue, scaling may occur and flake off successive layers. For this to happen, large amounts of water must continue to enter behind the stone and must contain large amounts of salts.

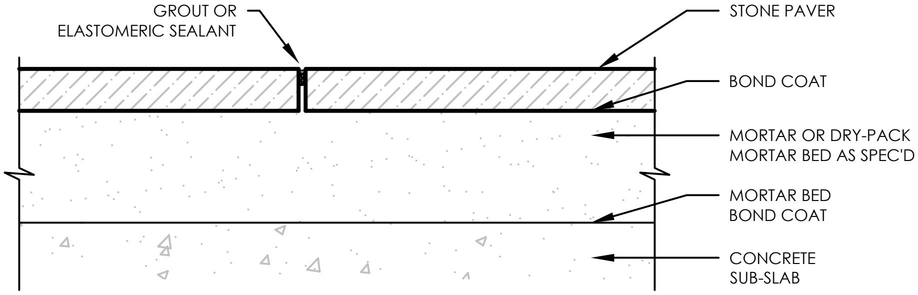
4.16. LIGHTING OF HIGH ANGLES OF INCIDENCE
Lighting with a high angle of incidence, in which the path of light is nearly parallel to the face of the wall surface, is a popular choice in both interior and exterior designs. This lighting style will exaggerate lippage, textural surface variation, and even warpage due to the extremely elongated shadow lines caused by the angle of incidence. Material and installation which are within industry tolerances may appear to be outside of tolerances due to the accentuation of the lighting technique. Inspection of areas receiving such lighting shall be done with the lighting turned off or otherwise blocked.

4.17. VARIATION IN GLOSS
It is almost impossible to uniformly read light reflection on a polished or high-honed-finish installation due to the natural characteristics of dimension stone. Due to the heterogeneous composition of natural stones, variable mineral hardness exists within the stone, producing variable reflectivity of light energy. Most stones, especially travertine marbles and limestones, will appear to reflect light unevenly.

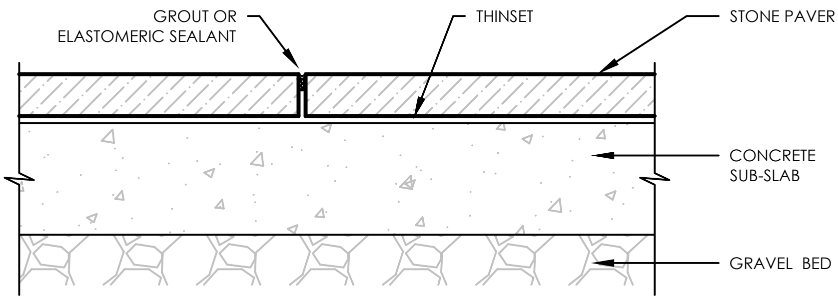
4.18. POLISHING WHEEL MARKS
Polishing wheel marks or other scratches caused during fabrication are unacceptable on honed or polished stone.

4.19. SNOW MELTING CHEMICALS
Many stones, especially limestones, are vulnerable to attack from snow melting chemicals, particularly salt. The attack is actually mechanical, rather than chemical. In solution, the salt can penetrate the pores of the stone, but when the water evaporates, the salt recrystallizes within the pore. The resultant recrystallization pressure can exfoliate the surface of the stone.

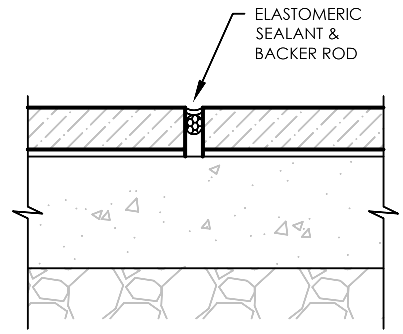
NOTES:



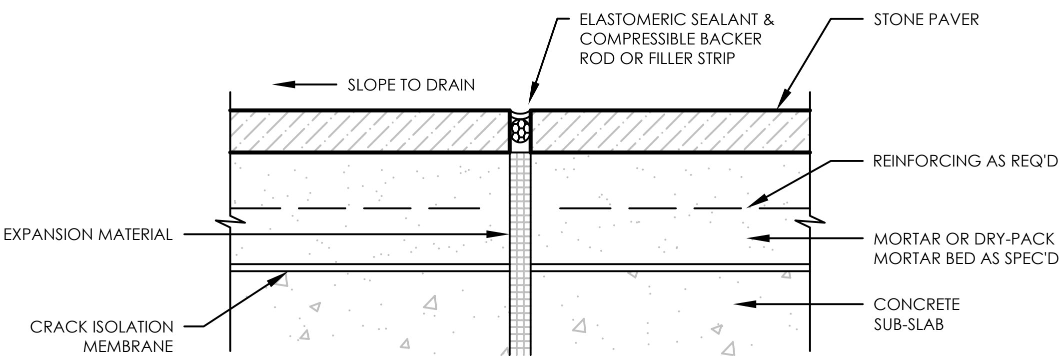
1 MORTAR BED WITH BOND COAT



2 MORTAR BED WITH THINSET



2A MOVEMENT JOINT



3 FULL MORTAR BED WITH MEMBRANE AND EXPANSION JOINT

NOTE: IT IS NOT THE INTENT OF THIS MANUAL TO MAKE EXPANSION, CONTROL, OR MOVEMENT JOINT RECOMMENDATIONS FOR A SPECIFIC PROJECT. THE SPECIFYING AUTHORITY MUST DESIGN AND LOCATE EXPANSION, CONTROL, AND MOVEMENT JOINTS ON THE CONSTRUCTION DOCUMENTS.

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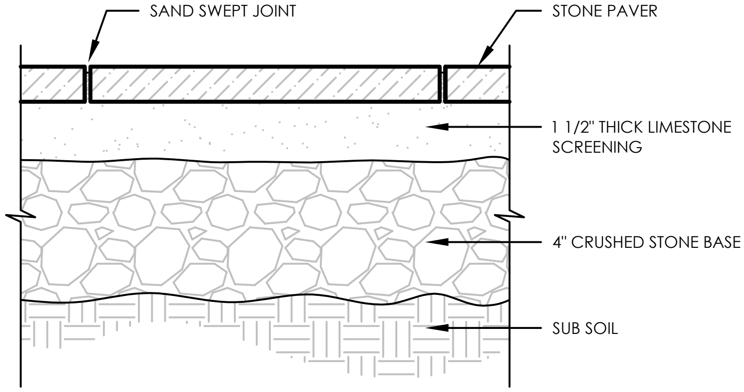
REV	DATE
0	MAR 2022

EXTERIOR STONE PAVING

DIMENSION STONE DESIGN MANUAL 2022

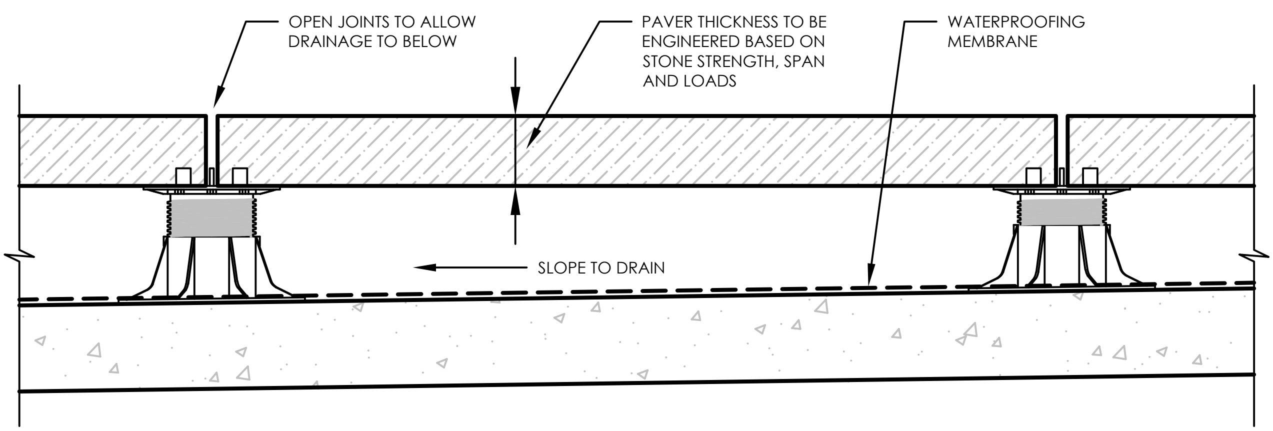
DRWG NO: 13-D-1

SCALE: 3" = 1'-0"



1 STONE PAVERS SET IN SAND BED

Scale: 3" = 1'-0"



2 PEDESTAL SUPPORTED STONE PAVERS

Scale: 1½" = 1'-0"

(GRAPHIC COURTESY OF BISON INNOVATIVE PRODUCTS)

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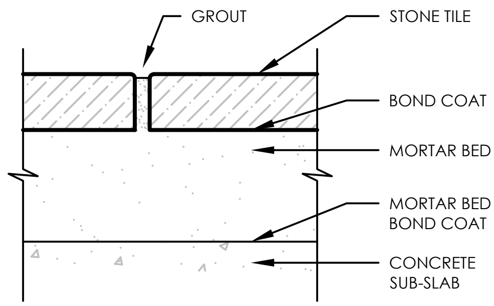
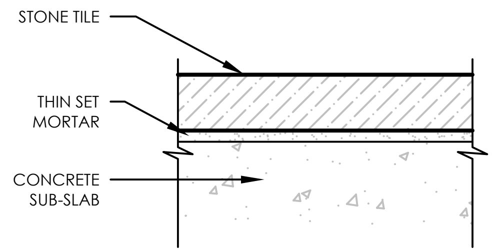
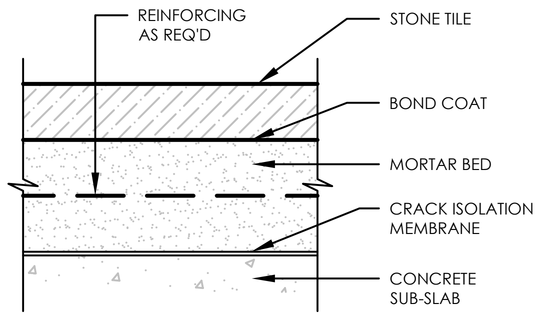
	0	MAR 2022	
			DRWG NO: 13-D-2 — SCALE: As Noted



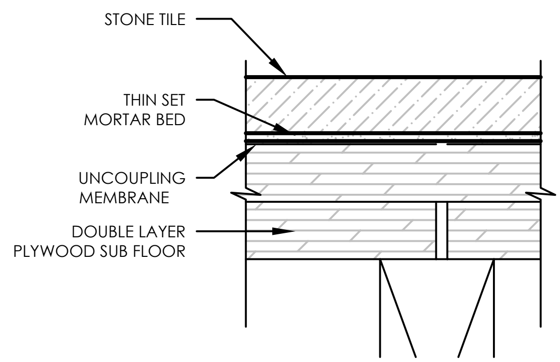
1 STONE TILE SET IN MORTAR BED



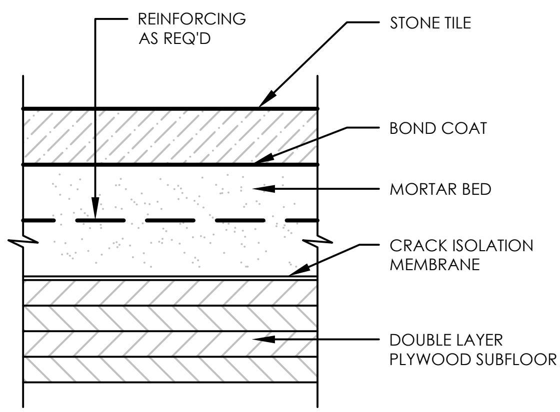
4 STONE TILE SET IN THIN-SET BED OVER CONCRETE SLAB



2 STONE TILE SET IN REINFORCED MORTAR BED



5 STONE TILE SET IN THIN-SET BED WITH UNCOUPLING MEMBRANE OVER WOOD FRAME



3 STONE TILE SET IN REINFORCED MORTAR BED OVER WOOD FRAME

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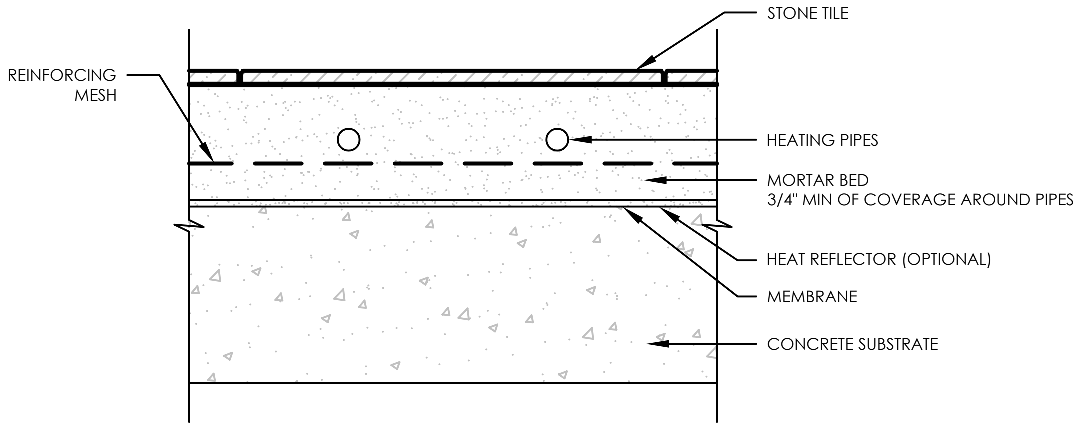
INTERIOR STONE FLOORING

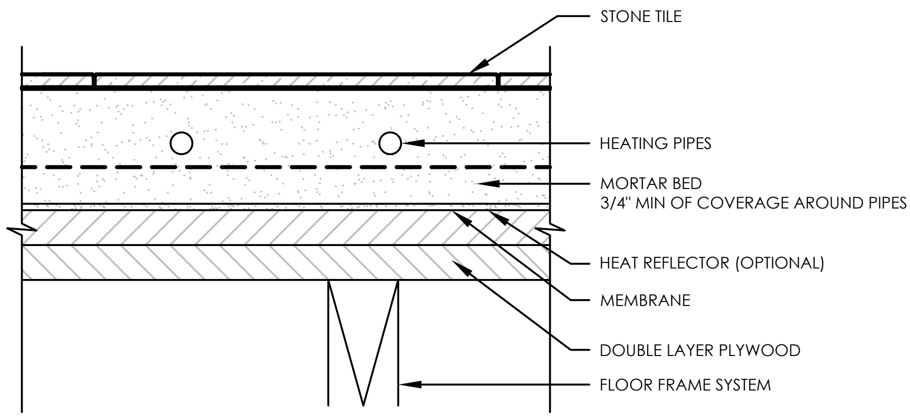
DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 13-D-3

SCALE: 3" = 1'-0"



1 STONE TILE OVER HYDRONIC RADIANT HEAT SYSTEM WITH CONCRETE SUBSTRATE



2 STONE TILE OVER HYDRONIC RADIANT HEAT SYSTEM WITH WOOD FRAME SUBSTRATE

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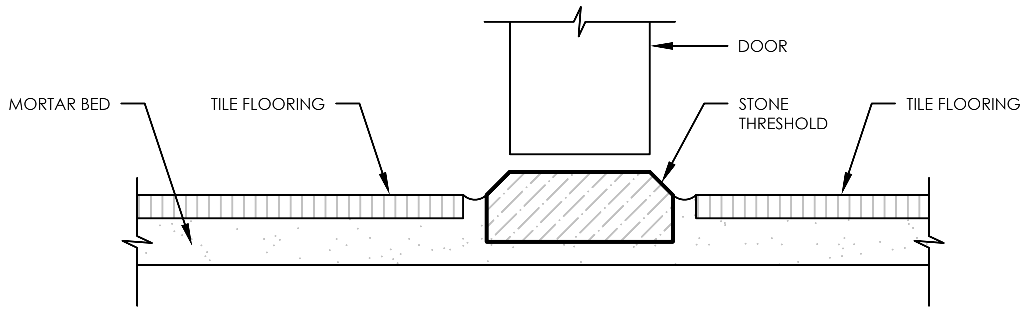
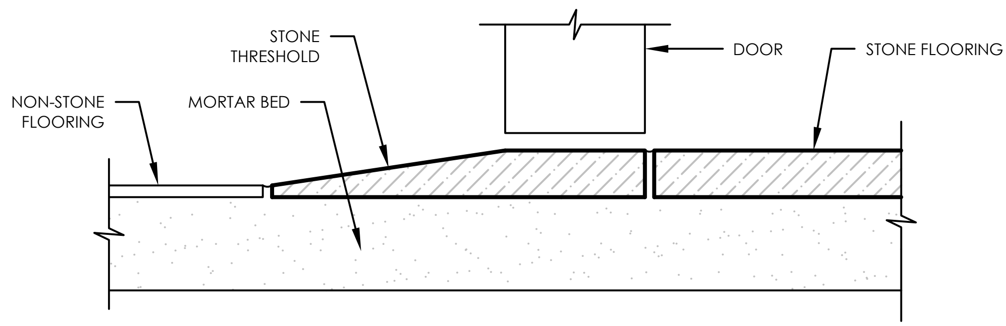
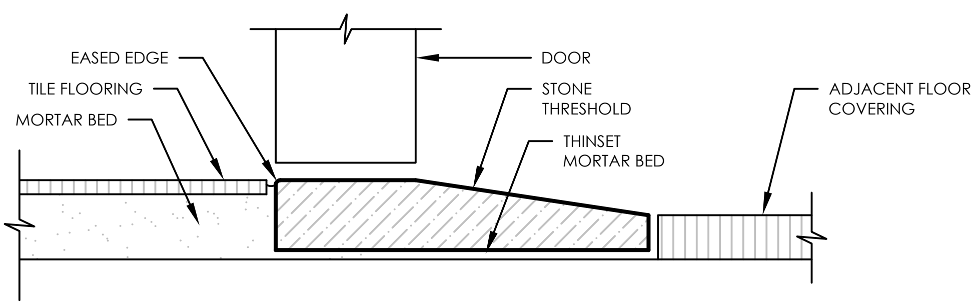
	0	MAR 2022	
			DRWG NO: 13-D-4 — SCALE: 3" = 1'-0"



1 VARYING BED DEPTH MORTAR METHOD



2 FULL MORTAR BED METHOD



3 THIN-SET METHOD

NOTES: 1. USE 100% COVERAGE OF BOND COAT MATERIAL BETWEEN THRESHOLD AND SUB-SLAB
2. MINIMUM ABRASIVE HARDNESS OF THRESHOLD MATERIAL SHOULD BE 12.0 (ASTM C241 OR C1353)

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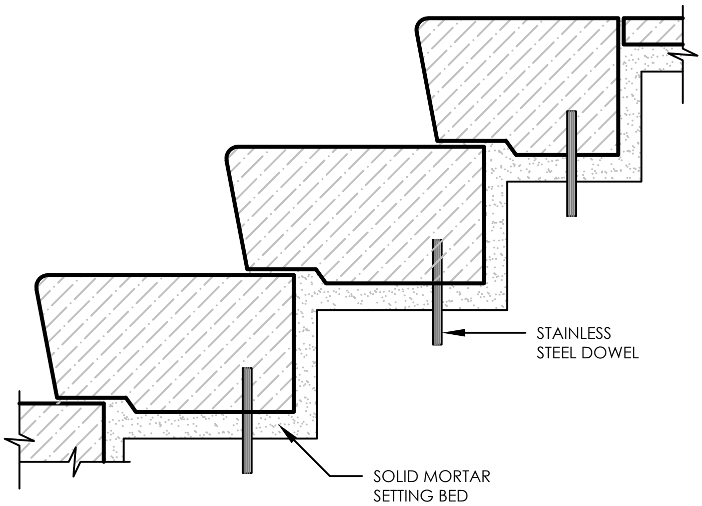
STONE THRESHOLDS

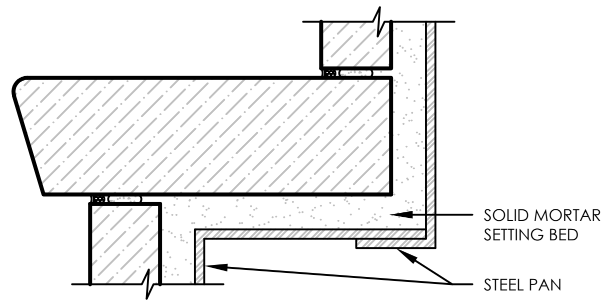
DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 13-D-5

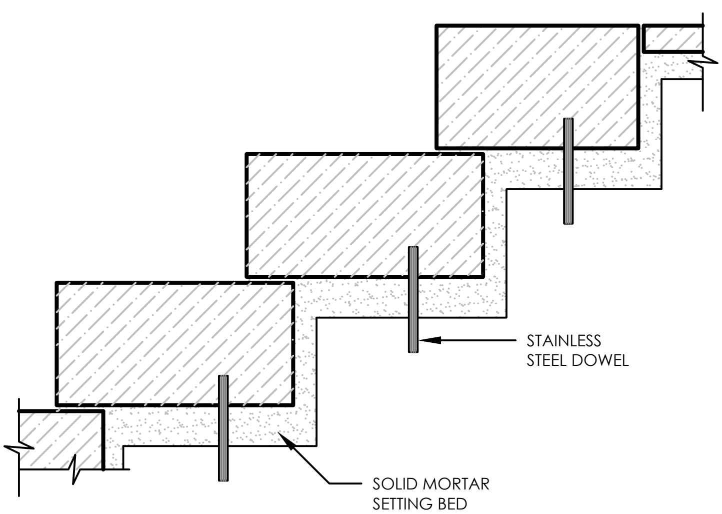
SCALE: 3" = 1'-0"



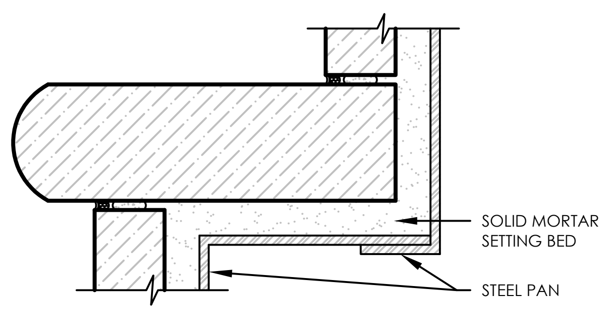
1 CUBIC STEP DETAIL
SCALE: 1½" = 1'-0"



2 STEP DETAIL ON METAL PAN
SCALE: 3" = 1'-0"



3 CUBIC STEP DETAIL
SCALE: 1½" = 1'-0"



4 STEP DETAIL ON METAL PAN
SCALE: 3" = 1'-0"

NOTES: 1. USE 100% COVERAGE OF BOND COAT MATERIAL BETWEEN THRESHOLD AND SUB-SLAB
2. MINIMUM ABRASIVE HARDNESS OF THRESHOLD MATERIAL SHOULD BE 12.0 (ASTM C241 OR C1353)

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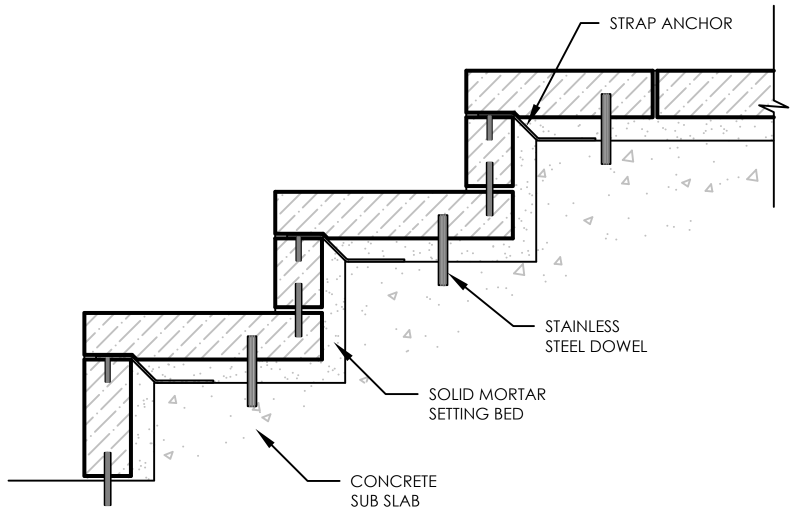
STONE STAIR DETAILS

DIMENSION STONE DESIGN MANUAL 2022

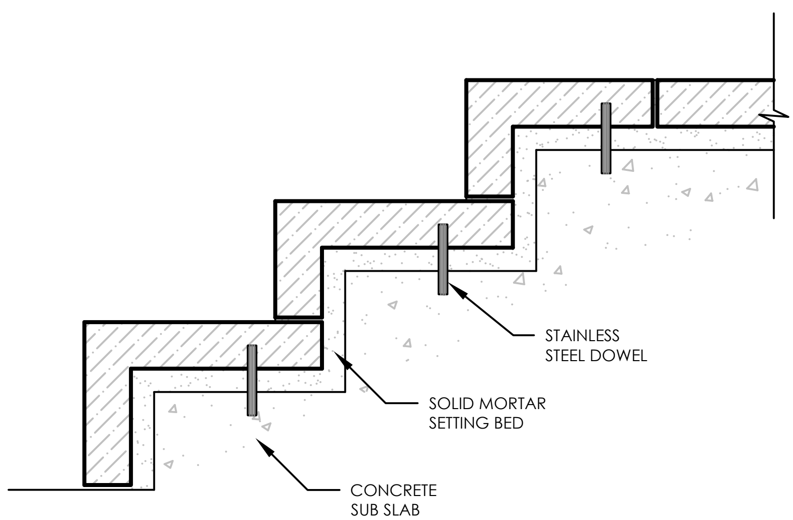
DRWG NO: 13-D-6

SCALE: As Noted

CAUTION: IF THIS SHEET IS NOT 8½" x 11", IT IS A REDUCED OR ENLARGED PRINT



5 VENEERED STEP DETAIL



6 HOOKED STEP DETAIL

NOTES: 1. A ROUGH OR TEXTURED FINISH IS RECOMMENDED FOR EXTERIOR USAGE
2. MINIMUM ABRASIVE RESISTANCE OF STONE TREAD MATERIAL SHOULD BE 12.0 (ASTM C241 OR C1353)
3. FABRICATION LABOR REQUIREMENTS COMMONLY MAKE DETAIL 6 A HIGHER COST ALTERNATIVE

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REV	DATE
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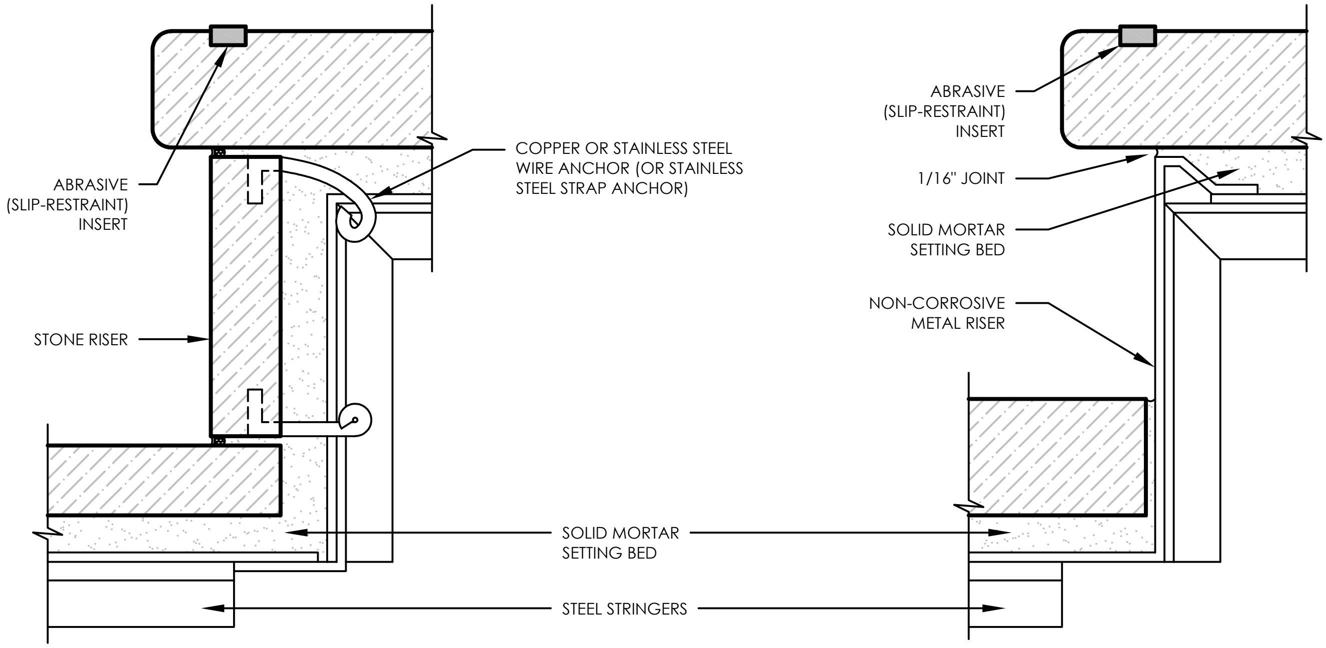
STONE STAIR DETAILS

DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 13-D-7

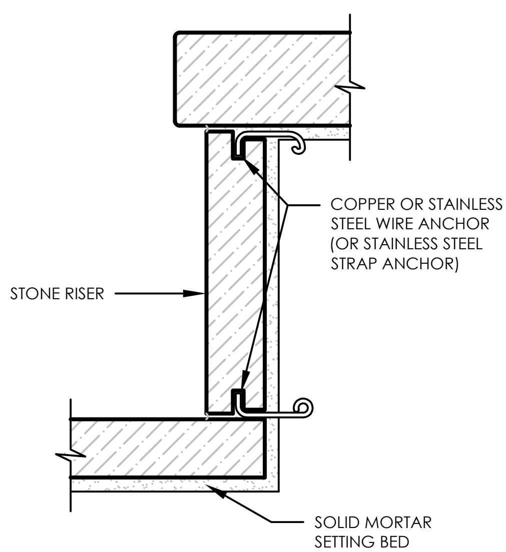
SCALE: 1 1/2" = 1'-0"

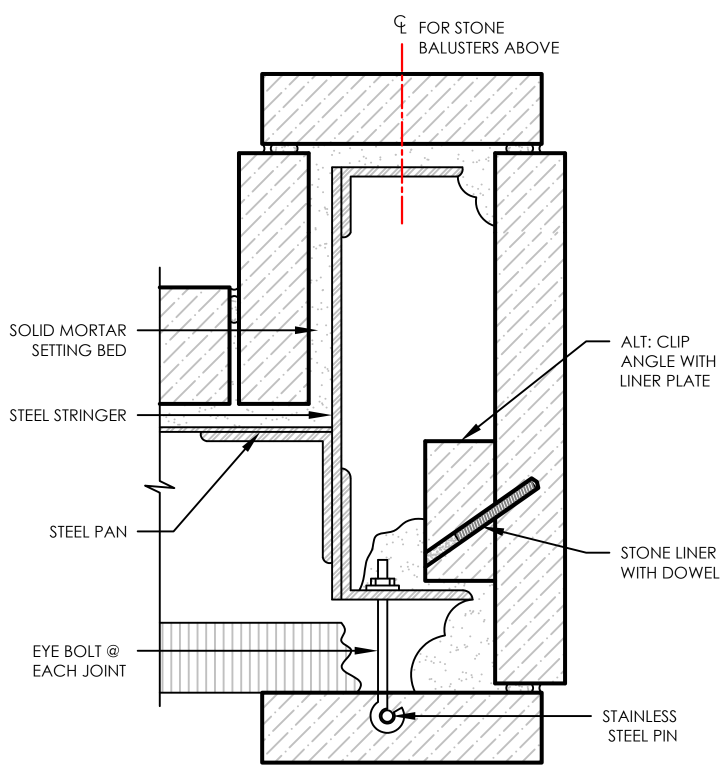
CAUTION: IF THIS SHEET IS NOT 8½" x 11", IT IS A REDUCED OR ENLARGED PRINT



1 STEP DETAIL ON METAL PAN

2 STEP DETAIL ON METAL PAN





3 VENEERED STEP DETAIL

4 STEP DETAIL ON METAL PAN

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REV	DATE
0	MAR 2022

STONE STAIR DETAILS

DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 13-D-8

SCALE: 3" = 1'-0"

VERTICAL SURFACES

1. DESIGN CRITERIA

Design of vertical surfaces, particularly in exterior applications, require several factors to be taken into account. Amongst others, these include climatic conditions such as wind, seismic, freeze-thaw cycles; material properties of the stone selected and the structural back up provided by the building engineer. The building classification, local building codes and material selected will dictate the appropriate minimum factors of safety, preferred method of installation and optimal anchoring system. These may vary from state to state and/or specified building classification. It is for these reasons that we strongly recommend a qualified stone engineer and accredited installer be engaged from preconstruction through final construction phases to ensure a successful project delivery.

1.1. STONE SELECTION AND SUPPLY

1.1.1. STONE PRODUCT DEFINITIONS

1.1.1.1. TILE. A stone tile is a thin, flat piece of natural stone used as finishing material, with a gauged thickness ranging from ¼" to ⅝" (6 to 16 mm) inclusive and having no dimension greater than 2' 0" (610 mm). Tiles are normally supplied in typical sizes, with all atypical pieces being field cut to fit.

1.1.1.2. CUT-TO SIZE. Cut-to-size stone products, also referred to as "slab stock" stone products, are custom fabricated pieces of natural stone. Fabrication of these products normally occurs in a shop setting, where each piece is custom fabricated to specific sizes, but partial fabrication may also occur in the field at the time of installation.

1.1.2. TOLERANCES. Natural stone tiles and cut-to-size products may have different fabrication tolerances due to their different methods of fabrication. Refer to the Chapter 22 on Tolerances of this manual for fabrication and installation tolerances.

1.1.3. LABOR ASSIGNMENT: The successful installation of both dimension stone and stone tile is dependent upon the experience and craft knowledge of the firm contracted to install the stone. The Natural Stone Institute endorses the use of NSI Accredited Natural Stone companies. See www.naturalstoneinstitute.org for a directory of installation companies accredited by the NSI.

1.1.4. ASTM C119 outlines the terminology relating to dimension stone and provides a brief description of some of the stone groups. There are numerous suitable materials available for cladding in each group, however one must be aware that stone, being a natural material, may have significantly varying properties within each group. Additionally, physical and mechanical properties of the stone, panel size, panel thickness, design loads, and climatic conditions can determine whether a stone is suitable for a given application.

1.1.5. As a general rule, stone panel thickness should be a minimum of 1¼" (30 mm) for exterior installations and a minimum of ¾" (20 mm) for interior installations, but in many cases heavier thicknesses are necessitated. Panel sizes and thicknesses may also be dictated by local codes, wind load requirements, areas of usage, and material performance as determined by ASTM standard specifications. Refer to ASTM C1528 for recommendations of minimum stone thickness.

1.1.6. SHOP DRAWINGS: Detailed shop drawings shall be provided by the stone contractor. Shop drawings shall address:

1.1.6.1. Stone type and finish

1.1.6.2. Stone sizes, thicknesses, joinery and patterning

1.1.6.3. Vein and rift directions, if appropriate

1.1.6.4. Joint sizes and treatments

1.1.6.5. Identification of mortar, adhesive, and grout types.

1.1.6.6. Details of mechanical anchorage, including anchor devices and metallurgy of same.

1.1.6.7. Structural Backup

1.1.6.8. Flashing and/or other means of water management

1.1.6.9. Relationship/interface between stone and adjacent building materials

1.1.7. FABRICATION: Exterior veneer units are precut and prefinished to dimensions specified on shop drawings and are typically delivered to the job site ready to install.

1.1.7.1. All required carving shall be performed by skilled tradespeople in strict accordance with approved full-size details or models. Architectural drawings will show approximate depth and relief of carving. Carved surfaces shall be left as produced by the carving tool(s), unless otherwise specified.

1.1.8. FINISHES: Most commercially available stone finishes are suitable for exterior veneer, however, some stones, notably calcitic materials such as marbles and limestones, will not retain a polished finish in exterior environments.

1.1.8.1. Some fabricator applied treatments, such as resin, may have inadequate resistance to weathering.

1.1.9. COLORS: A wide variety of color options are available, provided they meet or exceed the necessary performance specifications of the project.

1.1.10. Panel Sizes and Thicknesses may need to be determined by engineering analyses. The following properties should be considered when determining size and thickness of stone veneer units:

1.1.10.1. Flexural Strength (Ref: ASTM C880) or Modulus of Rupture (Ref: ASTM C99) of the stone

1.1.10.2. The anticipated loads

1.1.10.3. Required factors of safety

1.1.10.4. Generally, large panel dimensions can create supply and/or anchorage difficulties. The designer is encouraged to verify obtainable dimensions with the quarrier of the material prior to finalizing the design.

1.1.11. Each stone variety used for exterior veneer should conform to the applicable ASTM standard specification and the physical requirements contained therein. The specification for each stone type follows:

1.1.11.1. Granite: ASTM C615, Standard Specification for Granite Dimension Stone

1.1.11.2. Limestone: ASTM C568, Standard Specification for Limestone Dimension Stone

1.1.11.3. Marble: ASTM C503, Standard Specification for Marble Dimension Stone

1.1.11.3.1. Soundness Classifications: Refer to Chapter 7 for a complete discussion of Marble Soundness Classifications.

1.1.11.4. Onyx: No ASTM Standard exists at this time.

1.1.11.5. Quartz-based Stone: ASTM C616, Standard Specification for Quartz-based Dimension Stone

1.1.11.6. Serpentine: ASTM C1526, Standard Specification for Serpentine Dimension Stone

1.1.11.7. Slate: ASTM C629, Standard Specification for Slate Dimension Stone

1.1.11.8. Soapstone: No ASTM Standard exists at this time.

1.1.11.9. Travertine: ASTM C1527, Standard Specification for Travertine Dimension Stone

1.1.12. Caution is advised when using historical test data for natural stones. It is preferable to use data obtained from test specimens from current quarry production that is representative of the actual product being supplied. Test data should be obtained from testing agencies specializing in natural stone testing.

1.2. SAMPLES AND MOCKUPS

The stone supplier shall provide samples of the various dimension stones to be used per the requirements of the project specifications. Samples shall indicate the extremes of color, veining, and marking that the stone supplied to the project will have.

1.2.1. Pending the scope of the installation and the variability of the stone product, a full-sized visual mockup may be required to adequately demonstrate the range of the material's color and character. Mockups are intended to demonstrate the full range of color tones and natural characteristics of the stone to be expected across the entire project yet condensed into the much smaller surface area of the mockup. Therefore, the effects of the variation and characteristics of the stone will be more concentrated and appear more extreme than the actual project since the actual project will have less frequent occurrences of these elements.

1.2.2. Pending the scope of the installation and the variability of the stone product, a "dry-lay" may be required to adequately demonstrate the range of the material's color character, and finish, with the advantage of predetermining the actual position and orientation of each stone panel. The dry-lay allows the design professional to see the actual blend of the finished wall, and also allows the arrangement of pieces to be adjusted per his/her desires. Since each stone panel is dedicated to a specific location, crating and handling must be skillfully executed to prevent damage as there may or may not be a suitable replacement available for a given stone. A dry lay is generally considered to be a wise investment for decorative interior office lobby, floor and wall projects. It provides a beneficial team building experience and the formal approval of all stone prior to shipment helps eliminate jobsite anxiety and rejections.

1.2.3. A performance mockup may also be required to verify the structural and/or weatherproofing capabilities of the designed system.

1.3. INSPECTION

Inspection of supplied material to evaluate compliance with approved samples or mockups shall be done at a viewing distance of not less than 6'-0" (2 m) with natural lighting, from a vantage point that is perpendicular to the face of the stone.

1.4. FIELD REPAIR

1.4.1. During the progress of construction, changes are often necessary to accommodate other trade and design revisions. These changes may require job site cutting and some finishing of stone, and this can be satisfactorily executed by qualified mechanics.

1.4.2. Repair or patching is sometimes necessary due to damage of material either on-site or in transit. By allowing these repairs to be made on-site, progress of the job can be maintained, thus aiding the successful completion of the work. Repairs should not detract from the desired appearance or strength of the completed installation.

1.5. CAVITIES

Cavities behind stone facades are commonly used to provide space for anchorage, insulation, and other components in addition to accommodating fabrication and construction tolerances of both the stone and backup system.

1.5.1. Cavities shall have weeps, commonly at intervals of 3 to 4 ft (1 to 1.5 m) at their lowest point and at any level where water cannot freely travel vertically within the cavity (such as where continuous shelf angles or flashings exist).

1.5.2. Cavities shall be vented to provide additional evacuation opportunities for water vapor and to reduce possible pressure differentials between the cavity and the ambient pressure.

1.5.3. ADDITIONAL TECHNIQUES. With today's improved construction techniques, it is possible to produce structures that are highly resistant to natural weather conditions. Joints can be sealed with resilient sealants and the building interiors can be temperature- and humidity-controlled. Venting of the cavity is recommended to prevent moisture problems. It is recommended that a vapor barrier be installed at the exterior face of the backup wall. In most cases, the back face of the stone should not be sealed.

1.5.4. VENEER CAVITIES: Solid grouting of stone veneer cavities that would permit the capillary transmission of moisture through the wall from exterior to interior, and interior to exterior, is generally considered inadvisable. However in some cases, particularly rubble stone construction, solid-filled collar joints are used.

1.6. FLASHING

Condensate is expected to form within cavities and will travel downward within the cavity until it reaches a location where it is directed out. Flashing is required at any location where water must be prevented from seeping behind attached elements and at any location where water must be prevented from contacting the area below. Flashing can be either membrane or sheet metal.

1.7. ANCHORS

Anchorage systems must be securely attached and located as shown on the approved shop drawings and shall be plumb and in true plane. Numerous types of mechanical anchorage devices have been developed over decades. Most anchors will fall under one of the following categories:

1.7.1. STRAP ANCHORS: Anchors formed from light gauge (≤ 3/16", ≤5 mm) metal, usually stainless steel, and feature a "tab" that engages a slot penetration or "kerf" in the perimeter of the stone, are commonly referred to as "strap anchors". Strap anchors carry lateral loads only, with the gravity loads carried by other means.

1.7.2. PIN ANCHORS: Pin anchors consist of a pin swaged into a strap, with the strap attached to the backup structure and the pin penetrating a drilled hole in the edge of the stone. Pin anchors are more challenging to align between successive courses than strap anchors, but are sometimes preferable to strap anchors since the penetration required in the stone removes less material and in some cases results in greater lateral capacity for the anchor.

1.7.3. DOWEL ANCHORS: Anchors consisting of a simple section of dowel, usually stainless steel, are referred to as dowel anchors. These anchors engage a drilled hole in the edge of the stone, with the opposite end of the dowel penetrating a rigid material, oftentimes concrete, to provide the necessary connection. Dowel anchors typically carry lateral loads, but in some cases (i.e.: liner blocks) are responsible for gravity loads.

1.7.4. SHELF ANCHORS: Shelf anchors are usually a section of extruded angle or bent plates, either stainless steel or corrosion protected mild steel, that carry gravity loads.

1.7.5. BENT PLATE ANCHORS: Bent plates, either formed from one metal section or welded from multiple sections, carry bidirectional loads (lateral and gravity). Essentially, they are a hybrid combination of a strap and shelf anchor. They are usually made of stainless steel since a portion of the anchor penetrates and/or is in contact with the stone.

1.7.6. BACK ANCHORS: Back anchors include any of several devices that penetrate the back surface of a stone panel with a positive, mechanical locking feature. Most back anchors are capable of providing bidirectional load carrying capacity and can therefore be used to address both lateral and gravity loads.

1.7.7. MASONRY BED ANCHORS: These anchors do not penetrate the stone but are merely embedded in the mortar joints of split-face ashlar or similar installations. They can be wire loops or corrugated metal. These types of anchors are only recommended for stone greater than 3" (75 mm) in thickness.

1.7.8. WIRE TIE ANCHORAGE: Wire tie anchorage is a historically effective method of anchoring stone panels and has been used successfully for centuries. However, this installation must be carried out by a qualified and trained marble or stone mason. Additional considerations when using wire tie anchorage are listed below:

1.7.8.1. Wire anchors are not generally recommended for installations exceeding 15'-0" (4.5 m) vertically.

1.7.8.2. Copper is the most commonly used wire, although stainless steel wire (¼ Hard Series 304 stainless steel wire is often specified as it provides a reasonable balance between workability and strength) is recommended in lieu of copper wire for exterior or wet area interior applications.

1.7.8.3. A plaster or cementitious dollop, or "spot" is used in conjunction with the wire tie. When wire tie anchorage is used for exterior or wet areas the spot material shall be of a portland cement based compound. Setting plaster, moulding plaster, or other gypsum based products are strictly limited to interior, dry environments.

1.7.8.4. When copper wire is used, it is common in some geographical regions to twist the wire to stiffen the wire via metallurgical work hardening. Excessive work hardening of the wire can lead to embrittlement of the metal. Care must be taken to ensure that the physical properties of the wire have been improved and not degraded by this process.

1.7.9. OTHER ANCHORAGE DEVICES: Standard, custom, and proprietary anchorage devices are available for stone panel attachments. A representation of many of the commonly used devices can be found in the graphics section of this chapter. Additional information can also be found in the Natural Stone Institute's Technical Bulletin on Dimension Stone Anchorage.

1.7.10. THIN STONE ANCHORAGE: Natural stone in thicknesses of less than ¾" (20 mm) are usually not capable of accommodating mechanical anchors and must be secured by adhesive attachment.

1.7.11. ANCHOR SIZE: Anchor sizing is dependent upon materials, codes, physical conditions of the structure, wind and seismic requirements, thermal properties, etc. Anchors should be engineered separately for each condition.

1.7.12. METALLURGY: Anchors shall be of non-staining, corrosion resistant metals. Stainless steel, aluminum, bronze, brass, and copper wire are commonly used for their corrosion resistance. (See illustrations of typical anchors and accessories at the close of this chapter). In exterior cladding systems, stainless steel and aluminum are the most common, and series 304 stainless is the most common alloy of stainless steel used for anchorage. Copper, bronze and brass are normally limited to interior applications.

1.7.13. ANCHOR QUANTITY: Weight, size, shape, and type of stone along with loading requirements will determine the number, spacing and size of the anchors . Four anchors per panel is generally considered to be both minimum and optimum, although certain conditions may mandate additional anchor locations. IBC currently prescribes minimum anchorage quantities for non-engineered "stone veneer" and "slab type veneer" based on the surface area of the stone panels. Due to varying loads, stone properties, and anchor capacities, this may not necessarily be adequate, particularly when public or occupant safety may be compromised. It is recommended that exterior stone cladding systems be reviewed by an experienced stone cladding engineer to verify anchor and panel capacities. In all cases, anchorage shall be compliant with the project specifications, requirements of the engineer of record, and/or applicable codes.

1.7.14. ANCHOR PLACEMENT: Anchors shall be placed per the locations indicated on the approved shop drawings and engineer's calculations.

1.7.14.1. When possible, it is preferred to reduce flexural stresses in stone panels by positioning anchors at optimum locations in the panel.

1.7.14.2. In some cases, for instance anchoring highly decorative stones with limited soundness in interior installations, it is preferred to allow the field mechanics to determine the anchor placement so that unsound regions of the stone panel can be avoided.

1.7.15. FILLING OF ANCHOR PREPS: Anchor preps in stone panels shall be filled to prevent rattling of the stone panel and to prevent moisture collection in the anchor prep in wet area installations.

1.7.15.1. Fillers may be cementitious or elastomeric and must be non-expanding.

1.7.15.1.1. Only flexible filler materials are recommended for continuous kerf anchorage.

1.7.15.1.2. Cementitious fillers are generally used for stone that are fully bedded in mortar, while elastomeric fillers are commonly used for thin cladding which will have caulked joints.

1.7.15.1.3. Verify that the elastomeric material is non-staining.

1.7.15.2. Elastomeric fillers of high modulus sealants are commonly used to allow greater flexibility to accommodate building movements.

1.7.15.3. Extremely rigid fillers, such as epoxy are generally not recommended, although there are some instances where they are appropriate.

1.7.15.4. The use of gypsum plaster (molding plaster) setting spots or gypsum based compounds for anchor preps fillers for exterior stone is not an acceptable practice.

1.7.15.5. Some anchors, specifically back-anchors, are designed to be used without filler in the anchor prep. Consult the anchor manufacturer's directions regarding the use, or nonuse, of filler for these anchors.

1.8. MORTARS AND ADHESIVES

1.8.1. PORTLAND CEMENT MORTAR: Portland cement mortar is a mixture of portland cement, sand, and lime in proportions of 1:3:½ to 1:4:½ for walls. Additional additives may be included in this mortar recipe. The stone is set with this mortar while the mortar bed is still in a plastic state.

1.8.1.1. Portland cement mortars can be reinforced with metal lath or mesh, backed with membranes, and applied on metal lath over sheathed studding.

1.8.1.2. Portland cement mortars are structurally strong, generally resistant to prolonged contact with water, and can be used to plumb and square surfaces installed by others.

1.8.2. THIN-SET MORTAR: Thin-set mortar, often times called "dry-set mortar", is a mixture of portland cement (although a few are not cement-based) with sand and additives providing water retention. Thin-set mortars are used both as bedding/adhesive layers and also as a bond coat for setting stone with other mortar systems.

1.8.2.1. Thin-set mortar is available as a factory-sanded mortar to which only water need be added. Cured thin set mortar is generally tolerant of prolonged contact with water but does not form a water barrier.

1.8.2.2. Thin-set mortar is not intended to be used in trueing or leveling the substrate surfaces as tile is being installed.

1.8.2.3. Specifications for various thin-set mortar varieties can be found in ASNI A118 as below:

1.8.2.3.1. A118.1: American National Standard Specifications for Dry-Set Cement Mortar

1.8.2.3.2. A118.3: American National Standard Specifications for Chemical Resistant, Water Cleanable Tile-Setting and -Grouting Epoxy and Water Cleanable Tile-Setting Epoxy Adhesive

1.8.2.3.3. A118.4: American National Standard Specifications for Modified Dry-Set Cement Mortar

1.8.2.3.4. A118.5: American National Standard Specifications for Chemical Resistant Furan Mortars and Grouts for Tile Installation

1.8.2.3.5. A118.8: American National Standard Specifications for Modified Epoxy Emulsion Mortar/Grout

1.8.2.3.6. A118.11: American National Standard Specifications for EGP (Exterior Glue Plywood) Latex-Portland Cement Mortar

1.8.2.3.7. A118.15: American National Standard Specifications for Improved Modified Dry-Set Cement Mortar

1.8.3. Limestone (or other light-colored stones) Setting Mortar: Cement used in mortars for setting limestone and other light colored stones shall be of white portland cement per ASTM C150, or white masonry cement per ASTM C91. Nonstaining cement shall contain not more than 0.03% of water-soluble alkali when determined in accordance with procedure 15, calculation 16 of ASTM C91 or Federal Specification SS-C181C. However, if a large amount of standard cement has been used in the backup material and an effective water barrier has not been provided between the stone and the backup, the use of nonstaining cement may not prevent discoloration. Discoloration will reduce or disappear as the stone dries. The Indiana Limestone Institute recommends a 1:1:6 (portland: lime: sand) or Type N mortar be used with Indiana Limestone. At the present time, there are few masonry cement mortars produced labeled "nonstaining."

1.9. GROUTS

Cementitious grouts used as joint fillers can be sanded or unsanded as required. Sanded grouts tend to have greater strength and durability than unsanded grouts, but can introduce the risk of surface scratching when installed in stone varieties that are softer than the aggregate in the grout, and can be difficult or impossible to install in narrow (≤⅛", ≤3 mm) width joints.

1.9.1. Sanded portland cement grout is normally field-mixed in proportions of one part portland cement to one part clean, fine-graded sand (per ASTM C144) used for joints up to ⅛" wide; 1:2 for joints up to ½" wide; and 1:3 for joints over ½" wide. Hydrated lime may be added, not exceeding 1/5 part. Damp curing is preferable.

1.9.1.1. Sanded-portland cement grout should be applied with caution with softer varieties of stone with honed or polished finishes because it may scratch the stone surface. Masking of the stone may be necessary.

1.9.2. Unsanded portland cement grout is a commercially available mixture of portland cement and other ingredients, producing a water-resistant, dense, uniformly colored material, and is normally available in white or gray colors. Damp curing is advantageous for this material. Unsanded grout is typically used for joints of ⅛" (3 mm) or less, or when soft varieties of stone are used with polished finish which could be scratched by the aggregate in sanded grout.

1.9.3. Polymer Modified Portland Cement Grout is a mixture of any of the preceding grouts with polymer admixtures. The common polymer types are latex and acrylic. This grout is suitable for all installations subject to ordinary use and for most commercial installations. The use of polymer additives in portland cement grout increases the flexibility of the grout and reduces the permeability. Consult the grout and polymer manufacturers for specific instructions.

1.9.3.1.1. Specifications for polymer modified portland cement grouts can be found in A118.7 American National Standard Specifications for High Performance Cement Grouts for Tile Installation.

1.9.4. Coloring of Grouts: Many manufacturers offer grouting materials in colors. Architects and Designers find them pleasing for aesthetic reasons. Since some stones are more porous than others, test to determine the stability of the relationship between the colored joint filler and the stone before proceeding. Make certain pigments contained in the colored grout do not stain the stone. A mockup to test for staining and color consistency should be performed.

1.10. JOINT SEALANTS

1.10.1. Unlike grouting, which is almost always in the stone specification section, building sealants are normally covered in a separate specification section. While grouting is nearly always performed by stone setters, in most trade areas the installation of sealants is not in the trade jurisdiction of Marble Mechanics or Stonemasons.

1.10.2. Sealants should comply with the requirements documented in ASTM C920 Standard Specification for Elastomeric Joint Sealants.

1.10.3. Common joint sealant chemistries include silicone, urethane, and polysulfide.

1.10.3.1. Strict adherence to the written instructions of sealant manufacturer is required.

1.10.3.2. Primers may be required for some sealant/substrate combinations. Check manufacturer's requirements.

1.10.3.3. Some grades of silicone sealants are not recommended by their manufacturers for application on high calcite content materials. Consult the Sealant Manufacturer's technical recommendation before applying a given sealant to calcite materials.

1.10.3.4. All sealants shall be tooled to ensure maximum adhesion to the contact surfaces.

1.10.3.5. Specialty sealants exist for specific in-service conditions. For example, mildew-resistant silicone sealants formulated with fungicide are often used for sealing interior joints in showers and around tubs, sinks, and plumbing fixtures.

1.10.3.6. Oil based organic sealants should not be used in conjunction with natural stone products because they may stain the stone.

1.10.3.7. It is recommended that exemplar projects of the same stone type and sealant type be reviewed, or a mockup be prepared to ensure the sealant is non-staining and compatible with the stone.

1.10.3.8. Some sealants contain plasticizers which may wick into the stone perimeter and cause staining. If exemplar applications are not available to verify that the sealant does not contain staining plasticizers, testing per ASTM C1248 or ASTM D2203 is recommended. An adhesion test may also be required.

1.10.4. BACKER RODS: An important feature in the determination of the joint sealant is the selection of the backer rod.

1.10.4.1. The backer rod performs three functions:

1.10.4.1.1. Controls the depth and shape of the sealant profile.

1.10.4.1.2. Provides support for the caulking sealant when it is being compressed during tooling.

1.10.4.1.3. Acts as a bond breaker for the sealant to prevent three-sided adhesion. (Three-sided adhesion can result in failure of the sealant.)

1.10.4.2. Backer rods are available as either "open cell" or "closed cell" type. Closed cell backer rods are generally preferred as they do not absorb water like an open cell rod. Caution is necessary when installing closed cell rods to avoid puncturing the closed cell rods. A punctured rod, during periods of increasing temperature will exhaust air as the air trapped within the rod expands. This leads to a possible bubble or breach of the sealant joint.

1.10.4.3. Consult the Sealant, Waterproofing, and Restoration Institute guidelines for further information on proper joint sealant design, selection, and installation.

1.11. JOINTS

1.11.1. EXPANSION, AND MOVEMENT JOINTS

1.11.1.1. Expansion Joints. In exterior stone walls, expansion joints may be provided to reduce the damaging effect of building and/or veneer movements due to thermal expansion, structural live load deflection, seismic displacement, and other applicable movements based on project conditions and material properties. Because of the many conditions and structural systems in which stone can be installed, the Specifying Authority or engineer of record shall show locations and details of expansion joints on project drawings and/or calculations.

1.11.1.2. Movement Joints are also required in fields of paving. Movement joints extend through the finish layer only, and provide an interruption to the accumulation of shear stress resulting from differential in expansion between the finish layer and substrate layers of the paving assembly. Reference ANSI A108.01 section 3.7 and ANSI A108.02 section 4.4 and TCNA EJ 171 for guidance on movement joint location and design.

1.11.2. Joint Size: Typical joint widths are:

1.11.2.1. Exterior Stone Cladding: Minimum ¼" (6 mm), preferably ⅜" (10 mm). Joints of ½" (12 mm) or larger are frequently required for large unit size installation.

1.11.2.2. Interior Stone Cladding: Minimum 1/16" (1.5 mm), preferably ⅛" (3 mm). Joints of ¼" (6 mm) or larger are frequently required for large unit size installation.

1.11.2.3. Tight or "hand-butted" joints are not recommended.

1.11.3. Shims: Shims shall be stainless steel or high-impact plastic or approved equal. Shim size shall distribute the loads to ensure that point loading does not affect stones performance.

1.11.3.1. Where permanent setting pads (shims) are required, 90 durometer neoprene or high-impact plastic is recommended. Placement of setting pads (shims) shall be positioned to accommodate effective load transfer and avoid interference with joint filler materials.

1.11.3.2. Shims used in joints of "stacked" veneer systems remain in the joint permanently to transfer load from course to course. Shims may be used to temporarily maintain joint width in other joint conditions but are to be removed prior to application of joint filler material.

1.12. LIPPAGE

1.12.1. Tolerances for allowable lippage can be found in Chapter 22 on Tolerances.

1.12.2. Allowable lippage is an installation tolerance and is additive to the inherent warpage of the stone unit.

1.12.3. Lippage tolerances may not be attainable in flamed, cleft, or otherwise textured finishes. In those installations, joint width should be increased to limit perceived lippage, and in some cases joints as wide as ¾" (20 mm) may be required.

1.12.4. Lippage tolerances may not be achievable in extremely large stone panels, in which case larger than typical joint widths are recommended to minimize perceived lippage.

1.12.4.1. It is recommended that exposed stone edges be gauged to the precise thickness specified, particularly when the condition includes multiple pieces in a continuous run.

1.13. SURFACE SEALERS

1.13.1. Sealing the Face of the Stone: This section does not imply that sealing the face of the stone is a necessary practice. Application of sealers is a common practice in certain instances, such as when high porosity stone is installed or when the stone is installed in a food or beverage service area. If any sealer coating is specified for any natural stone material, advice should be sought in detail from qualified stone suppliers or installers (See Chapter 3, pg. 3-5, Section 5.10).

1.13.1.1. While commonly referred to as "sealers" the products used to treat stone surfaces are typically an "impregnating repellent", which when properly applied will preserve the ability of the stone to transmit water vapor ("breathe").

1.14. THERMAL INSULATION

1.14.1. Because heat is easily transmitted through stone when stone is part of a system assembly, insulation should be provided by other contractors. A minimum 1" (25 mm) cavity shall be maintained between the stone and the insulation to prevent contact between the two materials.

1.14.2. To comply with regional energy codes, stone anchorage may require a thermal isolator to reduce the conductivity of the anchorage assembly.

1.15. FIRE RATINGS

Stone is not combustible according to underwriters' ratings, and therefore is considered a fire-resistant material. Because of its thermal conductivity, heat transfer is fairly rapid. Most stone is not considered a highly rated thermal insulator.

1.15.1. Underwriters' fire-resistance ratings evaluate whether or not a material will burn, as well as how long it will keep surrounding combustible materials from reaching temperatures that will cause them to ignite. Methods of estimating fire-resistance periods of masonry walls and partitions utilizing component laminae are given in "Fire Resistance Classifications of Building Construction," BMS92, National Bureau of Standards.

1.15.2. Fire resistance of a material does not constitute a "fire rating". Fire ratings are established for construction assemblies, of which the stone would be only one component. Because changing the stone variety would nullify the fire rating of the assembly, it is cost prohibitive to provide the testing and documentation required to include the benefit of the stone's fire resistance to a fire rated wall. Therefore, when a fire rating is required, it is normally achieved by construction of a fully fire rated wall behind the stone face, typically with multiple layers of gypsum board.

1.16. ENGINEERING

The attachment systems for many interior and low-rise stone installations of limited scope are designed by empirical methods and are not reviewed by a registered or licensed engineer. As the scope and complexity of installation increases, or the complexity of the project environment increases (e.g.: special wind or seismic regions), having the design completed and/or reviewed by a registered, licensed professional experienced in stone attachment system designs becomes necessary.

1.16.1. A knowledgeable and experienced Installer must provide an engineered and fabricated system that will satisfy functional and aesthetic requirements. However, determining which performance requirements and the criteria under each must be made by the Specifying Authority in consultation with the Structural Engineer.

2. EXTERIOR INSTALLATION SYSTEMS

Vertical Stone Surfaces are installed with a variety of conventional and proprietary systems. A brief discussion of the more common types is below:

2.1. INDEPENDENTLY SUPPORTED VENEER

Each stone panel is independently supported (relieved and restrained) by mechanical anchorage attached to the backup wall substrate (building structure, masonry backup, stud framing assembly, miscellaneous steel etc.).

2.1.1. The stone panels and associated anchorage are designed to accommodate vertical loads (stone unit self-weight) and lateral loads (wind and seismic forces) as required by governing codes and/or project specifications. Each of these loads is transferred directly to the backup wall substrate through the stone anchorage. Joints between each stone are designed to accommodate thermal expansion and differential movement between stone units, and therefore, must remain free of shims, mortar, or any other rigid material that would transfer load from one stone to another. The joints are typically filled with a non-staining sealant that possesses extension and compressive capacities adequate to meet the performance requirements for the project. A minimum joint width of ⅜" (10 mm) is recommended for exterior stone veneer. Larger joints may be required to accommodate specific project demands. Note: This system can also be installed as a rainscreen or open-joint façade omitting joint sealant between stone veneer units.

2.1.1.1. Concrete/CMU Substrates: Independently Supported veneer systems can be anchored directly to cast-in-pace concrete or Concrete Masonry Unit (CMU) backup walls. In most cases, the cores of CMU wall require filling to provide adequate capacity for the drilled anchors.

2.1.1.2. Metal Frame Substrates: Independently Supported veneer systems can be anchored to miscellaneous metal framework by either welding or bolting, or a combination of the two. All elements must have adequate corrosion protection.

2.1.1.3. Stud Walls: Independently Supported veneer systems can be anchored to stud frame walls.

2.1.1.3.1. Metal studs placed behind stone wall installations to support the stone must be engineered and sized to accommodate loads. Stud wall thickness must provide adequate pull-out capacity for fasteners (16 gauge or heavier is often required).

2.1.1.3.2. Continuous horizontal channels are frequently required to provide for more flexibility in attachment locations and to distribute loads uniformly over multiple studs.

2.1.1.3.3. Walls and partitions constructed of metal studs should be designed for a maximum deflection of L/720 for conditions utilizing thick-set or thin-set mortar installation methods.

2.1.2. Grid Systems, commonly composed of vertical and horizontal support framing of varying corrosion-resistant materials, such as aluminum, mild steel, cold-formed steel, or stainless steel. The framing is typically pre-installed in the stone setting cavity to the substrate or support wall. Stone supports are typically integrated in the system design.

2.1.3. Strut Systems are commonly composed of vertical support framing of varying corrosion-resistant materials such as aluminum, mild steel, cold-formed steel or stainless steel. The framing is typically pre-installed in the stone setting cavity to the substrate or support wall. Non-integrated stone supports are typically attached in a method similar to Independently Supported Veneer or "Stacked" Veneer with Relieving Supports.

2.1.4. Integrated Curtainwall Stone veneer installed in glazing channels of glazed curtain wall members or mechanically fastened to mullions in similar manner to metal spandrel panels in a manner similar to glass or curtainwall spandrel panels.

2.1.5. Bi-Material Composite Panels

2.1.5.1. Lightweight Natural Stone Veneer Panels Definition: This product is a bi-material panel using a thin (±5 mm) stone face adhesively bonded to a lightweight aluminum backer. Most stone varieties and finishes are available, although each manufacturer has several preferred stones available in their offerings. Attachment of these systems is commonly done with a proprietary attachment system available from the panel manufacturer.

2.1.5.2. Other backing materials are used in addition to aluminum, including carbon fiber, fiberglass, stone, and concrete.

2.2. STACKED VENEER

Restraint and relief are achieved by using a combination of lateral ties (straps, split-tail anchors, welded tees, or other positively engaged mechanical anchorage approved by a qualified design professional) and gravity relief supports.

2.2.1. Each stone panel is restrained by mechanical anchorage attached to the backup wall substrate (building structure, masonry backup, stud framing assembly, miscellaneous steel, etc.). The stone panels and associated anchorage are designed to accommodate lateral loads only (wind and seismic forces) as required by governing codes and/or project specifications. These loads are transferred directly to the backup wall substrate through the stone anchorage. Relieving supports (e.g., continuous angles or clips) are designed to accommodate the cumulative vertical load of the stone veneer units "stacked" between the relief support and expansion or control joint above, typically a live load joint at a floor/slab line. Relief supports are typically provided over all openings and at each story height (or maximum vertical spacing of 20' [6 m]). Within a "stack", vertical loads are typically transferred from one stone to another using load-bearing shims or mortar. The joints are typically filled with a non-staining sealant or mortar adequate to meet the performance requirements for the project.

2.2.2. Consideration of weeps and flashing is recommended when continuous relief angles are utilized. Relieving angles should be provided over all openings and at each story height (or maximum vertical spacing of 20' [6 m]). Angles should have ¼" (6 mm) weep holes every 2'-0" (600 mm). Refer to local codes for variance.

2.3. THICK BED, COURSED ASHLAR INSTALLATION

2.3.1. Coursed splitface ashlar veneers are anchored to the substrate wall to address lateral loads only. Dead loads (gravity loads) are carried downward through successive courses and ultimately borne by concrete corbels, shelf angles, or other means of transferring the load to the building frame.

2.3.2. The substrate wall may be cast in place concrete, concrete masonry units, or sheathed stud frame walls. In all cases appropriate waterproofing shall be applied to the substrate wall.

2.3.3. The stone product is typically split in a hydraulic guillotine, and will have irregular, cleft surfaces on both the front and back faces. The degree of this irregularity and depth of relief will vary pending the mineral structure, rift direction and intensity, and course height. The surfaces resulting from the guillotine will be both convex and concave. In many cases, the stone will be hand pitched in the field to create convex surfaces on all pieces yielding a "pillowed" look to each course of the wall.

2.3.4. When installing stone with a relatively uniform bedding thickness, an open cavity is usually maintained between the stone and the substrate wall. This cavity varies, pending construction tolerances and irregularity of the back surface of the stone, and can be anywhere from 1" to 4" (25 to 100 mm), and sometimes larger to accommodate insulation or other building envelope components. The cavity must be ventilated, and weeps must occur at the bottom course and at any course where water cannot travel vertically within the cavity (such as at a shelf angle location). Weeps must occur frequently, with lateral spacing typically every 3'-0" to 4'-0" (1.0 to 1.2 m) as joint pattern allows.

2.3.4.1. In some instances, for example field or rubble stone construction or other stone wall constructions using stone units of varying bedding thicknesses, a mortar-filled collar joint with a secondary drainage system is required in lieu of a vented cavity.

2.3.5. Dead load should be relieved at every floor line, and in no case shall the vertical dimension between relieving points exceed 20'-0" (6 m). Shelf angles used to relieve deadload may be mild steel with appropriate corrosion protection.

2.3.6. Lateral loads must be accommodated by anchors within the stone bed joints. Corrugated "brick ties" are not recommended. Masonry "loop" anchors, or anchors that penetrate the stone such as pin or bent strap anchors are preferred. These anchors shall be stainless steel. Anchor quantity and placement is governed by local codes, but typically requires one anchor for every 3 ft² (~4 anchors/m²). In some cases, for instance seismic regions, continuous rodding within the mortar bed may be required.

2.3.7. The stones shall be fully bedded in mortar. Type S mortar is typically used for harder stones (e.g., granite) and type N mortar is typically used for softer stones (e.g., limestone).

2.4. ADHERED VENEER

2.4.1. Thinset Adhered installation is generally limited to thin stone (¼" to ½" [6 to 12 mm] thickness) of heights not exceeding 15'-0" (4.5 m).

2.4.1.1. Units shall not exceed 36 inches (914 mm) in the greatest dimension nor more than 720 square inches (0.46 m²) in total area and shall not weigh more than 15 pounds per square foot (73 kg/m²) unless approved by the local governing officials and the engineer of record.

2.4.1.2. Recommended substrate materials are masonry and cementitious backer board.

2.4.1.3. Exterior Vertical Surfaces. When adhesive installation methods are used for exterior vertical surfaces, the stone shall be back buttered to achieve, as close as practical, 100% adhesive contact between the stone and the backup. Remove freshly installed tiles periodically during installation to verify adhesion level.

2.4.1.4. When thin stone tiles are installed on exterior vertical surfaces, they are fully reliant upon the backup and substrate for performance. Use of unstable backup materials should be avoided.

2.4.2. Thin-Bed Stone Adhered Systems are stone installation of ¾" to 1" (20 to 25 mm) stone units which are design to portray the look of thicker (±4" / 100 mm) stone veneers.

2.4.2.1. Thin-bed stone units shall not exceed 36 inches (914 mm) in the greatest dimension nor more than 720 square inches (0.46 m^2) in total area and shall not weigh more than 15 pounds per square foot (73 kg/m^2) unless approved by the local governing officials and the engineer of record.

2.4.2.2. Cast-in-place concrete, concrete masonry unit, and sheathed stud frame backup walls are suitable substrates for thin-bed stone installation.

2.4.2.3. An appropriate waterproofing membrane, either liquid or sheet applied, is required at the face of the substrate wall.

2.4.2.4. Thin-bed stone systems have limited adjustment capability, so concrete and CMU walls frequently require a metal lath with a scratch coat to provide for a more accurate plane to which the stone can be adhered. Sheathed stud frame walls always require metal lath with a scratch coat.

2.4.2.5. Corner units are often fabricated as an "L" shape to create the appearance of a thicker stone wythe.

2.4.2.6. Thin bed stone systems are adhered to the scratch coat with standard portland cement mortars or latex modified mortars.

2.5. STONE SOFFITS

Stone soffits may be anchored with back anchors, or edge anchors. In some cases soffits may be edge-supported.

2.5.1. When thinner stone panels are used for exterior soffits in high wind load environments and are only edge supported, additional measures to prevent uplift may be required.

2.5.2. Factors of Safety may need to be increased for soffit design to address the continuous loading condition of this application.

3. INTERIOR INSTALLATION SYSTEMS

Stone wall facing panels may be installed either by conventionally set method using nonstaining anchors, dowels, pins, cramps, wire, and mortar or plaster spots; nonstaining adhesive in securing thin tile units to interior vertical surfaces; or by one of the several mechanical methods.

3.1. ANCHORED SYSTEMS

3.1.1. Concrete/CMU Backup

3.1.1.1. Masonry Backup: May be poured-in-place concrete, hollow concrete block, brick, or other solid masonry surface. Normally, stone installation with this substrate will be set with a cavity.

3.1.2. STUD WALLS

3.1.2.1. Metal Studs: Must be engineered to accommodate all loads and be of adequate thickness to provide required fastener pullout values (16 gauge is generally recommended). Stone anchors may attach directly to the studs, or a horizontal track component may be used to carry the load of the anchor uniformly across several studs. Plywood, cementitious backer board, or gypsum board may be used as a non-loadbearing sheathing.

3.1.2.2. Wood Studs: Stone anchors may attach directly to the studs, or a horizontal track component may be used to carry the load of the anchor uniformly across several studs. Plywood, cementitious backer board, or gypsum board may be used as a non-loadbearing sheathing. The use of natural wood studs may require additional bracing, bridging, blocking or other provisions to prevent rotation or other deformation in the studs over time. When engineered studs are used, follow manufacturer's instructions for fastening and bracing requirements.

3.2. ADHERED SYSTEMS

In all conditions, the substrate must be installed sufficiently true and level so that the stone panels or tiles may be installed true and level and sufficiently rigid to ensure a satisfactory backup surface to the stone installation. (Industry standard: ⅛" in 10'-0" with no more than 1/32" between individual stones.)

3.2.1. For all applications, the stone tile shall be back buttered to achieve, as close as practical, 100% adhesive contact between the stone and the backup.

3.2.2. STONE TILE SYSTEMS

3.2.2.1. Stone Tile Installation References. The Natural Stone Institute has participated in the Tile Council of North America's (TCNA) development of the Handbook for Ceramic, Glass, and Stone Installation. This document is reprinted every year, although the handbook committee meets only biennially, so substantial revisions are likely to appear only biennially. This handbook includes a section dedicated to the installation of stone tile products. The details are not duplicated in the Natural Stone Institute publications. Contact the TCNA (www.tcnatile.com) or the Natural Stone Institute's Book Store to obtain a copy of the handbook.

3.2.2.2. Tile patterns shall be laid out so that no perimeter tile is less than ½ the width of the typical stone tile, except at the front of cutouts.

3.2.2.3. Suitable substrates for stone tile are masonry, cementitious backer board, and gypsum board. Do not use gypsum-based products in wet areas.

3.3. STONE BASE

Stone Base not exceeding 1-0" (300 mm) in height is most often adhesively attached. Stone base of greater heights generally requires mechanical anchorage.

3.4. STONE SOFFITS

Stone soffits are either edge supported, anchored with back anchors, or anchored with edge anchors. In some cases, thin (≤½", ≤12 mm) stone soffits in interior applications can be adhesively attached without mechanical anchorage. Consult the adhesive manufacturer for guidance in installation methodology and substrate recommendations.

3.4.1. Factors of Safety may need to be increased for soffit design to address the continuous loading condition of this application.

3.5. STONE FIREPLACE FACES

Anchorage of stone fireplace surrounds is accomplished similarly to other interior installations.

3.5.1. Provide adequate accommodations for expansion due to thermal effects, including absolute temperature and thermal gradients.

3.5.2. Caution is required in selecting joint sealer, anchor fillers, and/or adhesive materials that may be exposed to elevated temperatures. Consult the product manufacturer for recommendations.

4. TROUBLESHOOTING AND CAUTIONS

4.1. WET AREAS

Avoid the use of plywood or gypsum board as substrate materials. Provide a moisture barrier. Suitable substrates are masonry backup and cementitious backer board on metal or wood studs. Apply appropriate water proofing membranes to all substrates.

4.2. PROTECTION OF FINISHED WORK: During construction, the General Contractor shall protect all stone from staining and damage.

4.3. TOLERANCES

Fabrication and installation tolerances can be found is a separate chapter of this manual.

4.4. HYSTERESIS

Hysteresis is a phenomenon that affects certain "true" marbles. Unlike most stones, which return to their original volume after exposure to higher or lower temperatures, these marbles show small permanent increases in volume after each thermal cycle. This can result in differential expansion within the stone, which is more likely to be accommodated or restrained in thick veneers than in thin ones. If it is not restrained, bowing of the marble panels ensues. Bowing also stretches the face, which makes stones more porous and increases the vulnerability to corrosion from acids in the atmosphere and deterioration from freezing and thawing effects. If marbles with this tendency are selected, research shall be performed to determine the minimum thickness needed to overcome effects of hysteresis.

4.5. GYPSUM

The use of gypsum-based products as fillers in anchor preparations is not recommended in any environment and is specifically prohibited for any wet or potentially wet environment.

4.5.1. Ettringite: Ettringite can be formed by the combination of gypsum and portland cement. Ettringite has a volume that is greater than the sum of the volumes of the two parent components. Therefore, if portland cement and gypsum are mixed in a confined space (as in an anchor slot), extreme expansive forces will occur as the ettringite is formed, typically causing rupture of the anchor slot.

4.6. FIBERGLASS MESH BACKING

Producers frequently apply a fiber mesh reinforcement to the back surfaces of stone tiles and slabs to reduce breakage and also increase safety when handling large slabs. Caution should be used when using a stone that has a fiberglass mesh backing applied on the back face. The fiberglass, having been bonded to the stone with a resinous (commonly epoxy) adhesive, will not bond adequately with cementitious products. Only epoxy products, or products specifically made for fiberglass by the manufacture, should be used when installing stone with fiberglass mesh backing.

4.6.1. Regardless of the tenacity of the bond of the installation adhesive to the fiberglass mesh, the overall performance of the attachment system can be no greater than the bond between the fiberglass and the stone, of which the installer has no control. Testing of the bond at this interface is recommended.

4.7. GREEN COLORED STONE

Avoid the use of water-based adhesive when installing certain green marbles and/or serpentines. Some of these stones may warp through absorption of water from the setting bed. (Water drawn into the stone is held to the crystals by surface energy. This force tends to widen the intercrystalline space and thereby expand the wet side.)

4.8. SEALANT STAINING

Some elastomeric sealants contain oil-based plasticizers to reduce their modulus and increase their extension/compression capability. The plasticizers can wick into stone perimeters, causing darkening of the edge (picture framing) and accelerated dirt collection on the stone face. Caution should be used in specifying sealants to ensure compatibility with stone. It is recommended that either an exemplar project be identified using the same stone and sealant components with satisfactory results, or a testing regimen per ASTM C1248 or ASTM D2203 be performed.

4.9. EFFLORESCENCE

Efflorescence is a salt deposit, usually white in color that appears on exterior surfaces of stone walls and floors. The efflorescence is produced by salts leached to the surface of the stone by water percolating through the stone backup and joints. The most feasible means of prevention is to stop the entrance of large amounts of water. If the conditions bringing about the efflorescence continue, scaling may occur and flake off successive layers. For this to happen, large amounts of water must continue to enter behind the stone and must contain large amounts of salts.

4.10. DOWN WASHED LIGHTING

The use of down washed lighting and/or lighting of high angles of incidence, in which the path of light is nearly parallel to the face of the wall surface, is a popular choice in both interior and exterior designs. This lighting style will exaggerate lippage, textural surface variation, and even warpage due to the extremely elongated shadow lines caused by the slight angle of incidence. Material and installation which are within industry tolerances may appear to be outside of tolerances due to the accentuation of the lighting technique. Inspection of areas receiving down washed lighting shall be done with the down washed lighting turned off.

4.11. VARIATION IN GLOSS

It is almost impossible to uniformly read light reflection on a polished or high-honed-finish installation due to the natural characteristics of dimension stone. Due to the heterogeneous composition of natural stones, variable mineral hardness exists within the stone, producing variable reflectivity of light energy. Most stones, and especially travertine marbles and honed-finish surfaces, will appear to reflect light unevenly.

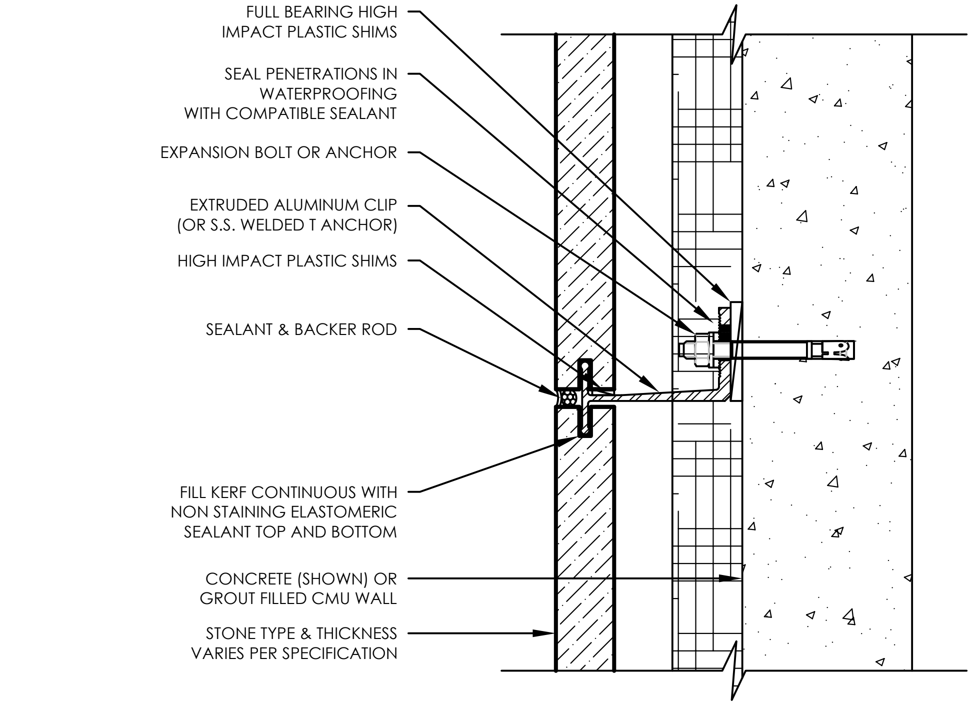
4.12. POLISHING WHEEL MARKS

Polishing wheel marks or other scratches caused during fabrication are unacceptable on honed or polished stone.

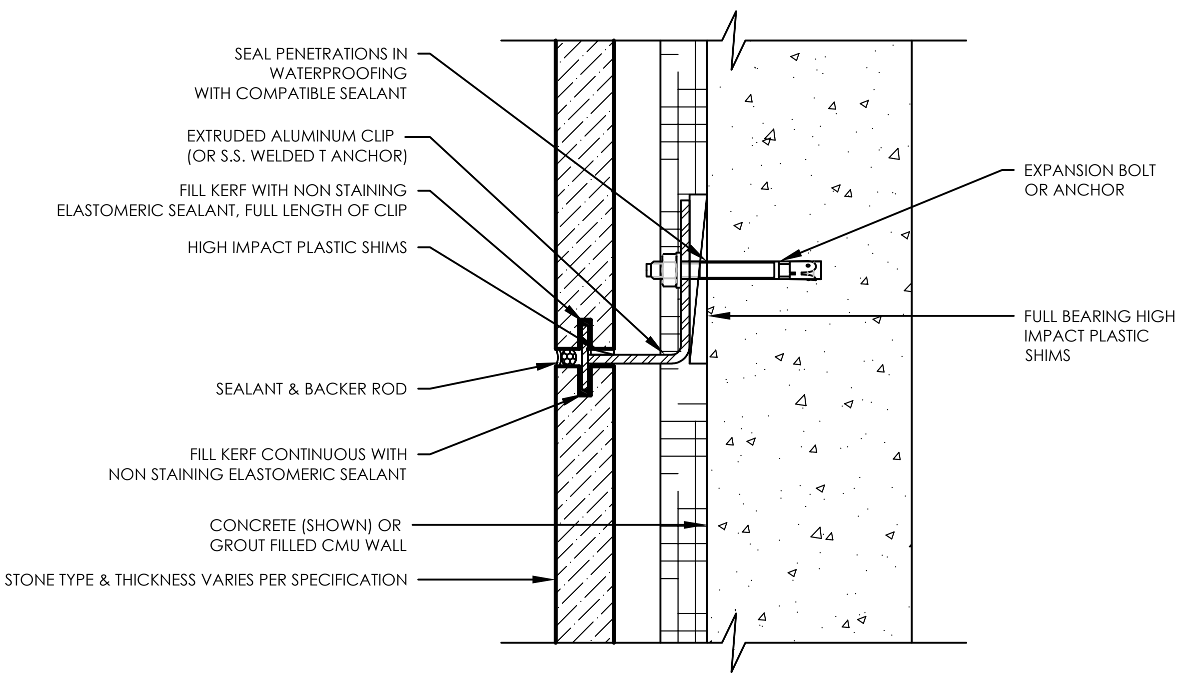
4.13. GEOGRAPHICAL VARIATION IN PRACTICE

Some installation methods and materials are not recognized and may not be suitable in some geographic areas because of local trade practices, building codes, climatic conditions, or construction methods. Therefore, while every effort has been made to produce accurate guidelines, they should be used only with the independent approval of technically qualified persons.

NOTES:



1 EXTRUDED ALUMINUM OR WELDED STAINLESS STEEL "T" ON CMU BACKUP



2 EXTRUDED ALUMINUM OR WELDED ST. STEEL "T" ON CONCRETE BACKUP

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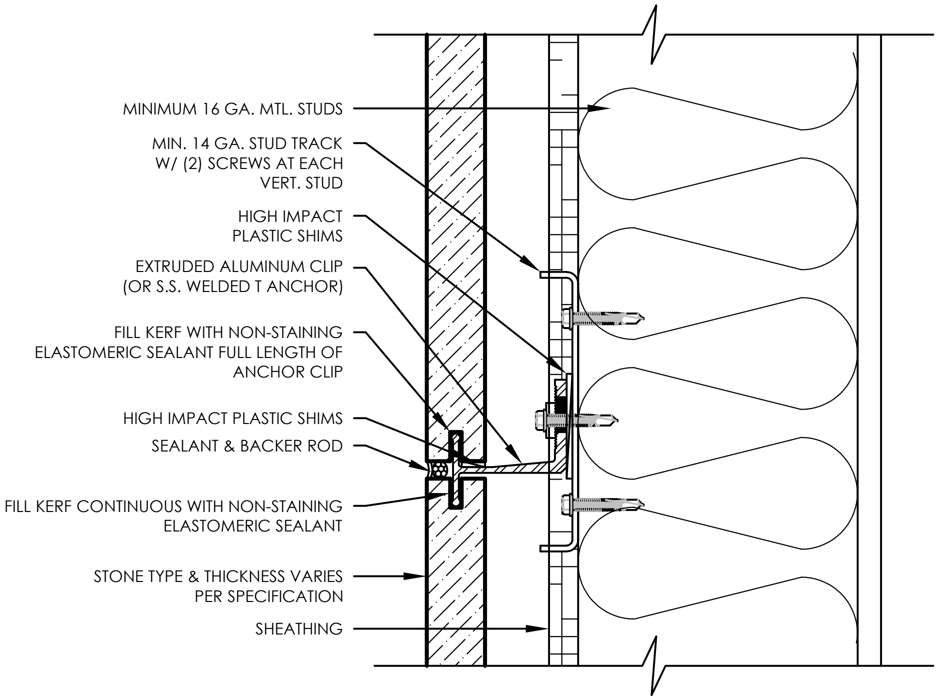
EXTERIOR STONE ATTACHMENT DETAILS

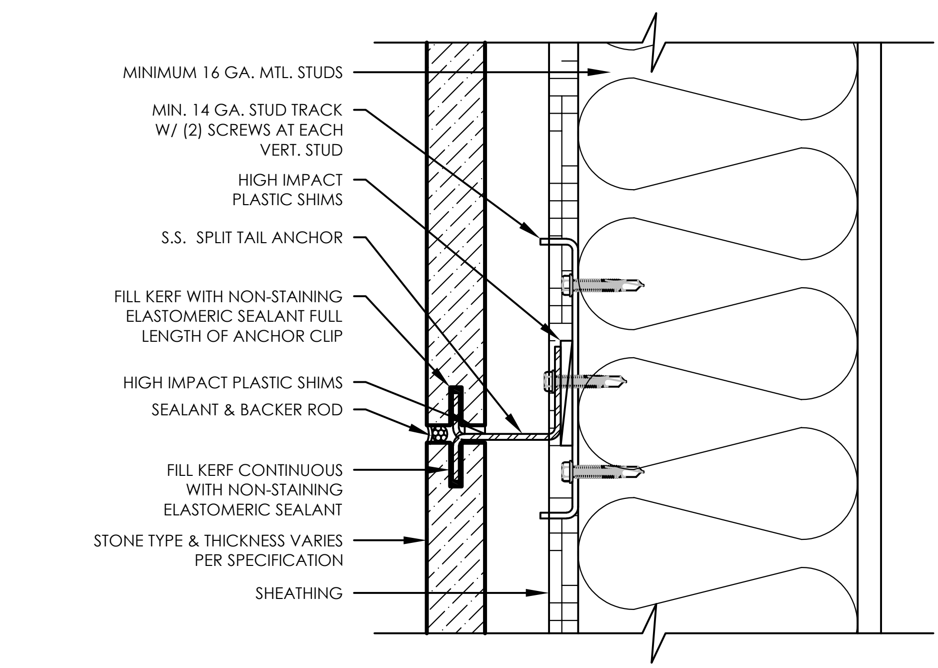
DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 14-D-1

SCALE: 3" = 1'-0"



1 EXTRUDED ALUMINUM OR WELDED ST. STEEL "T" ON METAL STUD BACKUP



2 STAINLESS STEEL SPLIT-TAIL ANCHOR ON METAL STUD BACKUP

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EXTERIOR STONE ATTACHMENT DETAILS

DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 14-D-2

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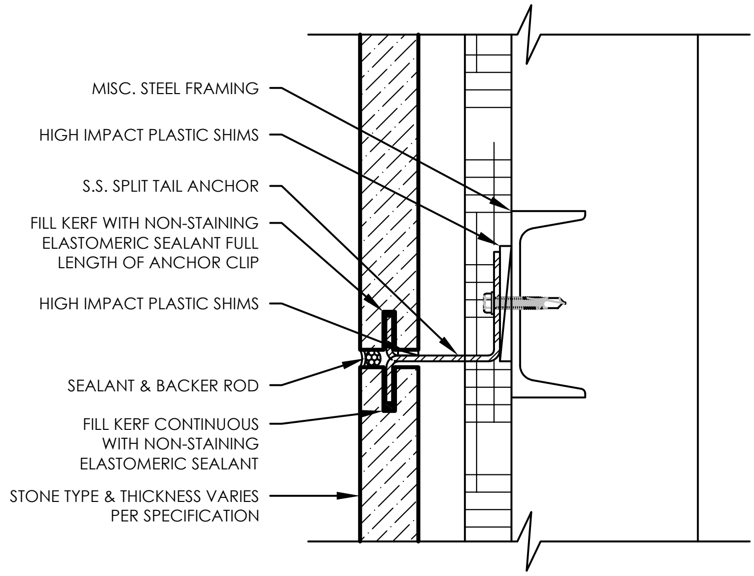
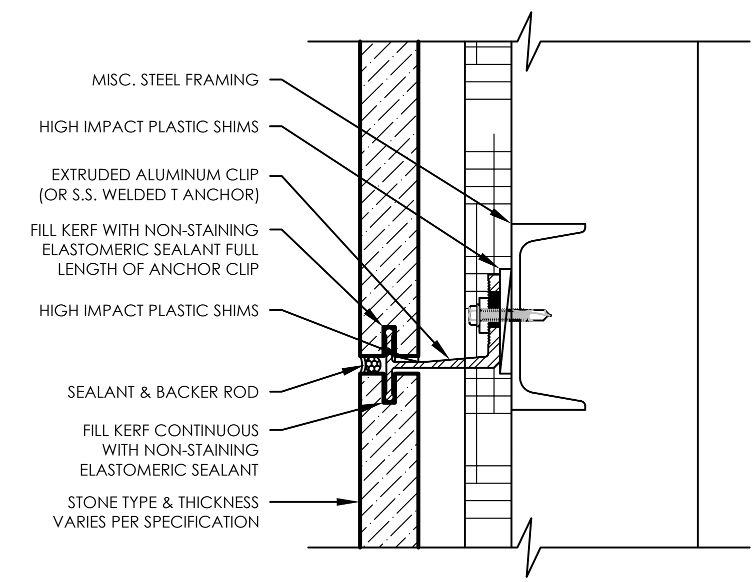


1 STAINLESS STEEL SPLIT-TAIL ANCHOR ON MISC. METAL BACKUP



2 EXTRUDED ALUMINUM OR WELDED ST. STEEL "T" ON MISC. METAL BACKUP

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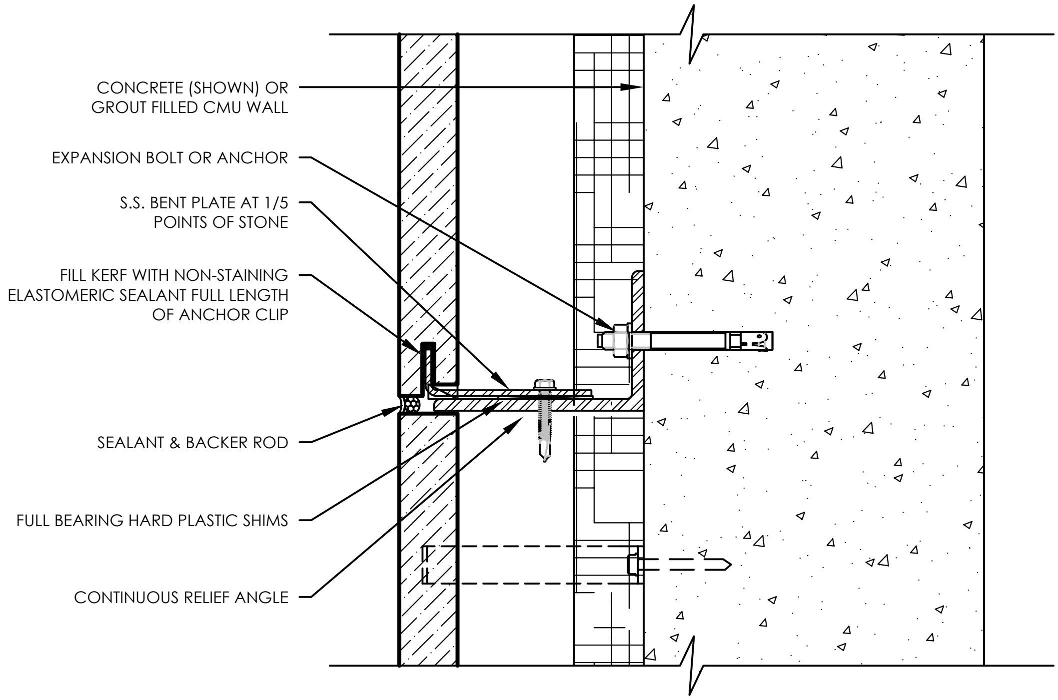
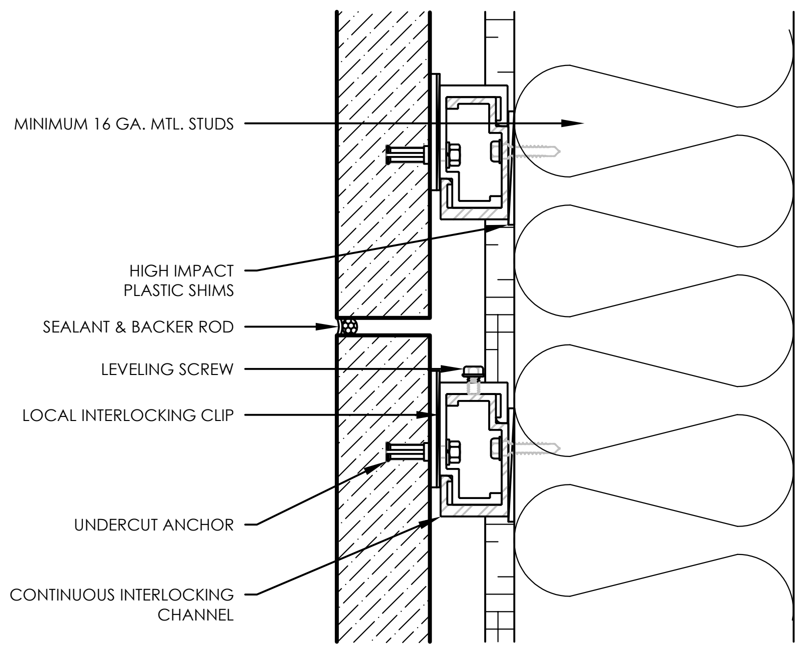
	0	MAR 2022	DIMENSION STONE DESIGN MANUAL 2022
			DRWG NO: 14-D-3 — SCALE: 3" = 1'-0"



1 RELIEF ANGLE CONNECTION ON CMU/CONCRETE BACKUP



2 INTERLOCKING GRID SYSTEM CONNECTION ON METAL STUD BACKUP

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EXTERIOR STONE ATTACHMENT DETAILS

DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 14-D-4

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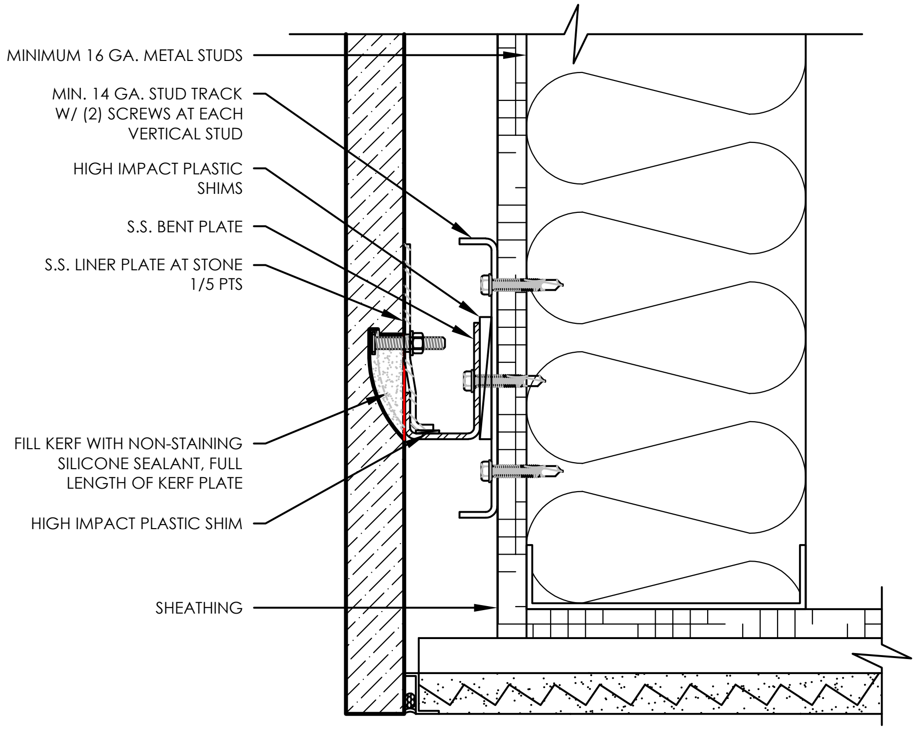
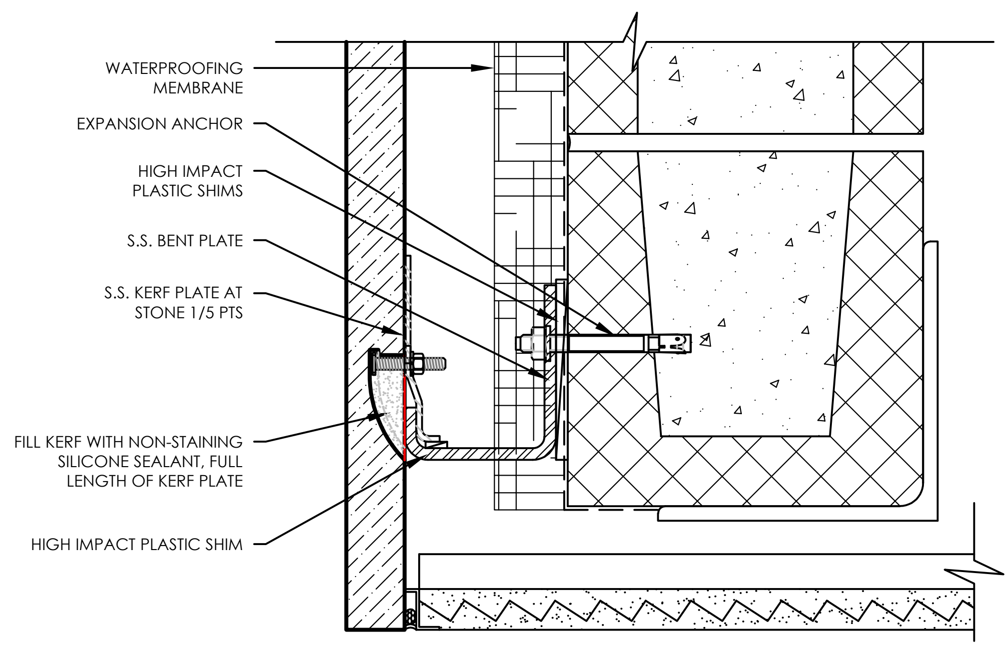


1 BACK ANCHOR & ST. STL. CLIP FOR "BLIND" CONNECTION ON METAL STUDS



2 BACK ANCHOR & ST. STL. CLIP FOR "BLIND" CONNECTION ON CMU/COMCRETE

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	0	MAR 2022	DIMENSION STONE DESIGN MANUAL 2022
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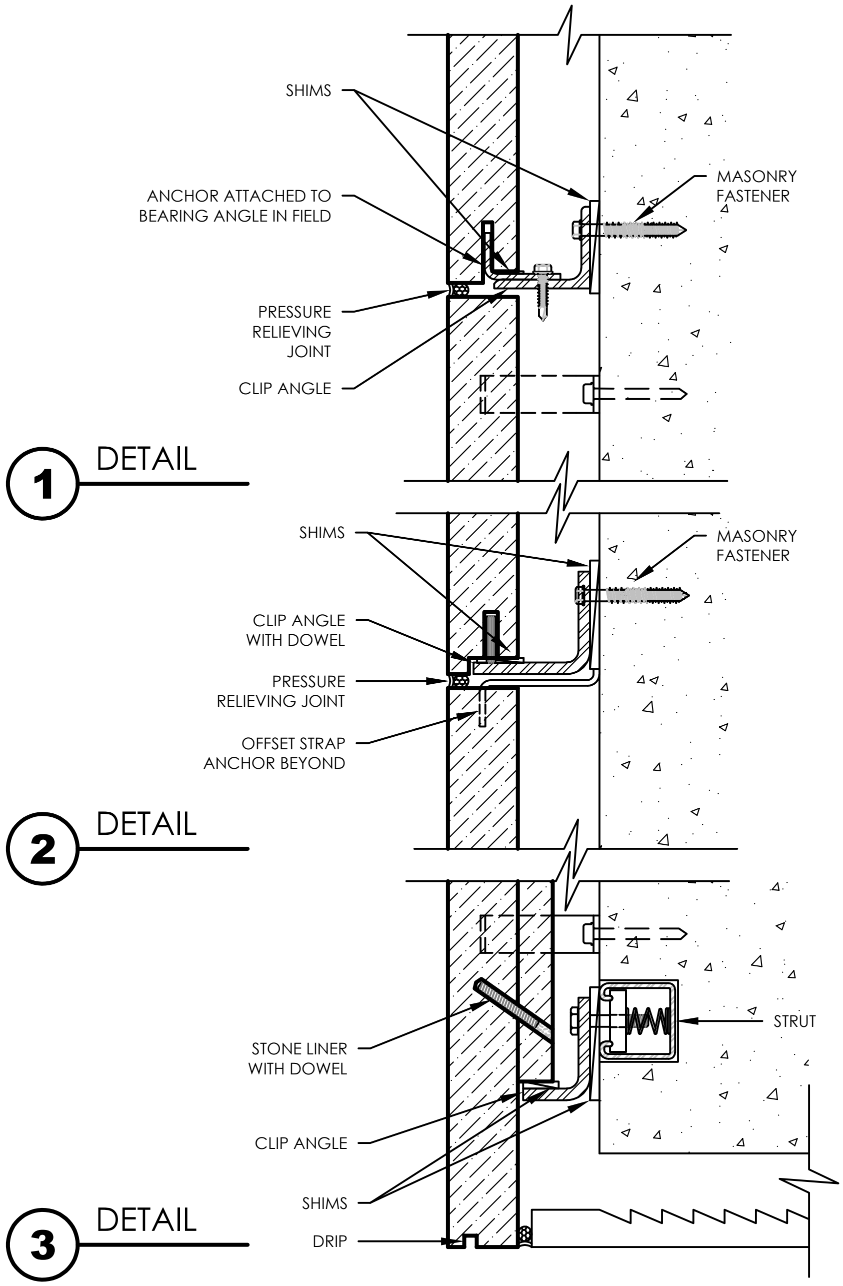

NOTE: 1. ALLOW ADEQUATE SPACE FOR ANCHOR BOLT HEADS.
2. NEVER ANCHOR THROUGH A PRESSURE RELIEVING JOINT.
3. ALL METALS IN DIRECT CONTACT WITH THE STONE MUST BE STAINLESS STEEL.

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EXTERIOR STONE RELIEF DETAILS WITH REBATED BEARING

DIMENSION STONE DESIGN MANUAL 2022

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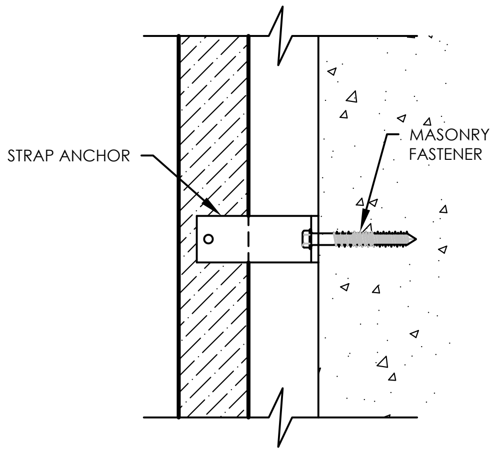
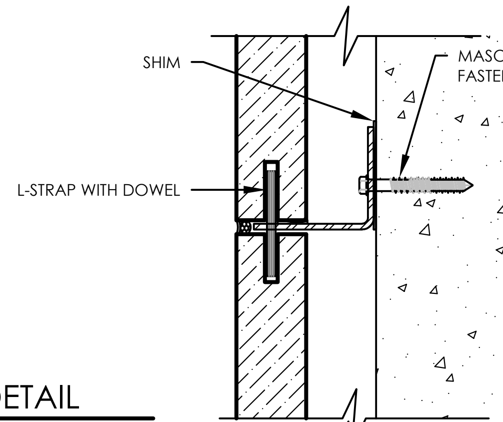
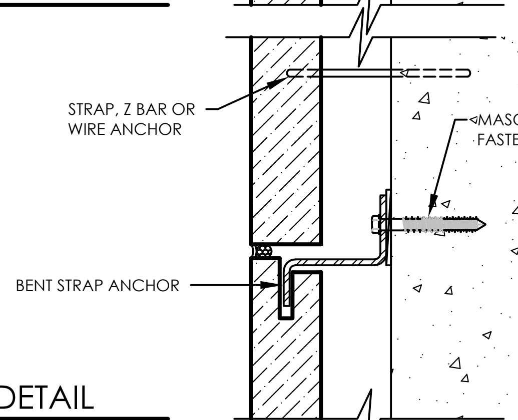


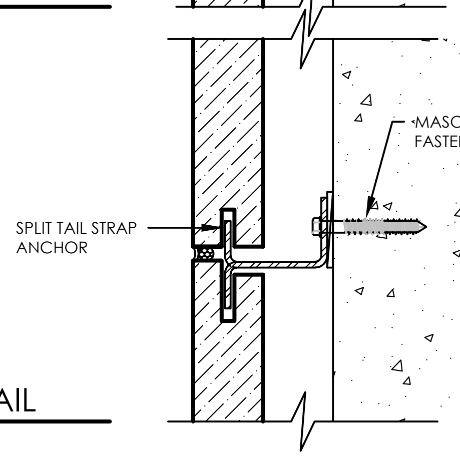
A DETAIL
OPTION TO ANCHOR IN VERTICAL JOINT



1 DETAIL



2 DETAIL



3 DETAIL

NOTE: 1. ALLOW ADEQUATE SPACE FOR ANCHOR BOLT HEADS.
2. NEVER ANCHOR THROUGH A PRESSURE RELIEVING JOINT.
3. ALL METALS IN DIRECT CONTACT WITH THE STONE MUST BE STAINLESS STEEL.

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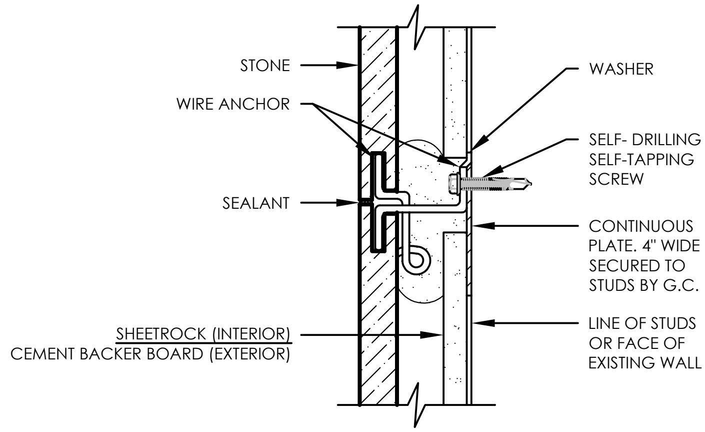
EXTERIOR STONE VENEER
RESTRAINT ANCHORAGE DETAILS

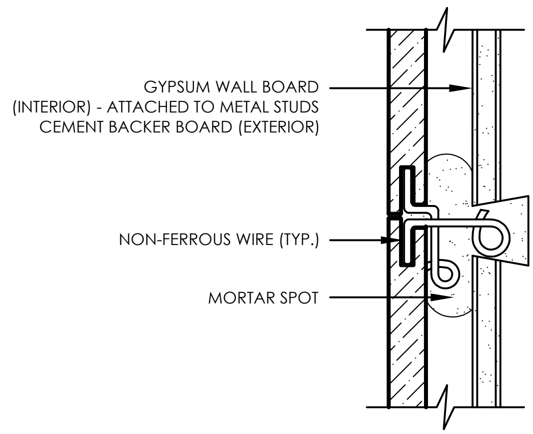
DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 14-D-7

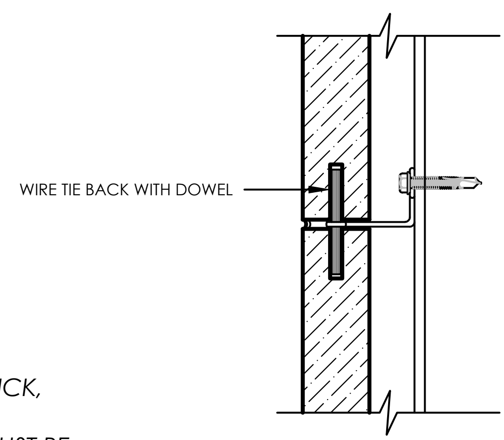
SCALE: 3" = 1'-0"



1 DETAIL



2 DETAIL



3 DETAIL

NOTES:

1. *EXPANSION BOLTS SHOULD ONLY BE USED IN BRICK, CONCRETE, OR FILLED CORE CMU BACK-UP.*
2. *ALL METALS IN DIRECT CONTACT WITH STONE MUST BE STAINLESS STEEL*
3. *ALLOW ADEQUATE SPACE FOR ANCHOR BOLT HEADS*

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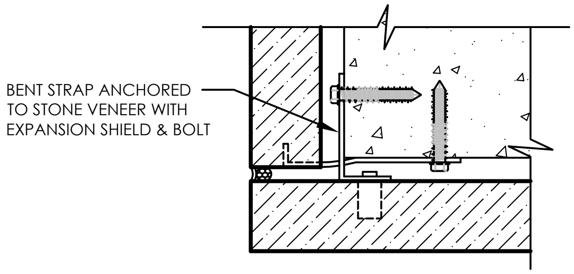
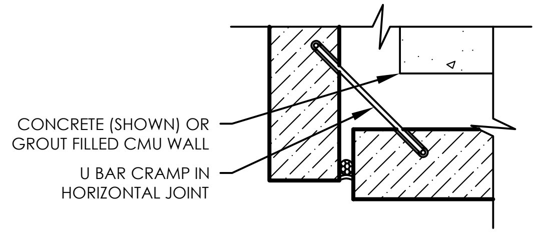
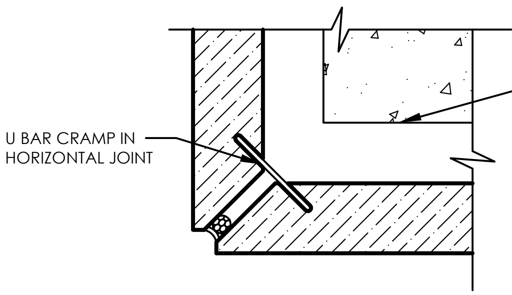
	0	MAR 2022		
			DRWG NO: 14-D-8	SCALE: 3" = 1'-0"



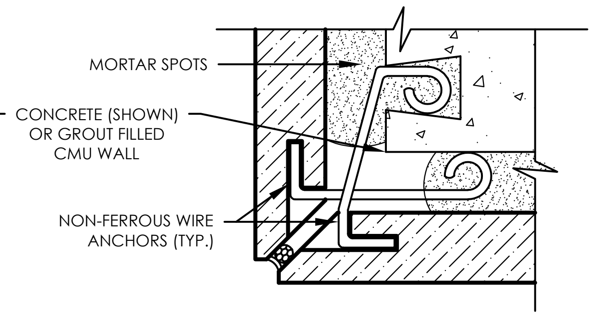
1 BUTT JOINT



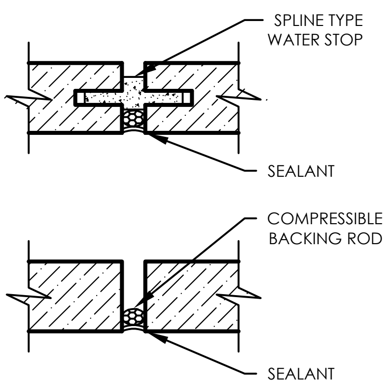
2 OFFSET BUTT JOINT



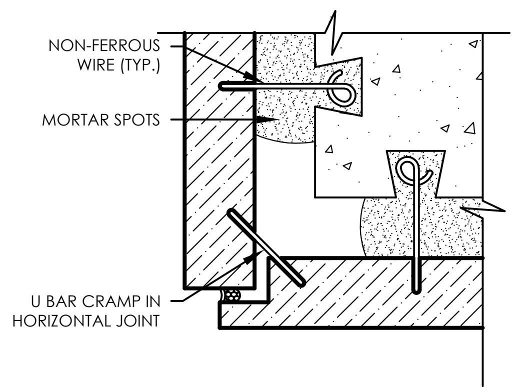
3 QUIRK MITER JOINT



4 QUIRK MITER JOINT



5 TYPICAL EXPANSION JOINTS



6 RABBETED JOINT

NOTE: ALL METALS IN DIRECT CONTACT WITH THE STONE MUST BE STAINLESS STEEL.

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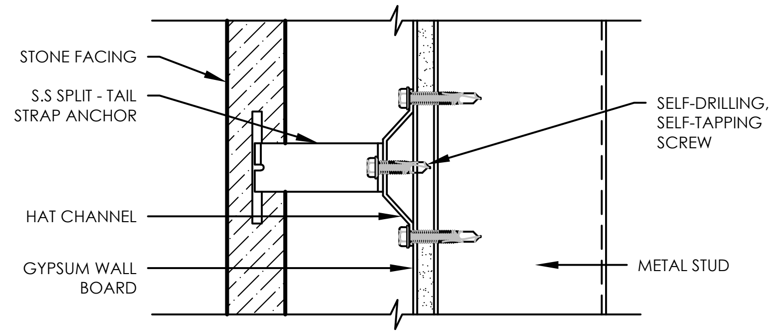
EXTERIOR STONE VENEER
CORNERS, EXPANSION JOINTS, REGLETS

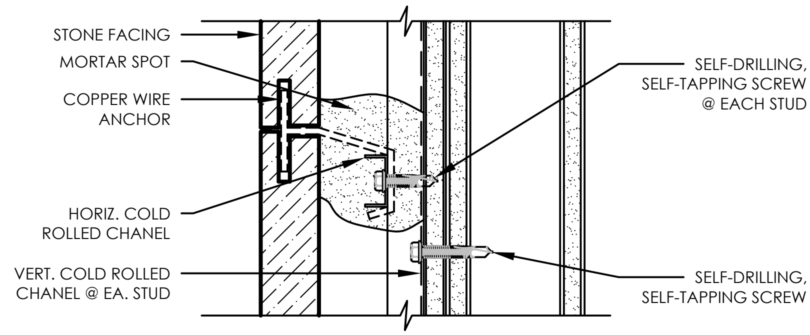
DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 14-D-9

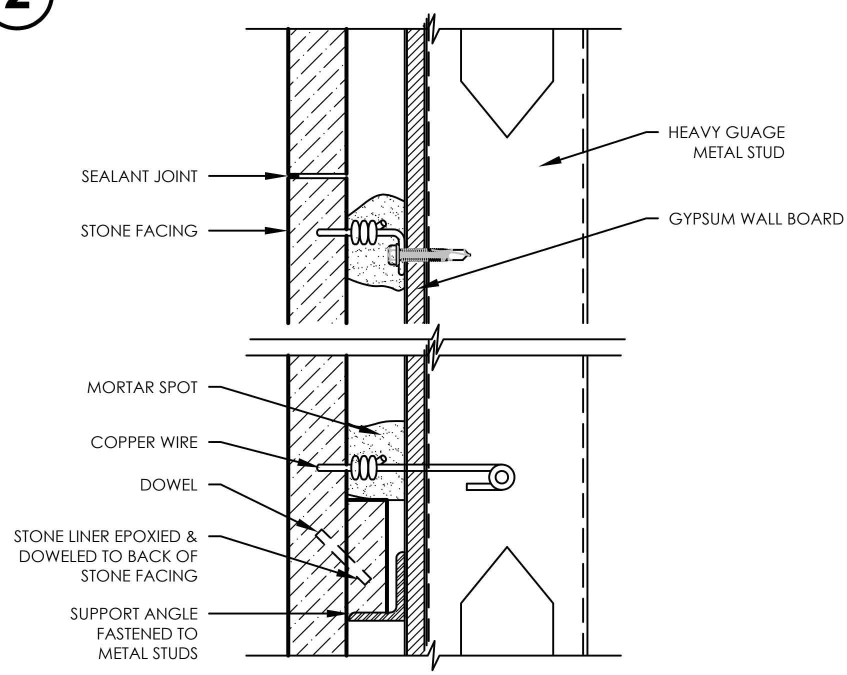
SCALE: 3" = 1'-0"



1 STRAP ANCHORED TO METAL STUDS



2 WIRE ANCHORED TO CHANNEL



NOTE: THIS CONDITION CAN ONLY BE USED IF THE OPPOSITE SIDE OF STUDS ARE EXPOSED AT THE TIME OF STONE INSTALLATION.

3 WIRE ANCHORED TO METAL STUDS

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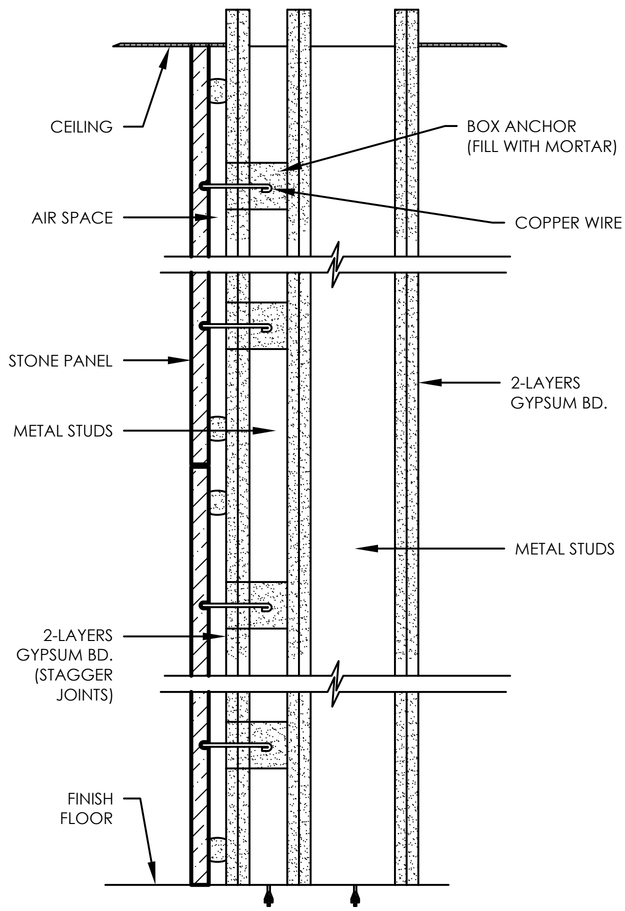
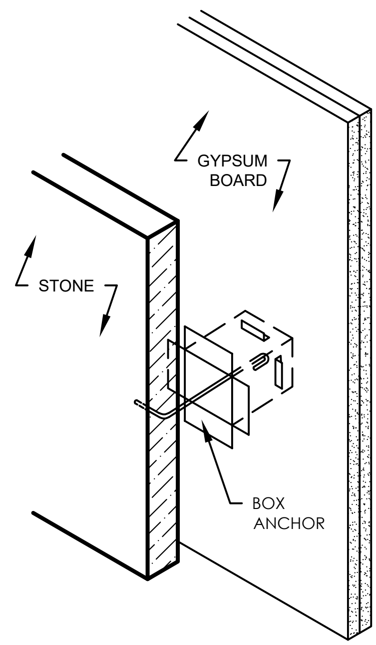
INTERIOR STONE CLADDING
WALL FACING DETAILS

DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 14-D-10

SCALE: 3" = 1'-0"





1 SECTION AT FIRE-RATED WALL
(CHECK APPLICABLE CODES)

NOTE: 1½" SETTING SPACE REQUIRED WHEN MARBLE LINERS ARE NOT EMPLOYED.

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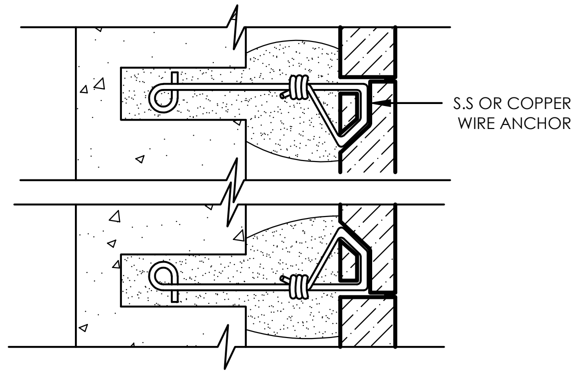
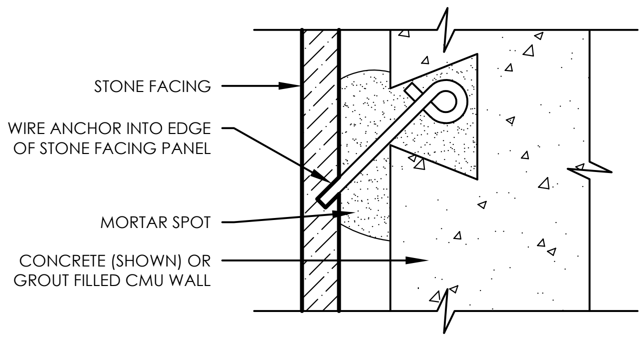
	0	MAR 2022	
			DRWG NO: 14-D-11 — SCALE: 3" = 1'-0"

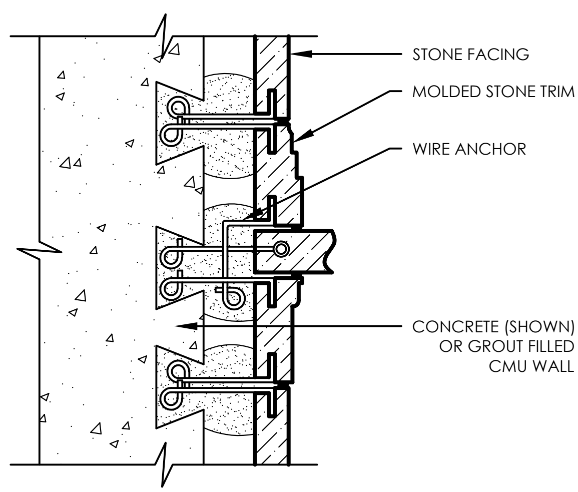


1 WIRE LACE ANCHOR

(TO BE USED ONLY WHERE EDGE CONDITION IS NOT AVAILABLE FOR ANCHORING)



2 WIRE ANCHOR IN MASONRY



3 WIRE ANCHORED MOULDED TRIM

NOTE: 1-1/2 INCH SETTING SPACE REQUIRED WHEN MARBLE LINERS ARE NOT EMPLOYED.

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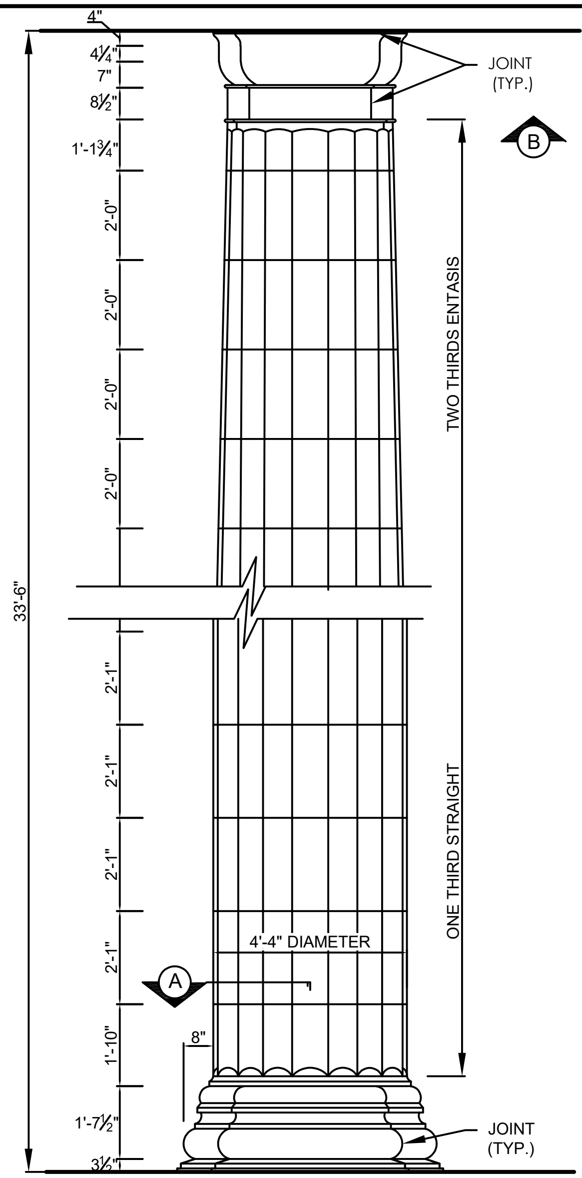
INTERIOR STONE CLADDING
COLUMN CLADDING DETAILS

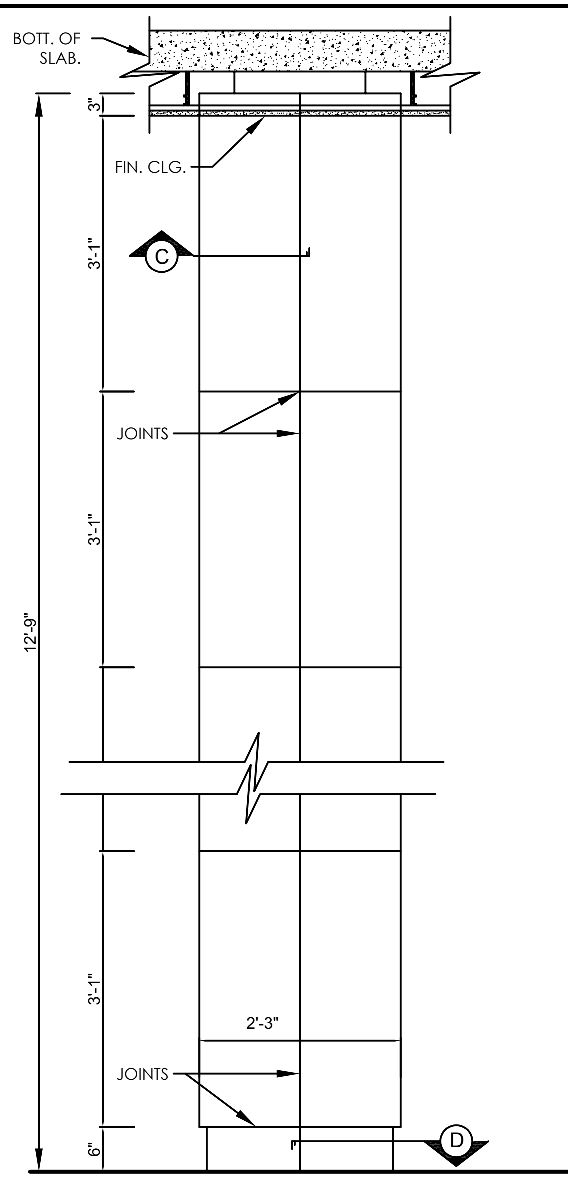
DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 14-D-12

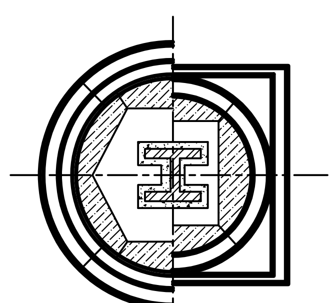
SCALE: 3" = 1'-0"



ELEVATION
1/4"=1'-0" (1:48)

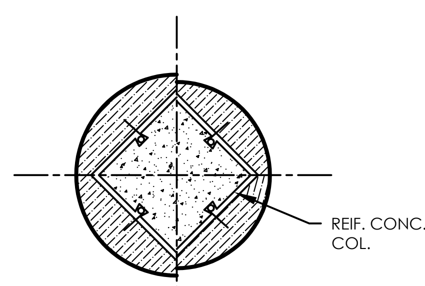


ELEVATION
1/2"=1'-0" (1:24)



PLAN A
1/4"=1'-0" (1:48)

PLAN B
1/4"=1'-0" (1:48)



PLAN C
1/2"=1'-0" (1:24)

PLAN D
1/2"=1'-0" (1:24)

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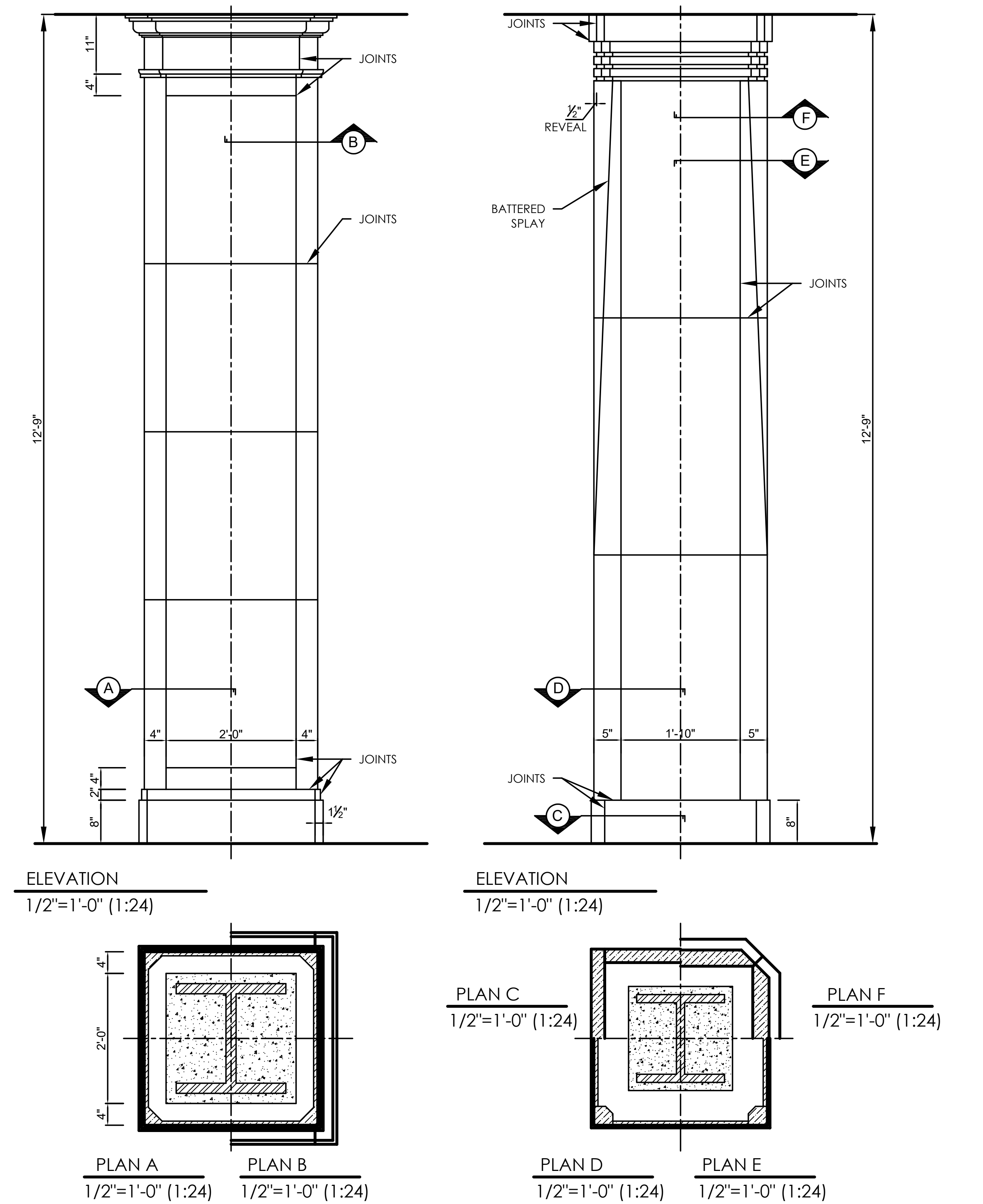
INTERIOR STONE CLADDING
COLUMN CLADDING DETAILS

DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 14-D-13

SCALE: As Noted

CAUTION: IF THIS SHEET IS NOT 8½" x 11", IT IS A REDUCED OR ENLARGED PRINT



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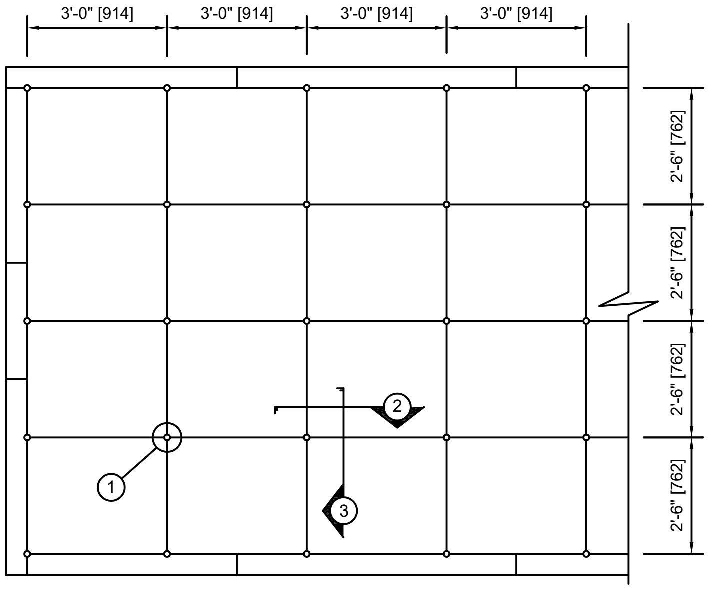
REV	DATE
0	MAR 2022

INTERIOR STONE CLADDING
COLUMN CLADDING DETAILS

DIMENSION STONE DESIGN MANUAL 2022

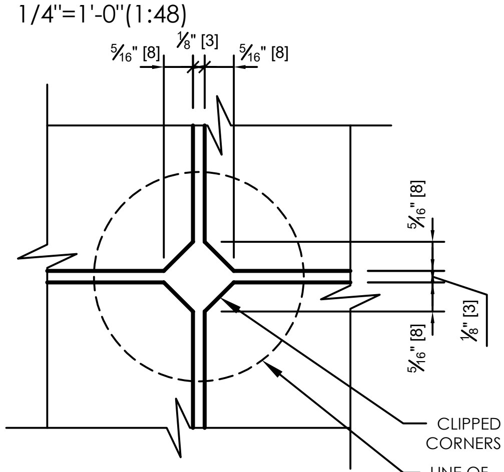
DRWG NO: 14-D-14

SCALE: As Noted

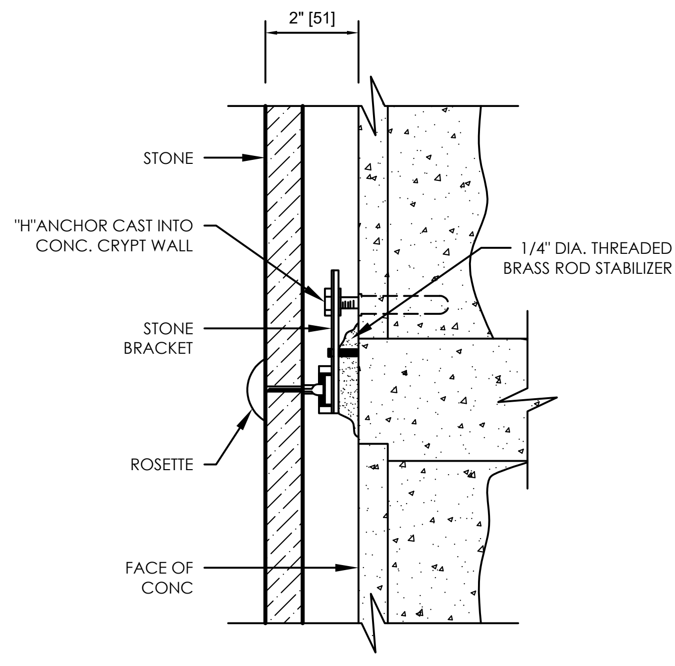


ELEVATION
1/4"=1'-0"(1:48)

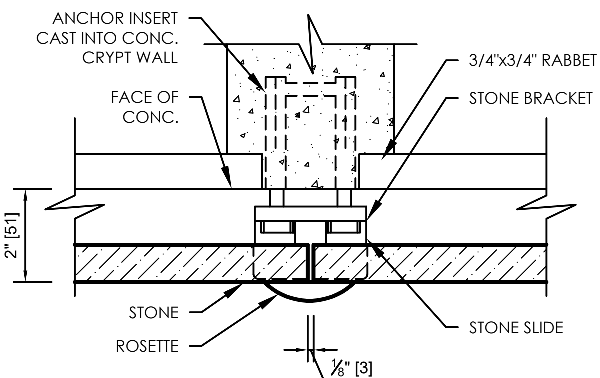
NOTE: DIMENSIONS ARE TO CENTER OF 1/8" JOINTS. TOP, BOTTOM AND SIDE TRIM PIECE WIDTH VARIES.



DETAIL 1
6"=1'-0"(1:2)



SECTION 3
3"=1'-0"(1:4)



PLAN 2
3"=1'-0"(1:4)

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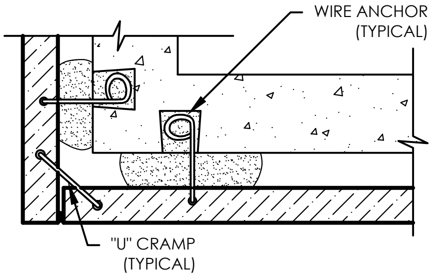
CRYPT COVER ATTACHMENTS WITH BRACKET & ROSETTE

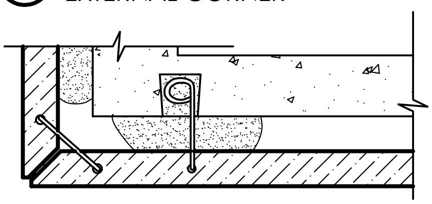
DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 14-D-15

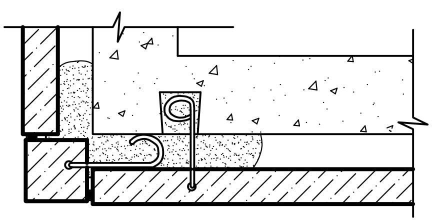
SCALE: As Noted



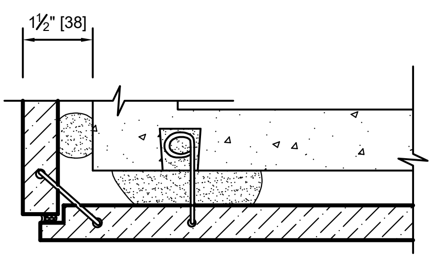
1 BUTT JOINT
EXTERNAL CORNER



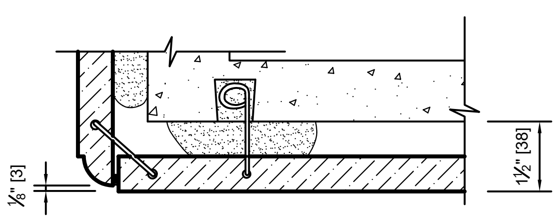
2 QUIRK MITER JOINT
EXTERNAL CORNER



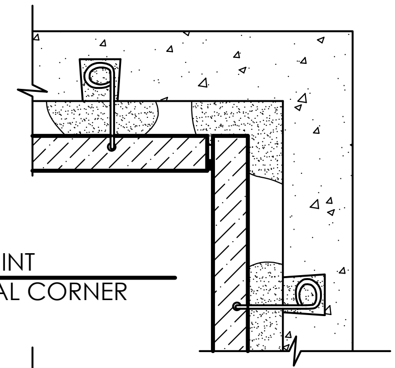
3 CORNER BLOCK JOINT
EXTERNAL CORNER



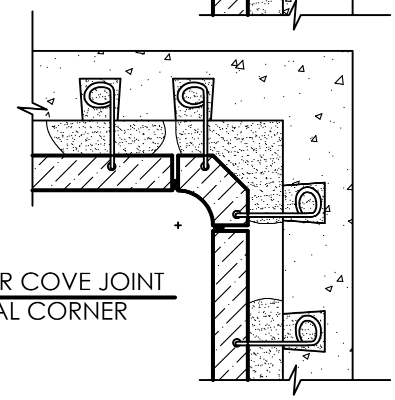
5 RABBETTED JOINT
EXTERNAL CORNER



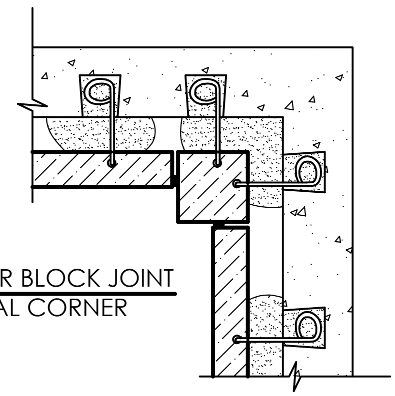
6 MOLDED JOINT
EXTERNAL CORNER



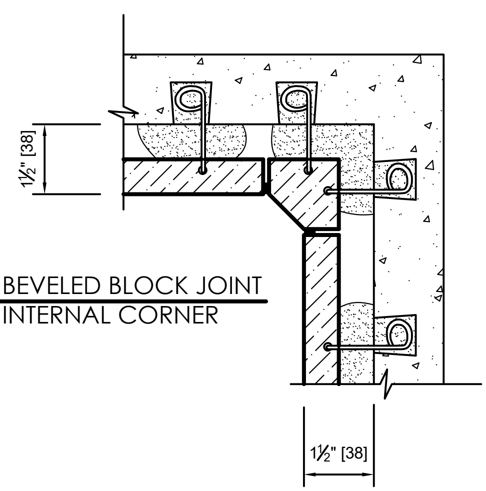
7 BUTT JOINT
INTERNAL CORNER



8 CORNER COVE JOINT
INTERNAL CORNER



9 CORNER BLOCK JOINT
INTERNAL CORNER



10 BEVELED BLOCK JOINT
INTERNAL CORNER

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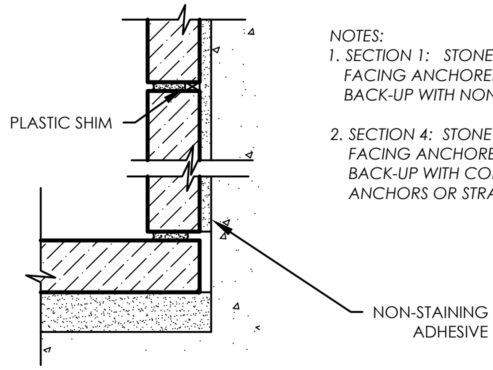
INTERIOR STONE ATTACHMENT
CORNER DETAILS

DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 14-D-16

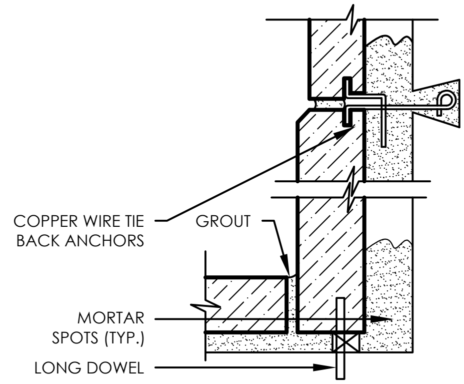
SCALE: 3" = 1'-0"



1 SECTION

NOTES:
1. SECTION 1: STONE BASE AND WALL FACING ANCHORED TO MASONRY BACK-UP WITH NON-STAINING ADHESIVE.

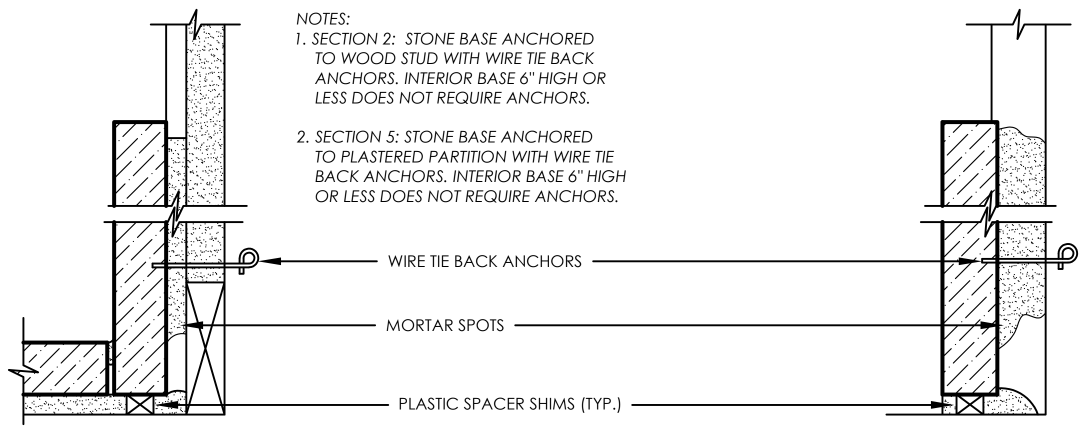
2. SECTION 4: STONE BASE AND WALL FACING ANCHORED TO MASONRY BACK-UP WITH COPPER WIRE TIE- BACK ANCHORS OR STRAP ANCHORS.



4 SECTION

NOTES:
1. SECTION 2: STONE BASE ANCHORED TO WOOD STUD WITH WIRE TIE BACK ANCHORS. INTERIOR BASE 6" HIGH OR LESS DOES NOT REQUIRE ANCHORS.

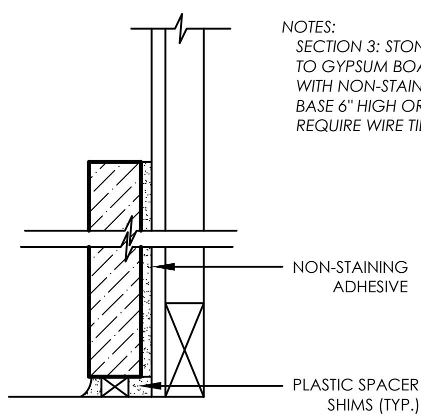
2. SECTION 5: STONE BASE ANCHORED TO PLASTERED PARTITION WITH WIRE TIE BACK ANCHORS. INTERIOR BASE 6" HIGH OR LESS DOES NOT REQUIRE ANCHORS.



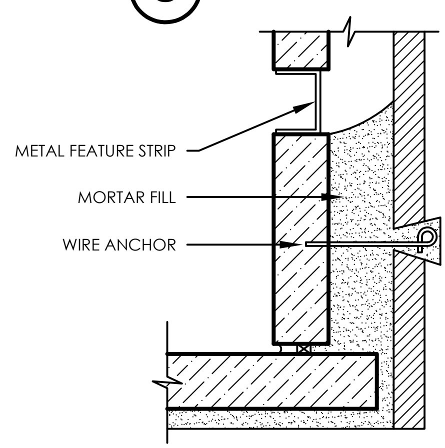
2 SECTION

5 SECTION

NOTES:
SECTION 3: STONE BASE ANCHORED TO GYPSUM BOARD PARTITION WITH NON-STAINING ADHESIVE. BASE 6" HIGH OR LESS DOES NOT REQUIRE WIRE TIE ANCHORS.



3 SECTION



6 SECTION

NOTE: ALL METALS IN DIRECT CONTACT WITH THE STONE MUST BE STAINLESS STEEL.

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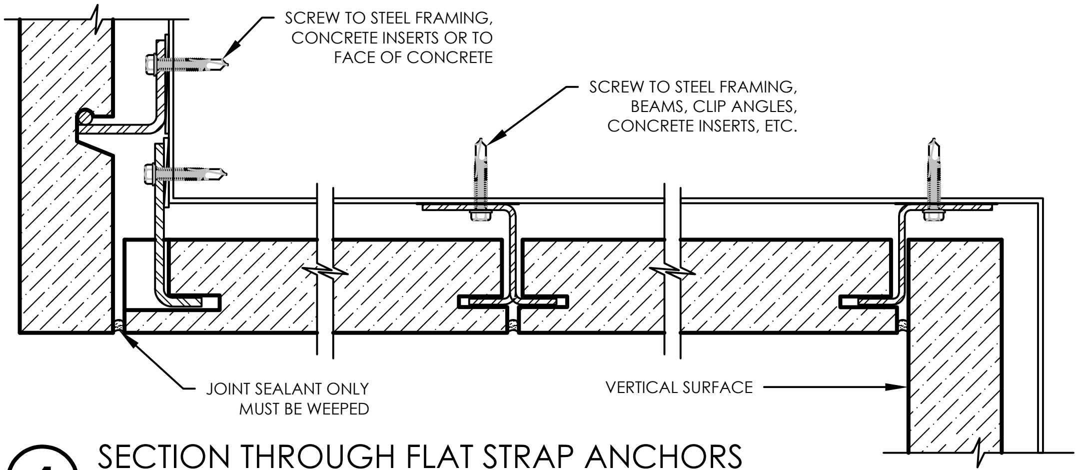
INTERIOR STONE ATTACHMENT
BASE DETAILS

DIMENSION STONE DESIGN MANUAL 2022

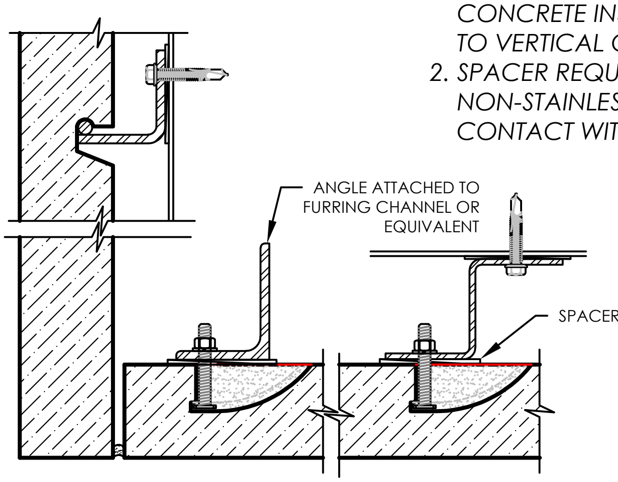
DRWG NO: 14-D-17

SCALE: 3" = 1'-0"

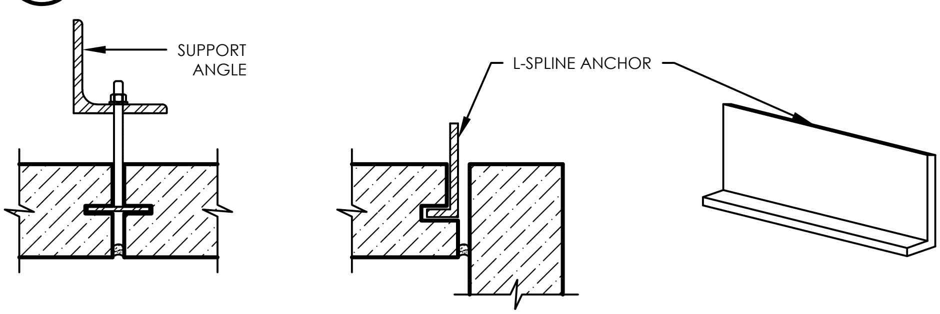


1 SECTION THROUGH FLAT STRAP ANCHORS

NOTE: 1. BOLT ANCHORS TO STEEL FRAMING, BEAMS, CLIP ANGLES OR CONCRETE INSERTS. USE EXPANSION BOLTS TO FASTEN TO VERTICAL CONCRETE SURFACES ONLY.
2. SPACER REQUIRED. 16 GA. STAINLESS STEEL OR AS SPECIFIED. NON-STAINLESS SUPPORT STEEL MUST NOT BE IN DIRECT CONTACT WITH STONE.



2 SECTION THROUGH BACK ANCHORS



3 SECTION THROUGH DISC & L-SPLINE ANCHORS

NOTE: CONSIDERATION SHOULD BE GIVEN TO ANCHORING EACH STONE SOFFIT PIECE INDEPENDENTLY FROM OTHER SOFFIT AND VERTICAL PIECES.

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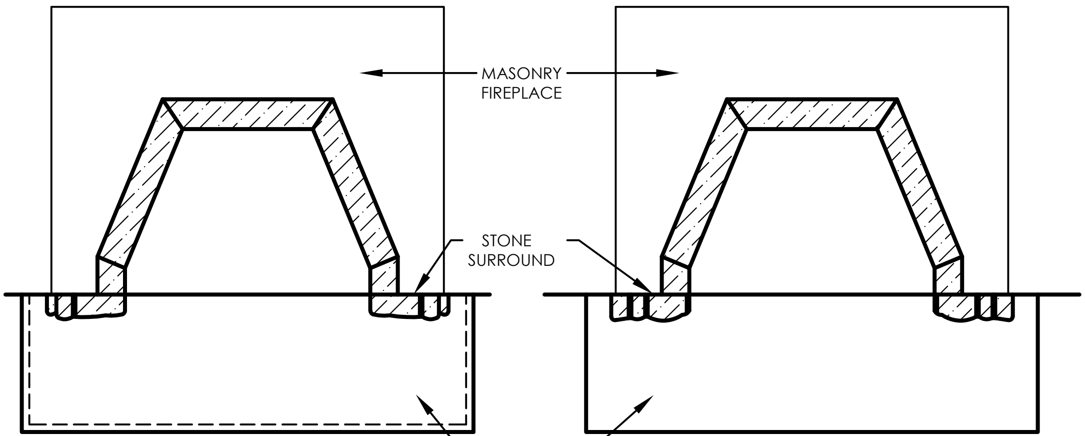
STONE SOFFIT ATTACHMENT DETAILS

DIMENSION STONE DESIGN MANUAL 2022

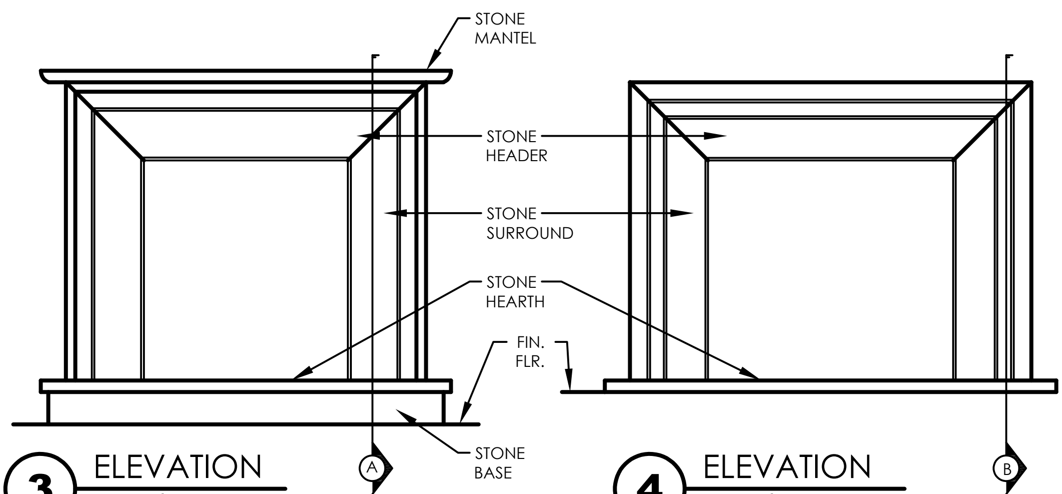
DRWG NO: 14-D-18

SCALE: 3" = 1'-0"



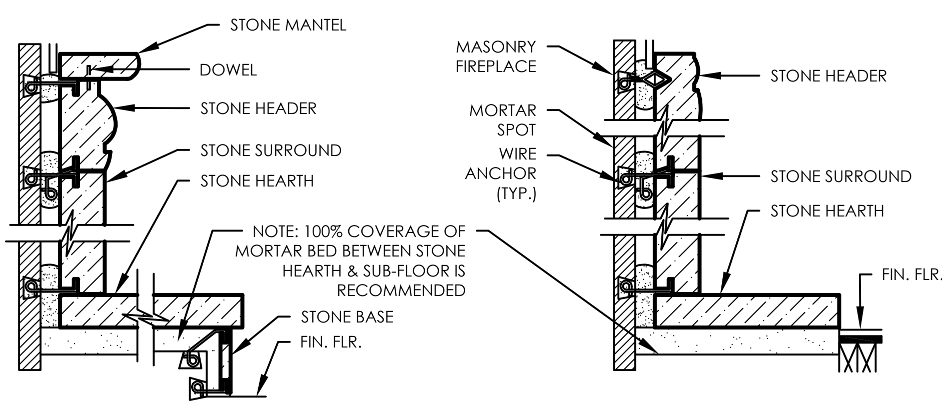
1 PLAN DETAIL
Scale: ½" = 1'-0"

2 PLAN DETAIL
Scale: ½" = 1'-0"



3 ELEVATION
Scale: ½" = 1'-0"

4 ELEVATION
Scale: ½" = 1'-0"



A SECTION
Scale: 1½" = 1'-0"

B SECTION
Scale: 1½" = 1'-0"

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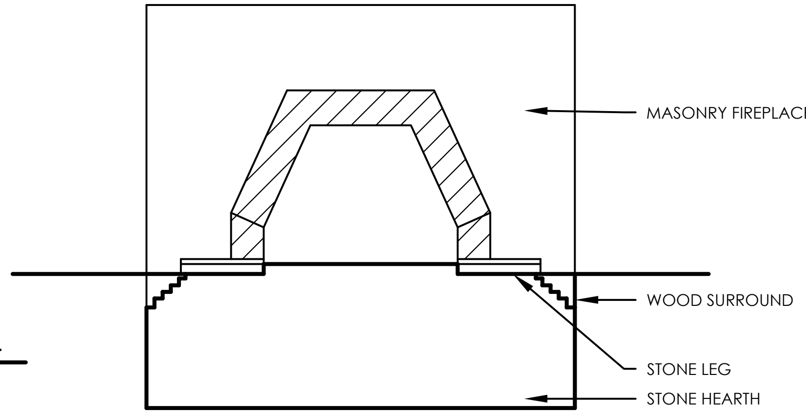
STONE FIREPLACE FACING ATTACHMENT DETAILS

DIMENSION STONE DESIGN MANUAL 2022

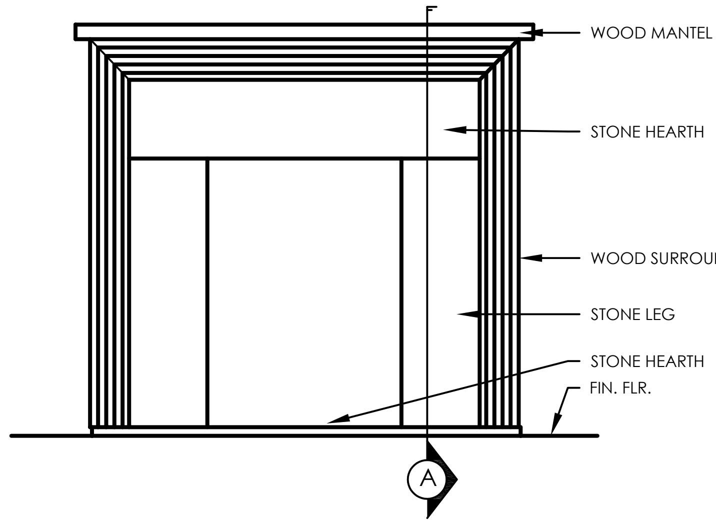
DRWG NO: 14-D-19

SCALE: As Noted

CAUTION: IF THIS SHEET IS NOT 8½" x 11", IT IS A REDUCED OR ENLARGED PRINT



1 PLAN DETAIL
Scale: ½" = 1'-0"



2 ELEVATION
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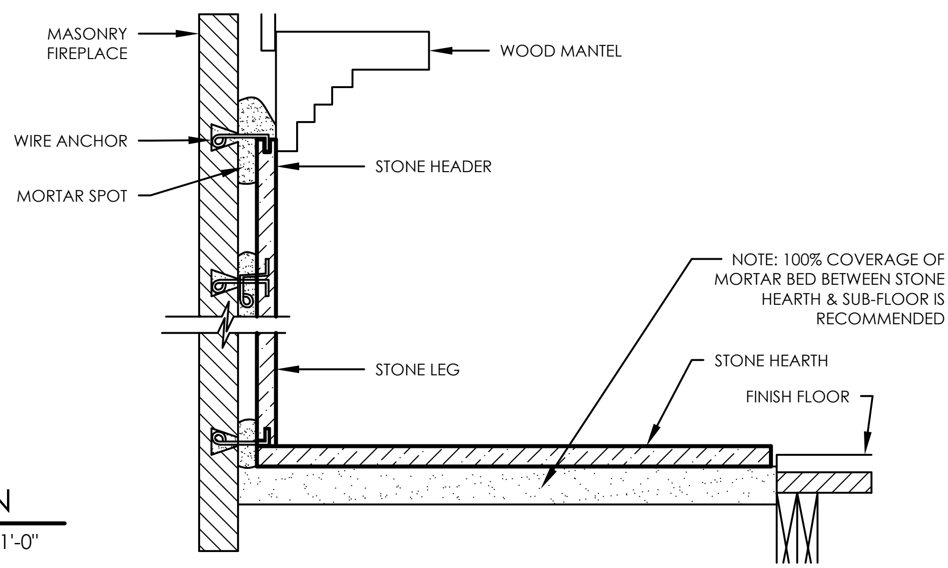

A SECTION
Scale: 1½" = 1'-0"

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STONE FIREPLACE FACING ATTACHMENT DETAILS

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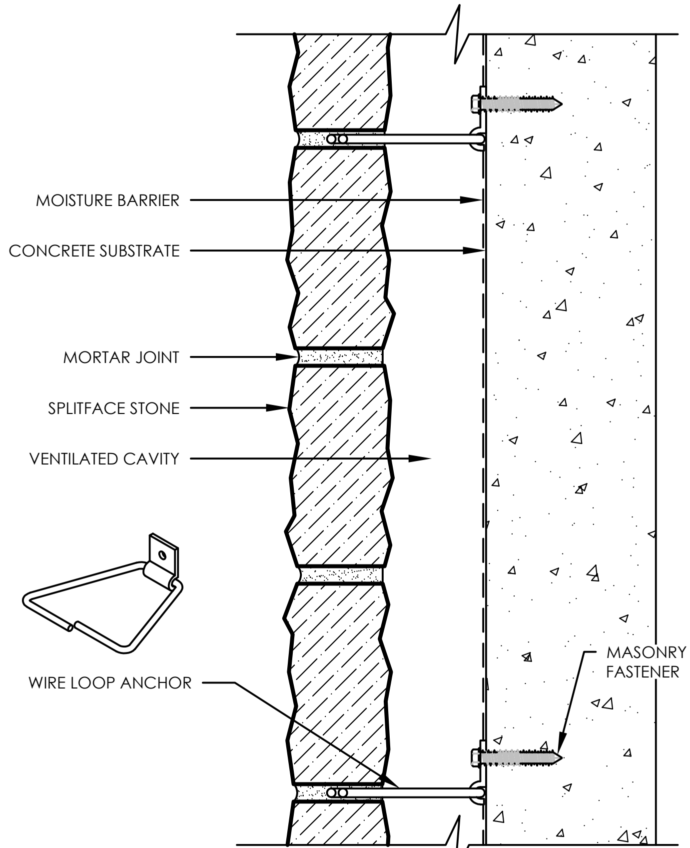
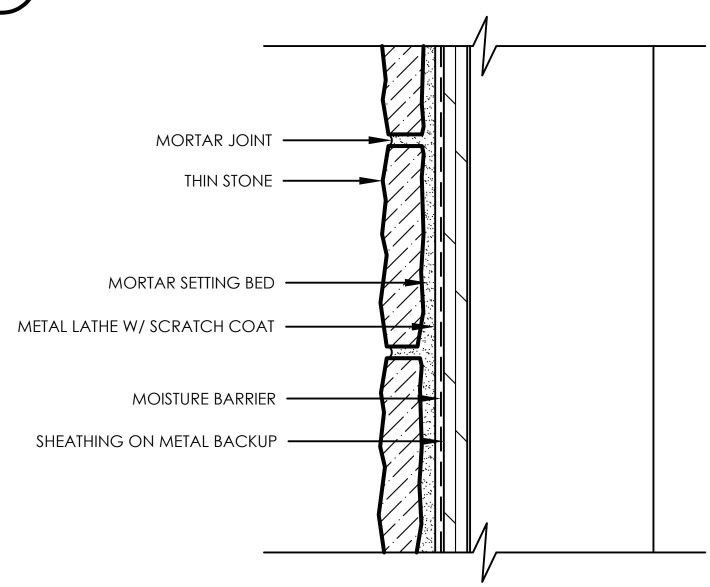
DRWG NO: 14-D-20

SCALE: As Noted



1 SPLITFACE ASHLAR ON CONCRETE BACKUP



2 THIN STONE VENEER ON MISC. METAL BACKUP

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SPLIT FACE ASHLAR AND THIN STONE VENEER ATTACHMENT DETAILS

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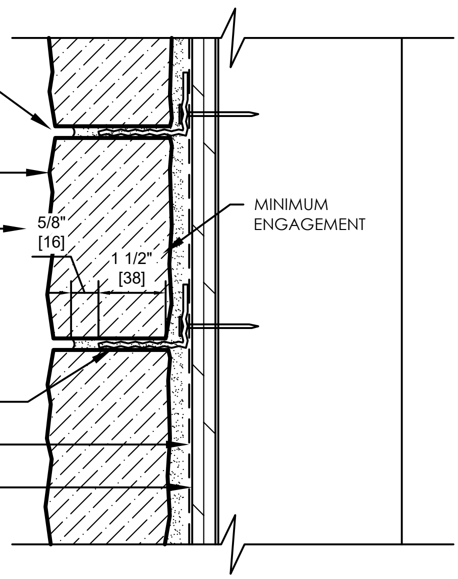
DRWG NO: 14-D-21

SCALE: As Noted



1 DRY STACK VENEER ON MISC. METAL BACKUP

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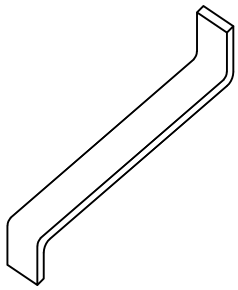
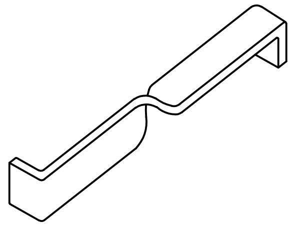
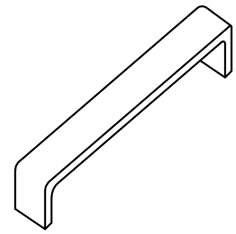
			DRWG NO: 14-D-22	SCALE: As Noted



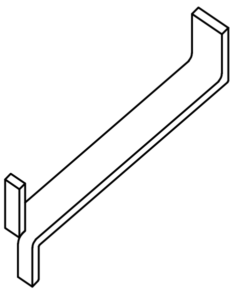
"Z" STRAP



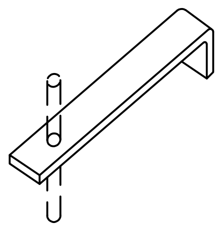
TWISTED STRAP
(FOR VERTICAL EDGE ANCHORS)



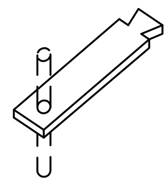
"U" CRAMP STRAP



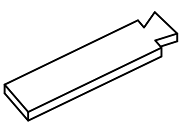
SPLIT-TAIL STRAP



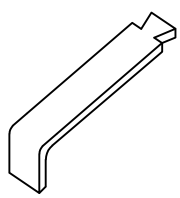
"L" STRAP
(HOLE FOR DOWEL)



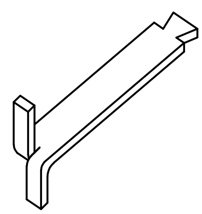
DOVETAIL STRAP
(HOLE FOR DOWEL)



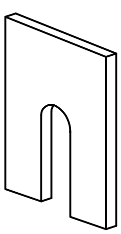
DOVETAIL STRAP



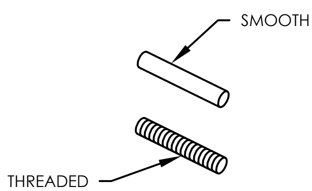
DOVETAIL "L" STRAP



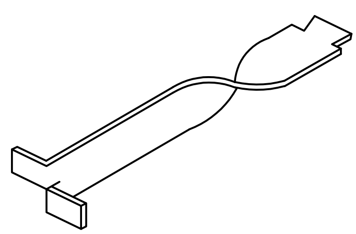
DOVETAIL SPLIT-TAIL STRAP



SHIM
(PLASTIC OR ST. STEEL)



DOWELS



DOVETAIL TWISTED
(TWO WAY STRAP)

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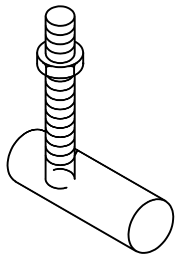
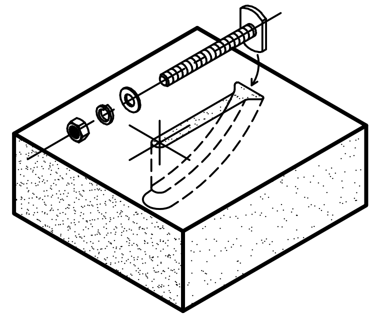
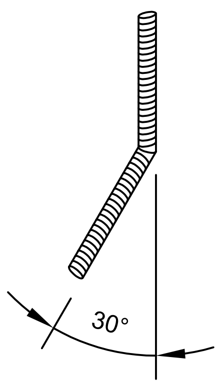
SCALE: Not to Scale



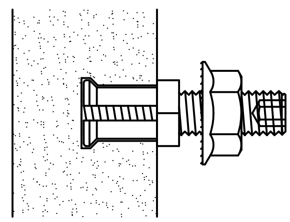
PLUG ANCHOR



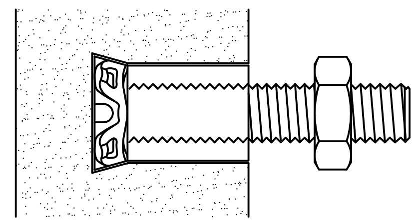
T-31 BACK ANCHOR



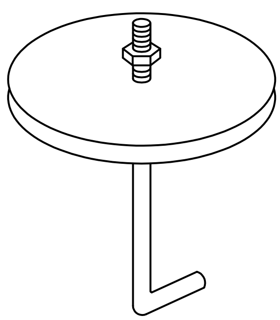
BENT ROD



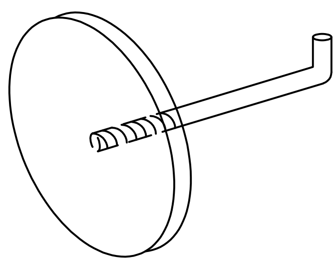
UNDERCUT BACK ANCHOR
(GRAPHIC COURTESY OF
KEIL BEFESTIGUNGSTECHNIK GMBH)



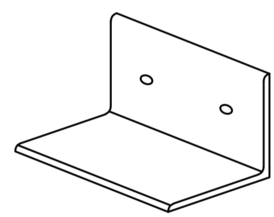
UNDERCUT BACK ANCHOR
(GRAPHIC COURTESY OF
FISCHER FIXINGS LLC)



SOFFIT HANGER



"L" STUD AND DISC



RELIEVING ANGLE-CLIP

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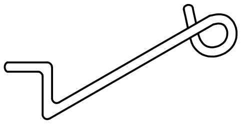
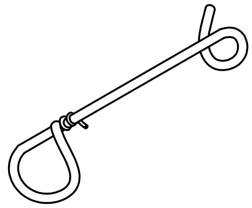
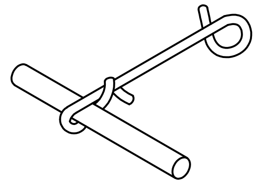


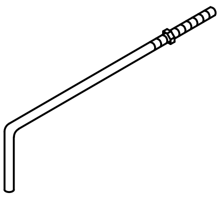
WIRE TIEBACK



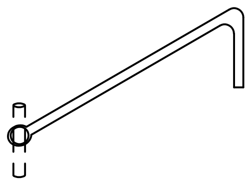
WIRE LACE ANCHOR



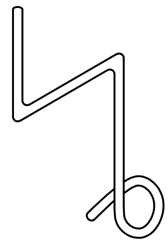
WIRE TIEBACK
(WITH DOWEL)



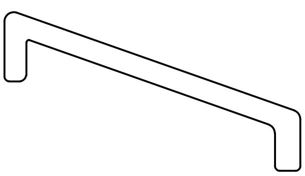
"L" BAR OR
HOOKED BOLT



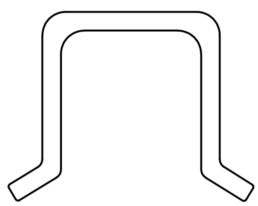
EYE ROD AND DOWEL



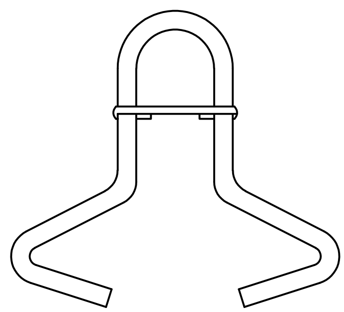
WIRE "GOOSE NECK"
ANCHOR



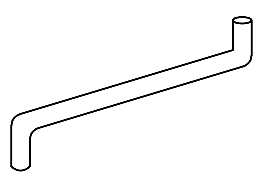
"U" CLAMP BAR



"HAIRPIN" PRECAST
ANCHOR



SPRING CLIP
(WITH COLLAR)



"Z" BAR

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NOTES:

WET AREAS – GENERAL INFORMATION

1.0 INSTALLATION OF DIMENSION STONE IN WET AREAS

This chapter of Natural Stone Institute's *Dimension Stone Design Manual* includes general notes and references that apply to the installation of natural stone in wet areas (urinal, toilet and shower partitions, slab and tile showers, steam rooms and steam showers). This chapter should be used in conjunction with chapters 13 and 14, Horizontal and Vertical Installation, respectively.

1.1 Installation Methods. There are several methods by which stone partitions and showers can be installed.[1] Consideration should be given to the various features of each method in making a selection for a specific installation. For more information about installation methods, see the detail drawings at the end of the chapter.

1.2 Labor Assignment. In most regions of the United States, the labor body responsible for installing a stone product will change pending if the stone product is a tile or a cut-to-size product. Labor jurisdiction practices vary regionally and locally, so research is encouraged to ascertain the labor group assigned to the field installation of a given product.

2.0 DESIGN CRITERIA

2.1 Oil-based putty and plumbing sealants should never be used in contact with stone.

2.2 Sound Stones. Only sound stones, free of any cracks, defects, geological flaws, and voids should be used. Variations in natural products are acceptable. Moisture sensitive stones should not be used in wet areas.

2.2.1 Avoid use of stones that are flawed. Moisture can travel through the flaw to the back face of the stone. Do not use Marble Soundness Classifications "C" or "D" stones, or stones that have adhered fiberglass mesh reinforcement.

2.2.2 Steam Showers. Soundness Classifications C and D marbles used in steam showers and around whirlpool tubs have a tendency to lose their fillings due to moisture, heat, and vibration. Stone tile with adhered fiberglass mesh reinforcement on their back surfaces are not to be used for steam shower applications.

2.2.3 Mesh Backing. Producers frequently apply fiber mesh reinforcement to the back surfaces of stone tiles and slabs to reduce breakage and also increase safety when handling large slabs. Caution should be used when handling these stones. Mesh and resin backing require special consideration when adhesives are chosen. Confirm compatibility of adhesive prior to setting units of this type. Slabs with mesh backing should not be used in free standing vertical applications.

2.3 Anchors. An alternate system that may be used is non-staining, corrosion-resistant dowels, pins, and wire anchors in lieu of standard commercial hardware. The design of these systems must provide for the transfer of loads from the stone through the anchor to the building structure.

2.4 White portland cement is recommended for most light-colored natural stone. White portland cement with a low alkali content is recommended for limestone.

[1] Natural Stone Institute endorses the use of a partial list of details published by the Tile Council of North America. For additional installation information, see the "Natural Stone Tile Installation Methods" section in the current edition of the *TCNA Handbook for Ceramic, Glass, and Stone Tile Installation*.

2.5 Use cement backer board instead of water-resistant drywall board (green board). Drywall will degrade and the paper on it will become a food source for mold and mildew when subjected to moisture. Do not use "green board" or any gypsum-based product unless a waterproof membrane completely protects the surface from moisture infiltration.

2.6 Positive water movement. All horizontal surfaces (e.g., seats, sills, curbs, etc.) must slope toward drain or toward other surfaces sloped toward a drain.

2.7 Geographic Methods. Some installation methods and materials are not recognized and may not be suitable in some geographic areas because of local trade practices, building codes, climatic conditions, or construction methods. Therefore, while every effort has been made to produce accurate guidelines, they should be used only with the independent approval of technically qualified persons.

3.0 TECHNICAL DATA

3.1 Each stone variety used for stone partitions or shower rooms described in this chapter should conform to the applicable ASTM standard specification and the physical requirements contained therein. The specification for each stone type follows:

3.1.1 Granite: ASTM C615, Standard Specification for Granite Dimension Stone.

3.1.2 Limestone: ASTM C568, Standard Specification for Limestone Dimension Stone.

3.1.3 Marble: ASTM C503, Standard Specification for Marble Dimension Stone, Soundness Classification "A."

3.1.4 Onyx: No ASTM Standard exists at this time.

3.1.5 Quartz-based Stone: ASTM C616, Standard Specification for Quartz-based Dimension Stone.

3.1.6 Serpentine: ASTM C1526, Standard Specification for Serpentine Dimension Stone.

3.1.7 Slate: ASTM C629, Standard Specification for Slate Dimension Stone.

3.1.8 Soapstone: No ASTM Standard exists at this time.

3.1.9 Travertine: ASTM C1527, Standard Specification for Travertine Dimension Stone.

4.0 TERMINOLOGY

4.1 Definitions.

4.1.1 Hot mop. A substrate employing layers of asphalt applied while hot to create a waterproof barrier.

4.1.2 Cold applied membrane. A liquid applied bonded membrane, impervious to water.

4.1.3 Wet set. Tile installation method prescribed by ANSI A108.1A.

4.1.4 Dry pack. A mortar mixed with inadequate water component to facilitate complete hydration, thereby dependent upon water of opportunity to complete chemical cure. Dry packs are used due to their compatibility and greater ability to allow lateral transfer of water. Dry packs frequently include aggregates coarser than sand.

4.1.5 Positive flow. To move along in the direction of a drain or other planar surfaces sloped towards a drain.

4.1.6 Negative flow. To move along in the direction away from a drain or other planar surfaces sloped towards a drain.

4.1.7 Sheet applied bonded membrane. A waterproof membrane providing a barrier to positive liquid migration per ANSI A118.10.

4.1.8 Shower pan (membrane or liner). Water containment sheeting per ASTM D4551 PVC or ASTM D4068 CPE.

WET AREAS – STONE TOILET PARTITIONS

1.0 PRODUCT DESCRIPTION

1.1 Basic Use. Toilet partitions for all building types.

1.2 Fabrication. Stone toilet partitions are precut, predrilled, and prefinished to dimensions specified on the shop drawings and delivered to the job site ready to install. Certain job conditions make it necessary to perform some fabrication steps at the job site.

1.4 Types. Partitions may be designed as floor-supported or ceiling-suspended.

1.5 Finishes. Polished finish is most common due to ease of maintenance. See chapter 3, Stone Selection, for other commonly available finishes.

1.6 Colors. Some of the commercially available varieties are unsuitable due to reduced soundness of the material or susceptibility to acid attack.

1.7 Sizes. Stone size is limited by the stone deposit and quarrying method of the selected stone and design requirements of the specific project. Appropriate stone thickness will be determined by many factors including soundness of the stone, anchorage capacity and placement, span between supporting members, etc.

1.8 Technical Information. Every construction condition requires engineering based on specific factors for each project– panel weight, backup material, stone mechanical and physical properties, etc. The most stringent code documents always take precedence. Contact the engineer or manufacturer of each anchoring system for its particular technical information and engineering formulas.

1.8.1 The deflection of the material under maximum anticipated load shall not exceed L/720.

2.0 INSTALLATION

2.1 Preparatory Work. A solid substrate and a structurally adequate plumbing wall should be provided for proper installation.

2.2 Methods. Partitions are assembled using corrosion resistant hardware. Ceiling-suspended units are fastened to structural steel supports in the ceiling. Ceiling-suspended units may require a metal spline. Floor-supported units require concrete floor construction to secure anchor bolts. Anchorage methods are to comply with applicable codes.

2.2.1 All joints are filled with non-staining sealants or grout. Where so specified, joints requiring sealant shall be first filled with an approved rope backer rod. The backer rod shall be installed to a depth that provides optimum sealant profile after tooling.

2.3 General Precautions. During construction, the General Contractor shall protect all stone from staining or damage.

2.4 The ceiling channel to which the stile should be attached shall be furnished and installed by others.

2.5 Unless otherwise noted, channels, head rails, splines, pilasters, threaded pipe and other fittings are to be supplied by others.

WET AREAS –
STONE URINAL PARTITIONS

1.0 PRODUCT DESCRIPTION

1.1 Basic Use. Urinal partitions (or as junior toilet partitions where doors are not desired) for all building types.

1.2 Fabrication. Stone urinal partitions are precut, predrilled, and prefinished to dimensions specified on the shop drawings and are delivered to the job site ready to install. For certain job conditions it is preferable to finish the stone at the job site.

1.3 Types. Partitions may be designed as wall hung or floor-supported (with or without overhead brace).

1.4 Finishes. Polished finish is most common due to ease of maintenance. See chapter 3, Stone Selection, for other commonly available finishes.

1.5 Colors. Some of the commercially available varieties are unsuitable due to reduced soundness of the material or susceptibility to acid attack.

1.6 Sizes. Stone size is limited by the stone deposit and quarrying method of the selected stone and the design requirements of the specific project. Appropriate stone thickness will be determined by many factors including soundness of the stone, anchorage capacity and placement, span between supporting members, etc.

1.7 Technical Information. Every construction condition requires engineering based on specific factors for each project–panel weight, backup material, stone physical and mechanical properties, etc. The most stringent code documents always take precedence. Contact the engineer or manufacturer of each anchoring system for its particular technical information and engineering formulas.

1.7.1 The deflection of the material under maximum anticipated load shall not exceed L/720.

2.0 INSTALLATION

2.1 Preparatory Work. A solid substrate not more than two inches below finish floor and a plumbing wall should be provided for proper installation.

2.2 Methods. Partitions are available floor-supported or ceiling-hung. If ceiling-hung, the General Contractor shall furnish and install the ceiling channel. Unless otherwise noted, channels, head rails, splines, pilasters, threaded pipe and other fittings are to be supplied by others

2.2.1 Partitions are assembled using corrosion resistant hardware. Floor-supported units are set on dowels into the finished floor. Ceiling-hung units are bolted to overhead support. All ceiling-hung units must have a metal spline. Wall-mounted urinal partitions must be attached to the wall at a minimum of three locations.

2.2.2 All joints are filled with non-staining sealants or grout. Where so specified, joints requiring sealant shall be first filled with an approved rope backer rod. The backer rod shall be installed to a depth that provides optimum sealant profile after tooling.

2.3 General Precautions. During construction, the General Contractor shall protect all stone from staining and damage.

WET AREAS –
STONE SLAB SHOWER PARTITIONS

1.0 PRODUCT DESCRIPTION

1.1 Basic Use. Shower partitions for all building types.

1.2 Fabrication. Stone shower partitions are precut, predrilled, and prefinished to dimensions specified on the shop drawings and are delivered to the job site ready to install. For certain job conditions it is preferable to finish the stone at the job site.

1.3 Types. Partitions may be designed as wall hung or floor-supported (with or without overhead brace). Partitions are also available as free-standing units with precast terrazzo receptors.

1.4 Finishes. Polished finish is most common due to ease of maintenance. See chapter 3, Stone Selection, for other commonly available finishes.

1.5 Colors. Some of the commercially available varieties are unsuitable due to the lack of soundness of the material or its susceptibility to acid attack.

1.6 Sizes. Stone size is limited by the stone deposit and quarrying method of the selected stone and the design requirements of the specific project. Appropriate stone thickness will be determined by many factors including soundness of the stone, anchorage capacity and placement, span between supporting members, etc.

1.7 Technical Information. Every construction condition requires engineering based on specific factors for each project– panel weight, backup material, stone physical and mechanical properties, etc. The most stringent code documents always take precedence. Contact the engineer or manufacturer of each anchoring system for its particular technical information and engineering formulas.

1.7.1 The deflection of the material under maximum anticipated load shall not exceed L/720.

2.0 INSTALLATION

2.1 Preparatory Work. A solid substrate and a plumbing wall should be provided for proper installation.

2.1.1 Waterproofing (ANSI A118.10) is typically the responsibility of other trades prior to installation of stone. Shower pan or waterproof membrane (ANSI A118.10) must be installed to turn up vertical wall surface at least 3" (75 mm) above the finished surface of the shower curb. The integrity of the waterproof membrane of the floor up to the curb height should be verified by the contractor before commencing work by flood test per building and plumbing code requirements per ASTM D5957, "Standard Guide for Flood Testing Horizontal Waterproofing Installations." Test shower pan or waterproof membrane and drainage fitting for leaks before beginning stone work.

2.1.2 Shower pan or moisture proofing must be pre-sloped at a minimum pitch of ¼" per foot (20 mm per m) to the weep holes of he shower drain assembly. Surround the drain with pea gravel or other weep protection to prevent mortar from blocking weep holes.

2.1.3 Partitions are assembled using corrosion resistant hardware. All joints are sealed with non-staining sealants or grout. Where so specified, joints requiring sealant shall be first filled with an approved rope backer rod. The backer rod shall be installed to a depth that provides optimum sealant profile after tooling.

2.2 Methods. Stone shower partitions are to be installed to allow service or replacement of the partition without damaging adjacent finished surfaces. Stone shower partitions can be installed by one of the following methods:

2.2.1 Free-standing units. Partitions are assembled using corrosion resistant hardware. All joints are filled with non-staining sealants or grout.

2.2.2 Floor-supported units. Partitions are to be set on top of substrate. Floor-supported units are set on dowels into the finished floor.

2.3 General Precautions. During construction, the General Contractor shall protect all stone from staining and damage.

NOTES:

WET AREAS –
STONE SLAB RESIDENTIAL SHOWERS, STEAM ROOMS, AND STEAM SHOWERS

1.0 PRODUCT DESCRIPTION

1.1 Basic Use. Shower stalls, steam rooms, and steam showers for residential use.

1.2 Fabrication. Parts are precut and prefinished to dimensions specified on the shop drawings and are delivered to the job site ready to install. For certain job conditions it is preferable to finish the stone at the job site.

1.3 Limitations. Only sound stone varieties should be used. Marble selection is limited to Soundness Classifications “A” and “B”.

1.4 Finishes. Polished finish is most common due to ease of maintenance. See chapter 3, Stone Selection, for other commonly available finishes.

1.5 Colors. Some of the commercially available varieties are unsuitable due to the lack of soundness of the material or its susceptibility to acid attack.

1.6 Sizes. Stone size is limited by the stone deposit and quarrying method of the selected stone and the design requirements of the specific project. Appropriate stone thickness will be determined by many factors including soundness of the stone, anchorage capacity and placement, span between supporting members, etc.

1.7 Technical Information. Every construction condition requires engineering based on specific factors for each project– panel weight, backup material, stone physical and mechanical properties, etc. The most stringent code documents always take precedence. Contact the engineer or manufacturer of each anchoring system for its particular technical information and engineering formulas.

1.7.1 Construction of walls and partitions should be designed to maximum deflection of L/720 for conditions utilizing thick-set or thin-set mortar installation methods.

2.0 INSTALLATION – SLAB SHOWER STALLS

2.1 Preparatory Work. Shower pan or waterproof membrane (ANSI A118.10) must be installed to turn up vertical wall surface at least 3" (75 mm) above the finished surface of the shower curb. The integrity of the waterproof membrane of the floor up to the curb height should be verified by the contractor before commencing work by flood test per building and plumbing code requirements per ASTM D5957, “Standard Guide for Flood Testing Horizontal Waterproofing Installations.” Test shower pan or waterproof membrane and drainage fitting for leaks before beginning stone work.

2.1.1 Shower pan or waterproofing must be pre-sloped to a minimum pitch of ¼" per foot (20 mm per m) to the weep holes of the shower drain. Surround the drain with pea gravel or other weep protection to prevent mortar from blocking weep holes.

2.2 Method. Shower stall floor should be installed in a dry-pack mortar bed consisting of one part portland cement to four to five parts sand, 100% coverage of mortar bed material between floor and substrate is recommended. Moisture must be able to freely migrate laterally through the mortar bed and discharge via the weep holes in the shower drain assembly.

2.3 Stone wall panels are set firmly against masonry walls or waterproofed surfaces.

2.4 Joint width can be maintained by using plastic shims. Joints should be at least

1/16" (1.5 mm) wide and pointed with white cement, grout, or non-staining sealant. Joint width must be specified.

2.5 Anchors that contact the stone should be corrosion resistant metal (stainless steel, copper, bronze, brass, aluminum) and should be securely attached to the structure and the stone.

2.6 Exposed stone edges must be gauged to the precise thickness specified.

2.7 Face Sealing. Stone residential shower stalls may be sealed or unsealed.

2.7.1 If sealed, follow Manufacturer's written recommendations for cleaning, stripping, and resealing. The chemicals used should contain no acids or harshly alkaline ingredients. Both types destroy the polished finishes on some stone varieties.

2.7.2 Sealing does not eliminate the need for frequent cleaning of the wall or floor surfaces. A neutral detergent (pH of 7) is the recommended cleaning agent.

2.8 Stone Ceilings. For details and information regarding stone ceilings in residential showers, refer to the "Stone Soffits" section of this Manual in Chapter 14, Vertical Surfaces.

2.9 General Precautions. During construction, the General Contractor shall protect all stone from staining and damage.

3.0 INSTALLATION – SLAB STEAM ROOMS AND STEAM SHOWERS

Steam rooms are highly specialized applications. All electrical and plumbing fixtures should be rated for steam rooms. Steam rooms for continuous use require a membrane (ANSI A118.10) with a water vapor permeance (perm rating) of 0.5 or less. Professional design and installation are critical to avoid damage to adjacent material due to vapor migration and heat transfer.

3.1 Waterproofing. A waterproofing membrane (ANSI A118.10) must extend a minimum of 3" above the top of the finished surface of the curb. All backup surfaces must be waterproofed with a membrane authorized by the Manufacturer for steam room applications. All horizontal surfaces shall be pre-sloped to a minimum pitch of ¼" per foot (20 mm per m) toward the shower drain assembly. The integrity of the waterproof membrane on the floor up to the height of the curb should be verified by the contractor before commencing work by flood test per building and plumbing code requirements per ASTM D5957, "Standard Guide for Flood Testing Horizontal Waterproofing Installations."

3.2 Methods. Stone may be installed by using any of the approved methods. Exterior methods must be used in the shower. Avoid use of gypsum board in shower areas.

3.3 Ceilings are to be sloped ½" per foot (40 mm per m) up to 2" per foot (170 mm per m) for textured finishes to bring moisture to the face of the wall opposite the shower head, or the principal wall(s) of the room. For example, consider sloping the ceiling away from the wall including a bench or doorway. Sloping ceiling from the center can minimize rundown on the walls. Large, one-piece shower ceilings should be supported by the shower walls. An additional anchor should be installed at the cutout for the fan or fan/light combination.

3.4 Finished surface must be sloped toward the shower drain assembly at a minimum pitch of ¼" per linear foot (20 mm per m) and a maximum pitch of ½" per linear foot (40 mm per m).

3.5 Grout is to be full stone depth. Cured grout should not be easily penetrated with a pocket knife blade.

3.6 Installation materials must be authorized by the Manufacturer for steam room applications. Water should be potable and free of any staining agents. Stone tiles may be used.

3.7 Stone may be installed using any of the following methods:

3.7.1 A thin-set method on a mortar bed or cementitious backer board for tile only. Setting material suitability may be affected by the size of stone units to be installed. Consult with adhesive manufacturer for specific recommendations.

3.7.2 Mortar bed (wet set) method. The method (ANSI A108.1A) that requires that the stone be set on a mortar bed that is still plastic.

3.7.3 Mechanically anchored. An installation system over a waterproofed backing of scratch coat or cementitious backer board for pieces greater than 2' x 2' (600 x 600 mm). Weep holes should be provided at the base of the cavity or as shown on architectural drawings, to evacuate accumulated condensation from the air space between the back face of the stone and the substrate. Additionally, openings should be provided at the top of the installation to accommodate ventilation of the cavity

3.8 Effects of Steam on Stone and Anchorage. Steam is a catalyst. Many stones contain elements and metallic compounds that will react with steam and form other elements not common to the stone's variety. Color change in background and veining could result, and the stone's structural integrity may be compromised. Use non-corroding hardware in all conditions where in contact with stone.

3.9 Additional Moisture Control. Adhered stone should be solid-set to avoid moisture at the back face. Weep holes should be provided to evacuate moisture from any voids which may have developed between the back face of the stone and the substrate.

3.10 Provision for Steam Generator. Oversize the diameter of the hole in the stone for the steam pipe a minimum of ¼" (6 mm). Center the steam line in the hole and use high temperature silicone or insulation to act as a heat barrier between the steam and the stone material.

3.10.1 Install steam shower controller per Manufacturer's installation instructions. When installing on cleft or irregular surfaced stone, ensure control is sealed to wall.

NOTES:

WET AREAS – STONE TILE RESIDENTIAL SHOWERS, STEAM ROOMS, AND STEAM SHOWERS

1.0 PRODUCT DESCRIPTION

1.1 Basic Use. Shower stalls, steam rooms, and steam showers for residential use.

1.2 Fabrication. Parts are precut and pre-finished to dimensions specified on the shop drawings and are delivered to the job site ready to install.

1.3 Limitations. Only sound stone varieties, including Soundness Classification Groups A and B marbles, should be used. Stone tile with adhered fiberglass mesh reinforcement on their back surfaces are not to be used for shower applications. Due to the nature of stone tile production, it can be expected that wide ranges in color and veining will occur. It is unreasonable to expect the Installer to produce specific matching patterns or strict adherence to a specific range of colors from tiles pulled one by one out of a carton unless specific instructions are given and agreed to before the installation is begun.

1.4 Finishes. Polished finish is standard. See chapter 3, Stone Selection, for other commonly available finishes.

1.5 Colors. Most of the commercially available varieties are suitable. However, some varieties are unsuitable due to the reduced soundness of the material or susceptibility to acid attack.

1.6 Sizes. Stone size is limited by the stone deposit and quarrying method of the selected stone and the design requirements of the specific project. Appropriate stone thickness will be determined by many factors including soundness of the stone, anchorage capacity and placement, span between supporting members, etc.

1.7 Technical Information. Every construction condition requires engineering based on specific factors for each project– panel weight, backup material, stone physical and mechanical properties, etc. The most stringent code documents always take precedence. Contact the engineer or manufacturer of each anchoring system for its particular technical information and engineering formulas.

1.7.1 The deflection of the material under maximum anticipated load shall not exceed L/720.

1.8 Exposed stone edges must be gauged to the precise thickness specified.

2.0 INSTALLATION – TILE SHOWER STALLS

2.1 Preparatory Work. Shower pan, waterproof membrane (ANSI A118.10), or vapor retarder membrane (ANSI A108.02-3.8) must be specified (see current TCNA B414 STONE for details). Turn shower pan membrane up vertical wall surface at least 3" (75 mm) above the finished surface of the shower curb [6" (150 mm) above floor in showers without curbs]. The integrity of the waterproof membrane up to the height of the curb should be verified by the contractor before commencing work by flood test per building and plumbing code requirements per ASTM D5957, "Standard Guide for Flood Testing Horizontal Waterproofing Installations."

2.2 Method. Shower stall floor should be installed in a dry-packed mortar bed consisting of one part portland cement to four to five parts sand. 100% coverage of mortar bed material between floor and sub-slab is recommended.

2.2.1 Shower pan membrane must be sloped toward the shower drain assembly at a minimum pitch of ¼" per linear foot. Finished surface must be sloped toward the shower drain assembly at a minimum pitch of ¼" per linear foot (20 mm per m) and a maximum pitch of ½" per linear foot (40 mm per m).

2.2.2 A plumb, properly waterproofed backup wall with a maximum variation of 1/8" in 8'-0" (3mm per 2.5 m) must be provided. Thinset adhesive is spread over the substrate with a notched trowel, and the stone tile is put into place with a slight twisting motion. For all applications, the stone tile shall be back buttered to achieve, as close as practical, 100% adhesive contact between the stone and the backup.

2.3 Joint width can be maintained by using plastic shims. Joints should be at least 1/16" (6.5) wide. Joint width must be specified.

2.4 Movement Joints (Architect must specify type of joint and show location and details on drawings). Movement joints are mandatory according to TCNA EJ171.

2.5 Sealing. Stone tiles installed in residential showers may be sealed or unsealed, according to the Owner's preference.

2.5.1 If sealed, follow Manufacturer's written recommendations for cleaning, stripping, and resealing. The chemicals used should contain no acids or harshly alkaline ingredients. Both types destroy the polished finishes on some stone varieties.

2.5.2 Sealing does not eliminate the need for frequent cleaning of the wall or floor surfaces. A neutral detergent (pH of 7) is the recommended cleaning agent.

2.6 General Precautions. During construction, the General Contractor shall protect all stone from staining and damage.

3.0 INSTALLATION – TILE STEAM ROOMS AND STEAM SHOWERS

Steam rooms are highly specialized applications. All electrical and plumbing fixtures should be rated for steam rooms. Steam rooms for continuous use require a membrane (ANSI A118.10) with a water vapor permeance (perm rating) of 0.5 or less. Professional design and installation are critical to avoid damage to adjacent material due to vapor migration and heat transfer.

3.1 Installation materials must be authorized by the Manufacturer for steam room applications. Water must be free of metals and should be potable.

3.2 Preparatory Work. Shower pan (ANSI A118.10, ASTM D4068 or D4551 and meeting applicable building codes) must be specified (see current TCNA SR613 or SR614 for details). Turn shower pan membrane up vertical wall surface at least 3" (75 mm) above the finished surface of the shower curb [6" (150 mm) above floor in showers without curbs]. The integrity of the waterproof membrane up to the height of the curb should be verified by the contractor before commencing work by flood test per building and plumbing code requirements per ASTM D5957, "Standard Guide for Flood Testing Horizontal Waterproofing Installations."

3.3 Stone tile may be installed using any of the following methods:

3.3.1 Thin-set method on a mortar bed or cementitious backer board.

3.3.2 A full mortar bed. A full mortar bed or wet set method (ANSI A108.1A) that requires that the stone be set on a mortar bed that is still plastic.

3.3.3 Tiles as thin as 3/8" may be used. Reference current edition of TCNA *Handbook for Ceramic, Glass, and Stone Tile Installation* for additional details.

3.4 Effects of Steam on Stone. Steam is a catalyst. Many stones contain elements and metallic compounds that will react with steam and form other elements not common to the stone's variety. Color change in background and veining could result, and the stone's structural integrity may be compromised. Use non-corroding hardware in all conditions where in contact with stone.

3.5 Moisture Proofing. Stone should be solid-set to avoid creating a moisture collection cavity at the back face.

3.6 Ceilings are to be sloped ½" per foot (40 mm per m) up to 2" per foot (170 mm per m) for textured finishes to bring moisture to the face of the wall opposite the shower head, or the principal wall(s) of the room. For example, consider sloping the ceiling away from the wall including a bench or doorway. Sloping ceiling from the center can minimize rundown on the walls.

3.7 Slope shower pan membrane a minimum of ¼" per foot (20 mm per m) to weep holes in drain.

3.8 Grout is to be full stone depth.

3.9 Provision for Steam Generator. Oversize the diameter of the hole in the stone for the steam pipe a minimum of ¼" (6 mm). Center the steam line in the hole and use high temperature silicone or insulation to act as a heat barrier between the steam and the stone material.

3.9.1 Install steam shower controller per Manufacturer's installation instructions. When installing on cleft or irregular surfaced stone, ensure control is sealed to wall.

WET AREAS – ACCESSORIES AND STONE PENETRATIONS

1.0 ACCESSORIES

1.1 Accessories must meet all applicable building codes and be installed per Manufacture's recommendations.

1.2 Manufacturer's standard design hardware and accessories shall be made of non-corroding materials.

1.3 All built-in seats, sills, curbs, etc., shall be waterproof and installed over a pre-sloped, flashed, waterproof membrane. Finish surface and substrate should have a minimum slope of ¼" per foot (20 mm per m) toward the drain.

1.4 All built-in seats, sills, curbs, etc., must be dimensionally stable when moist and structurally sound.

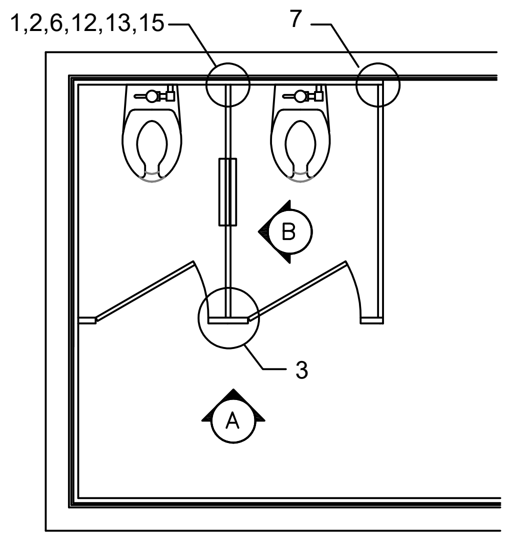
2.0 PENETRATIONS

2.1 Penetrating the waterproof system or the stone is often necessitated for the installation of recessed niches, all features of niches (e.g., shelves, lights), and corner seats, grab bars, fans or fan/light combinations, etc.

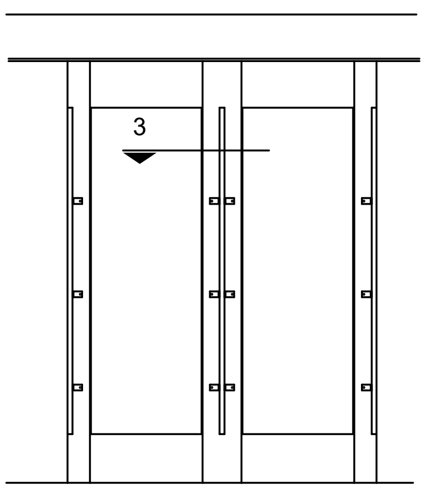
2.2 All openings, cut-outs or protrusions through the waterproofing system should be sealed with a suitable flexible sealant.

2.3 Any opening penetrating the waterproof envelope must be flashed and sealed to become an integral part of the system.

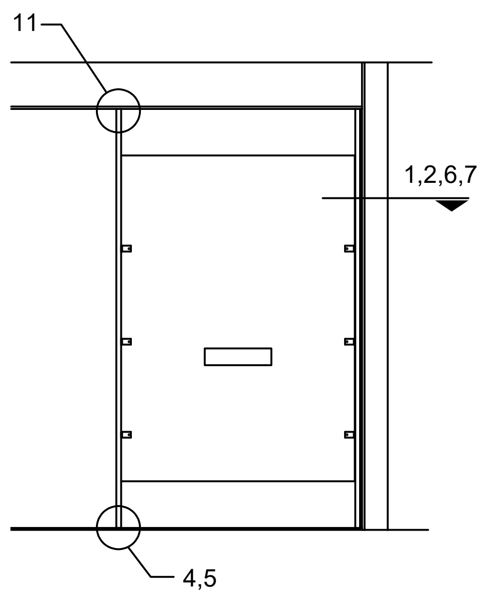
2.4 Any penetrations through the stone shall be made waterproof with a non-staining flexible sealant.



PLAN
TYPICAL LAYOUT



ELEVATION A
HARDWARE MOUNTED



ELEVATION B
HARDWARE MOUNTED

FLOOR SUPPORTED STALL

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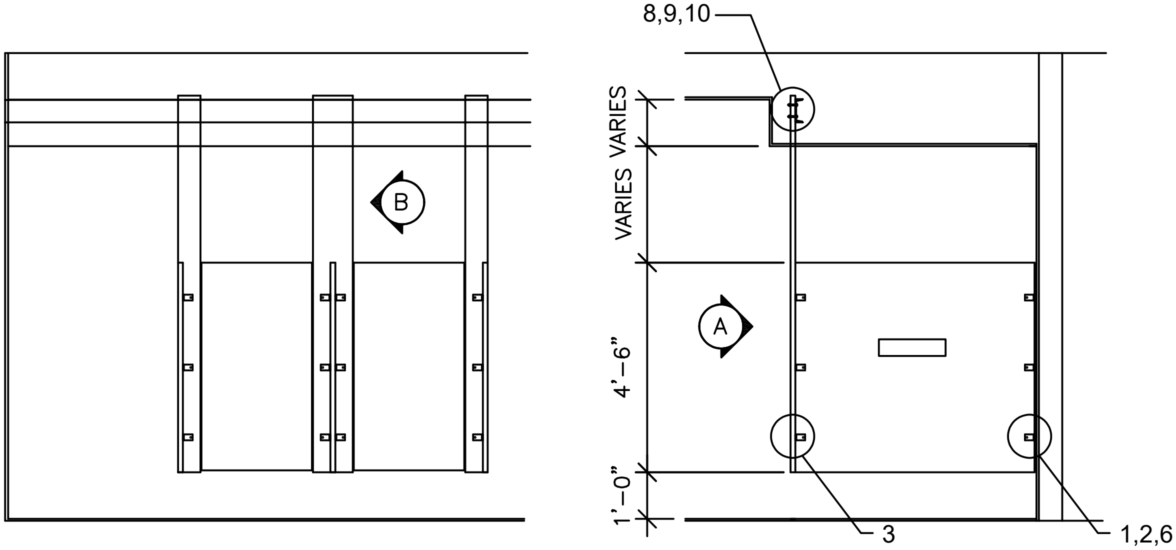
REV	DATE
0	MAR 2022

STONE TOILET PARTITIONS
(FLOOR-SUPPORTED)

DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 16-D-1

SCALE: ¼" = 1'-0"

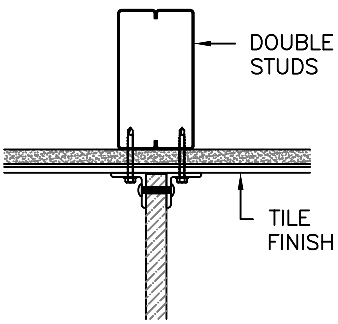


ELEVATION A
HARDWARE MOUNTED

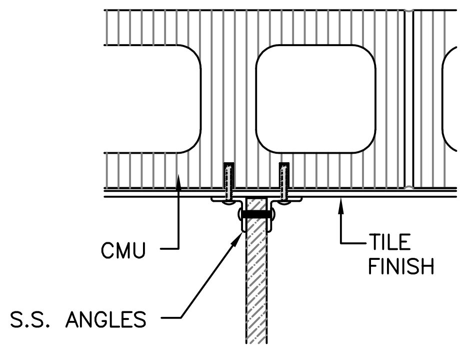
ELEVATION B
HARDWARE MOUNTED

CEILING MOUNTED STALL

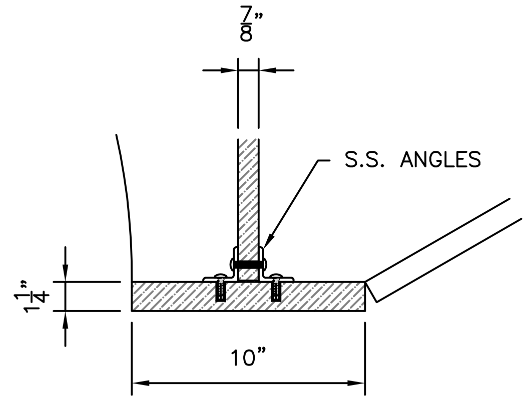
NATURAL STONE INSTITUTE 380 East Lorain Street, Oberlin, OH 44074 USA www.naturalstoneinstitute.org	REV	DATE	STONE TOILET PARTITIONS (CEILING-MOUNTED) DIMENSION STONE DESIGN MANUAL 2022	
	0	MAR 2022		
			DRWG NO: 16-D-2	SCALE: ¼" = 1'-0"



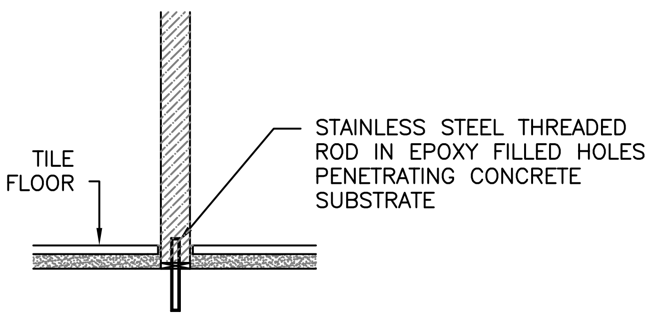
PLAN 1
HARDWARE MOUNTED



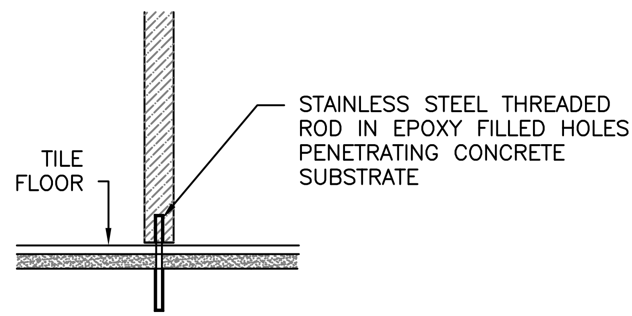
PLAN 2
HARDWARE MOUNTED



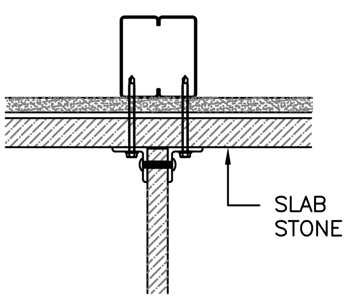
PLAN 3
HARDWARE MOUNTED



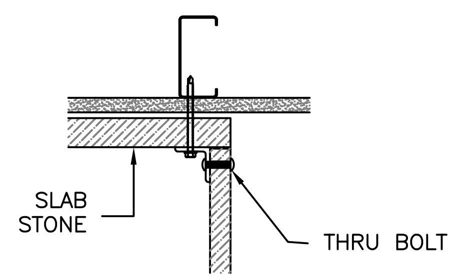
SECTION 4
FLOOR SUPPORTED



SECTION 5
FLOOR SUPPORTED



PLAN 6
HARDWARE MOUNTED



PLAN 7
HARDWARE MOUNTED

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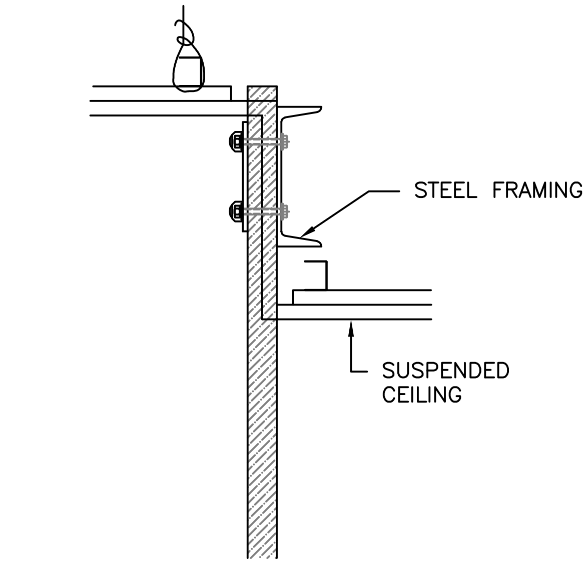
STONE TOILET PARTITIONS
(FLOOR-SUPPORTED)

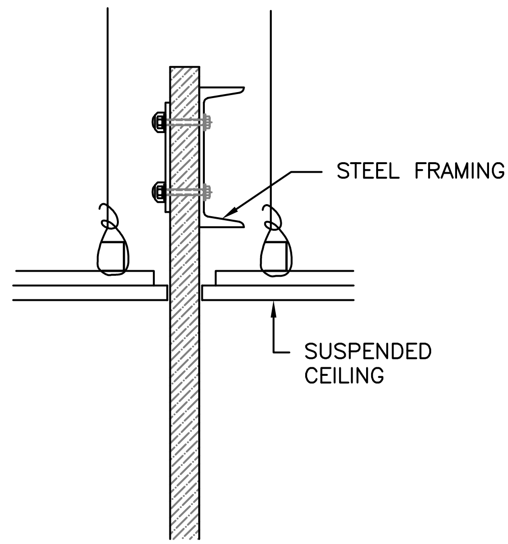
DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 16-D-3

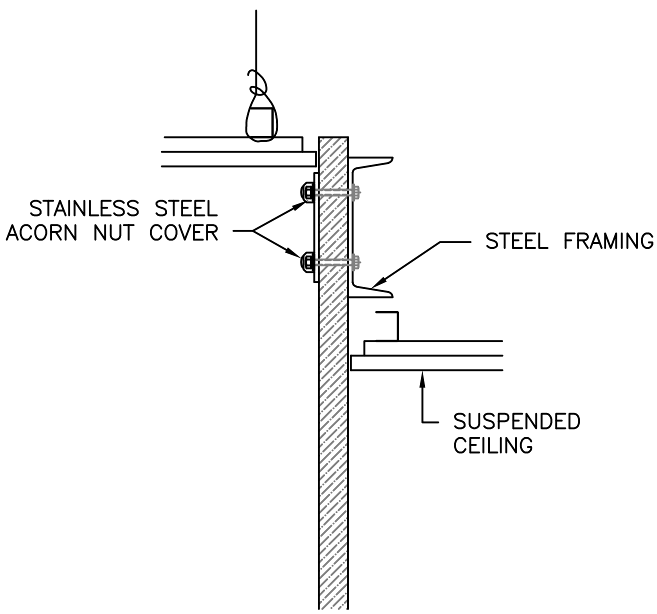
SCALE: 1½" = 1'-0"



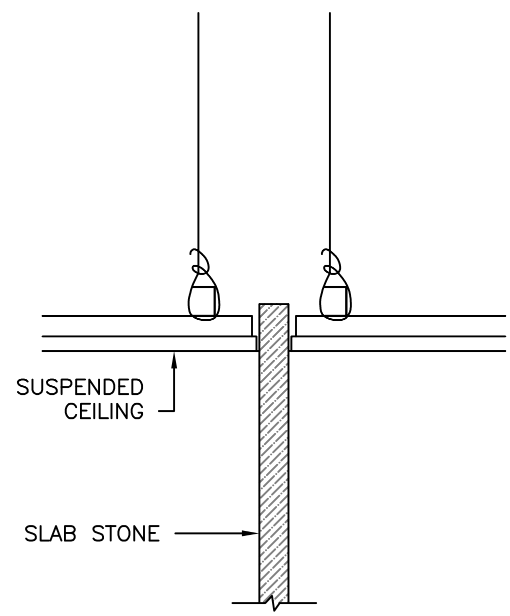
DETAIL 8
CEILING MOUNTED



DETAIL 9
CEILING MOUNTED



DETAIL 10
CEILING MOUNTED



DETAIL 11
FLOOR MOUNTED

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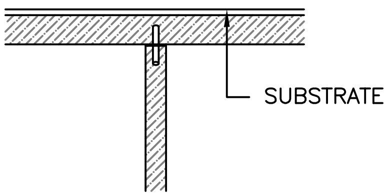
STONE TOILET PARTITIONS
(CEILING-MOUNTED)

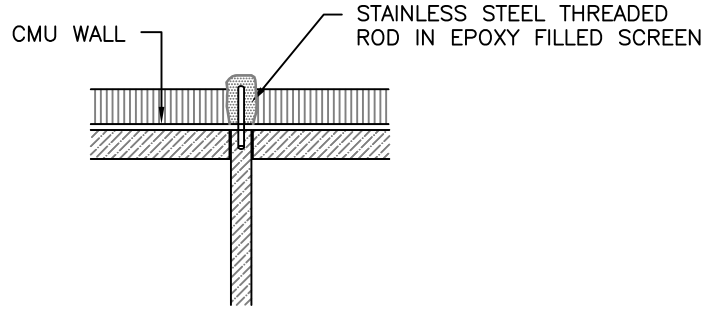
DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 16-D-4

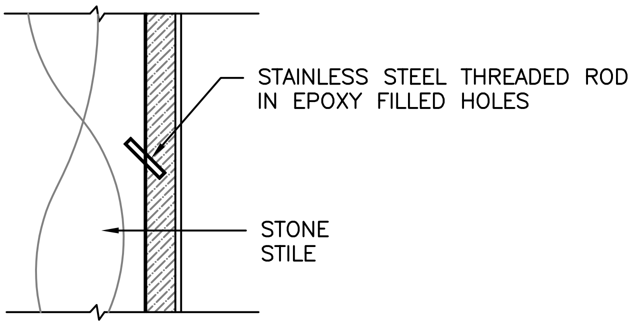
SCALE: 1½" = 1'-0"



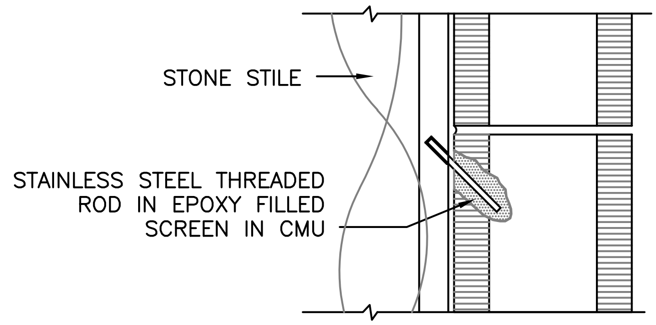
PLAN 12
DOWEL MOUNTED



PLAN 13
DOWEL MOUNTED



SECTION 14
DOWEL MOUNTED



SECTION 15
DOWEL MOUNTED

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STONE TOILET PARTITIONS
(DOWEL-MOUNTED)

DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 16-D-5

SCALE: 1½" = 1'-0"

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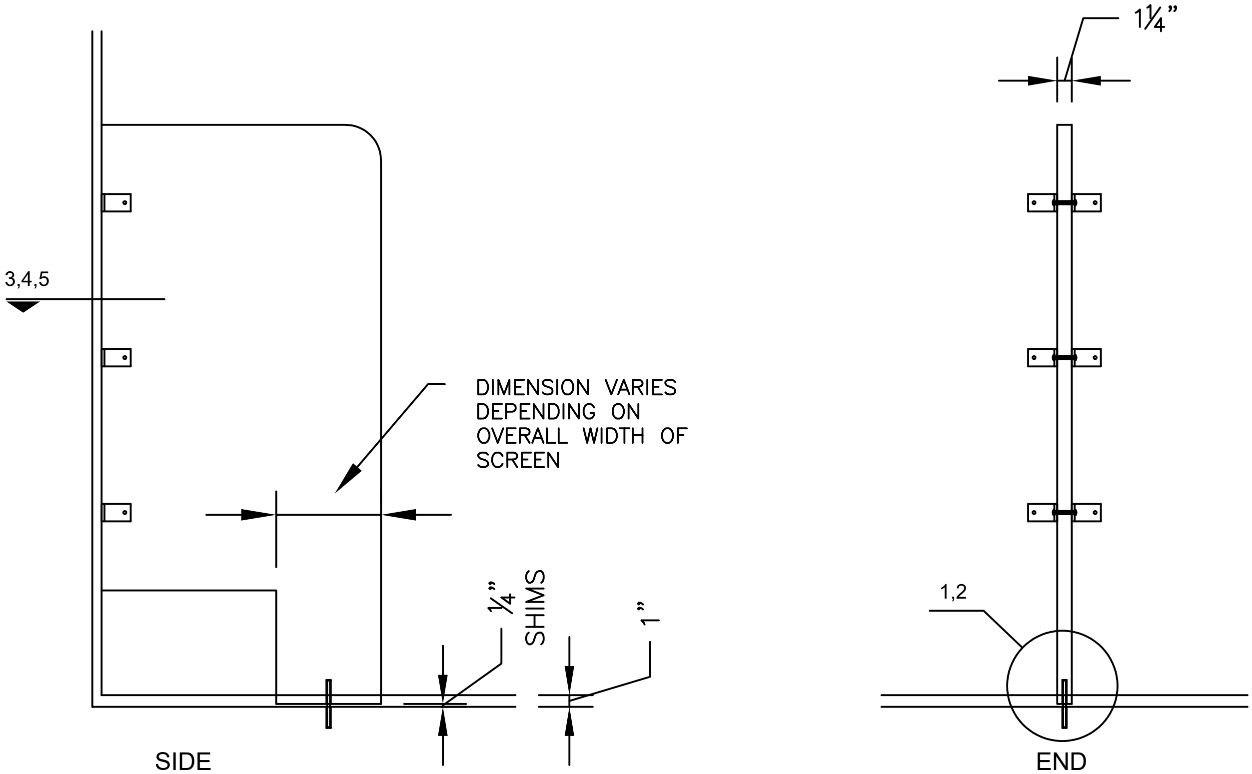
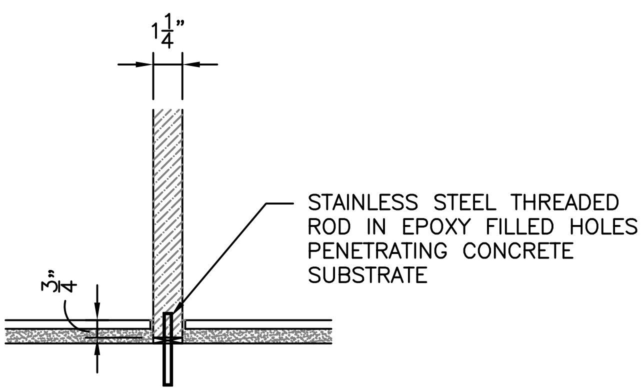
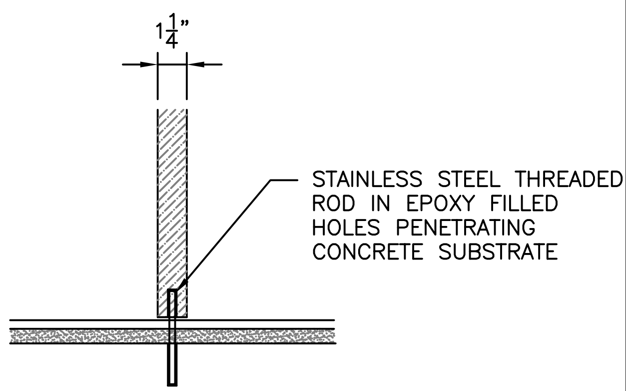


URINAL SCREEN ELEVATIONS - FLOOR SUPPORTED

3/4"=1'-0"



DETAIL 1
LEG PENETRATING FLOOR



DETAIL 2
LEG RESTING ON FLOOR

1 1/2"=1'-0"

NATURAL STONE INSTITUTE	REV	DATE	STONE URINAL PARTITIONS (FLOOR-SUPPORTED)
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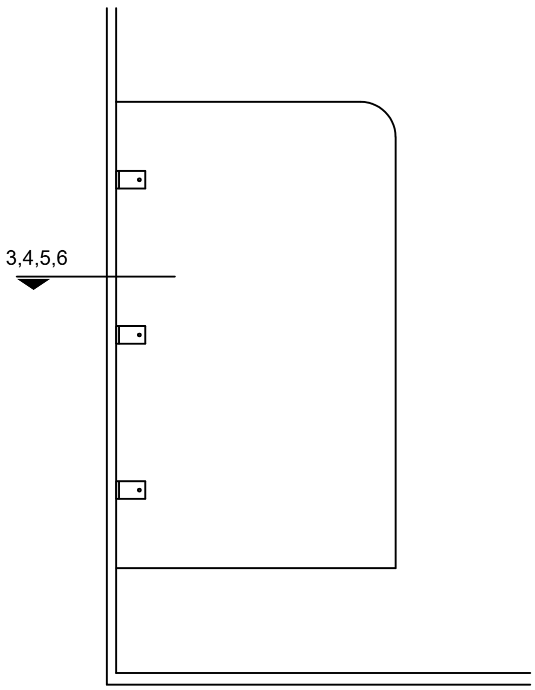
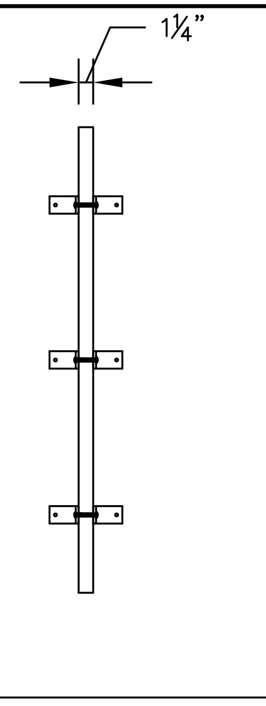
			DRWG NO: 16-D-6 SCALE: AS NOTED

CAUTION: IF THIS SHEET IS NOT 8½" x 11", IT IS A REDUCED OR ENLARGED PRINT



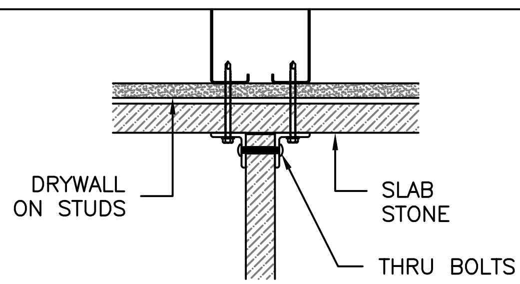
SIDE



END

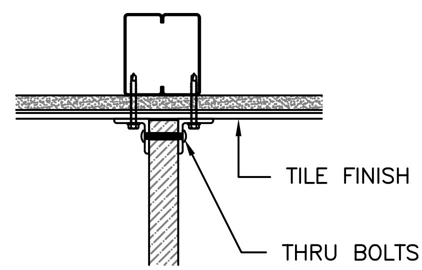
URINAL SCREEN ELEVATIONS - WALL MOUNTED

3/4"=1'-0"



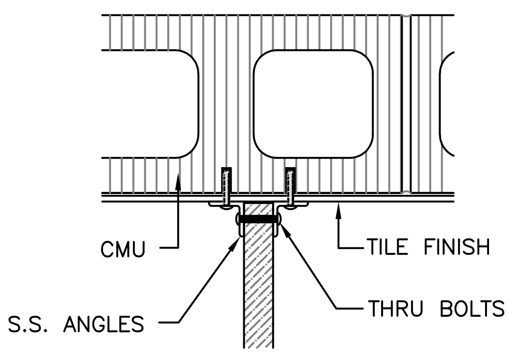
PLAN 3

HARDWARE MOUNTED



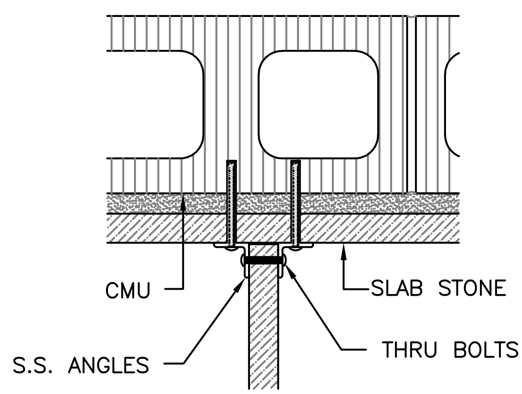
PLAN 4

HARDWARE MOUNTED



PLAN 5

HARDWARE MOUNTED



PLAN 6

HARDWARE MOUNTED

1 1/2"=1'-0"

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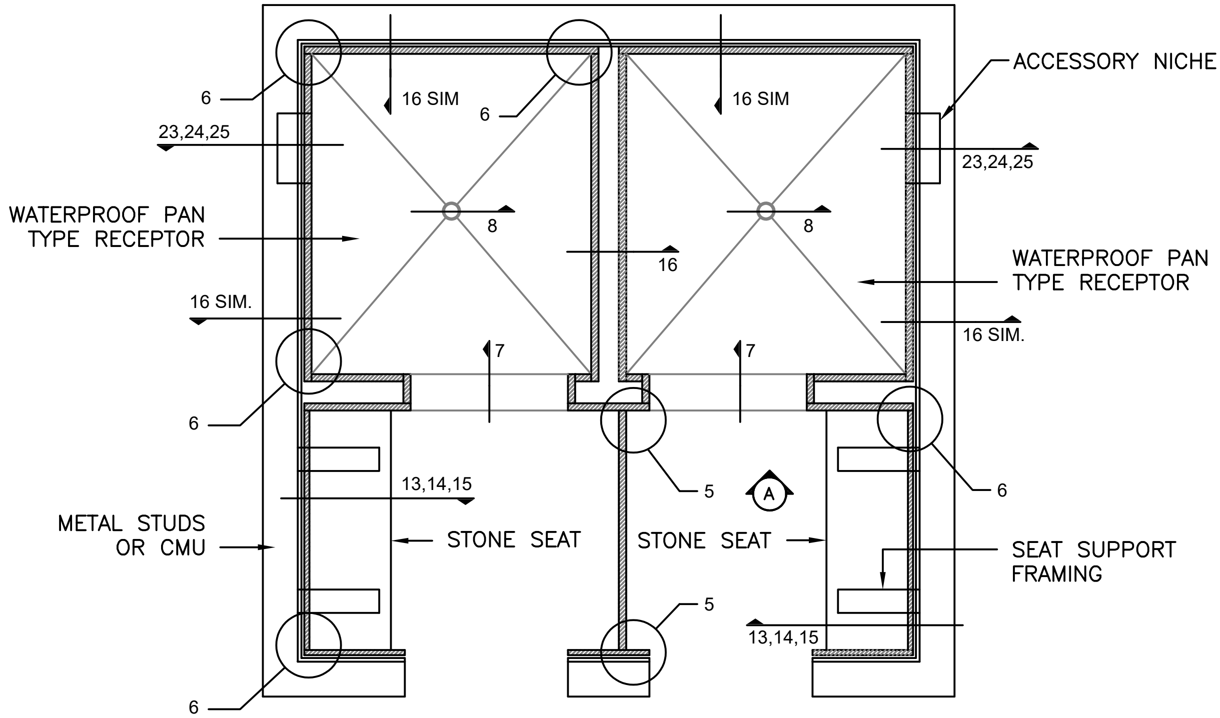
STONE URINAL PARTITIONS
(WALL-MOUNTED)

DIMENSION STONE DESIGN MANUAL 2022

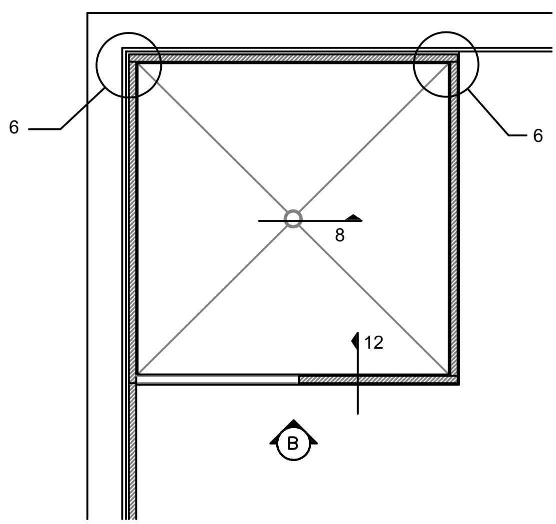
DRWG NO: 16-D-7

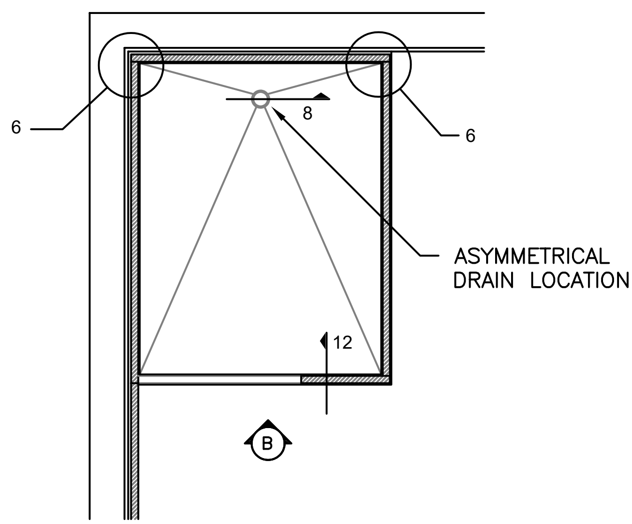
SCALE: AS NOTED



PLAN
WATERPROOF PAN RECEPTOR TYPE

3/8"=1'-0"





PLAN
PRECAST RECEPTOR TYPE

PLAN
PRECAST RECEPTOR TYPE

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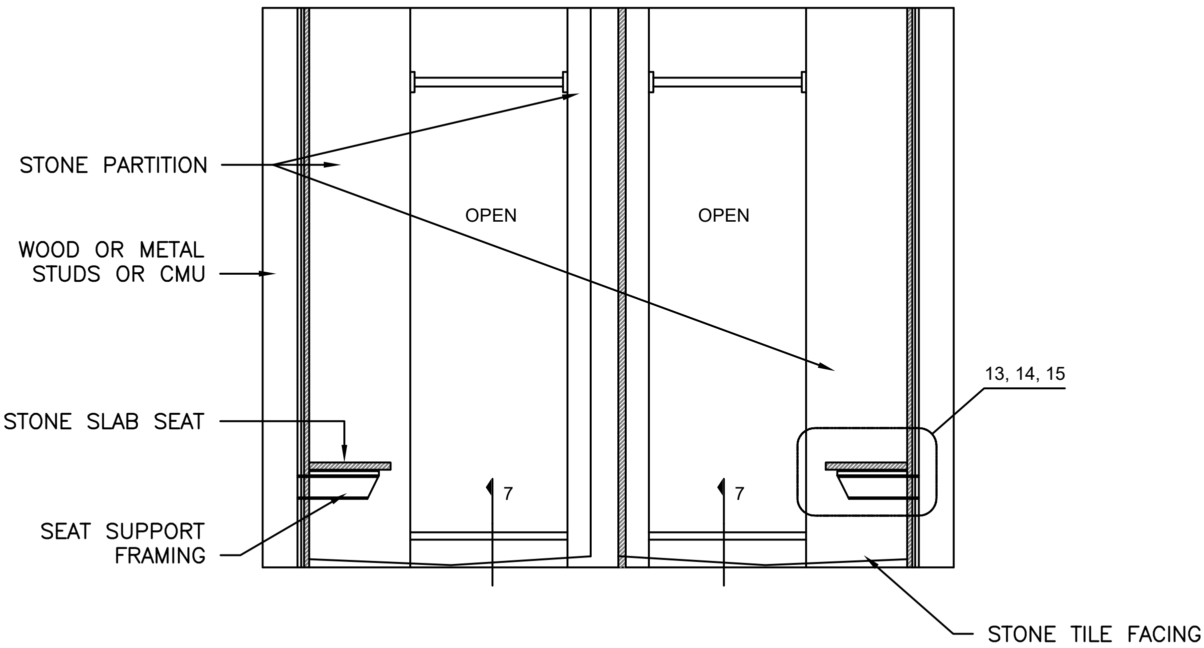
STONE SHOWER PARTITIONS - PLANS

DIMENSION STONE DESIGN MANUAL 2022

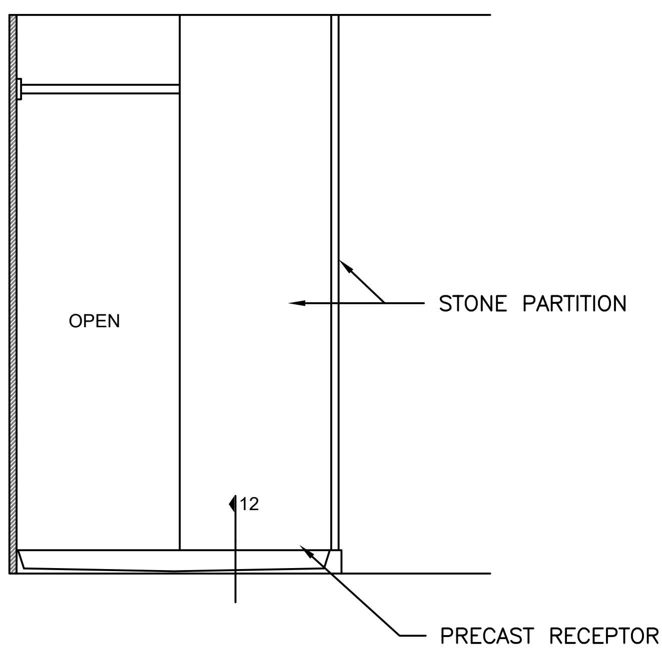
DRWG NO: 16-D-8

SCALE: ⅜" = 1'-0"



ELEVATION A
WATERPROOF PAN RECEPTOR TYPE

3/8"=1'-0"



ELEVATION B
PRECAST RECEPTOR TYPE

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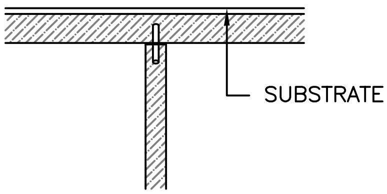
STONE SHOWER PARTITIONS - ELEVATIONS

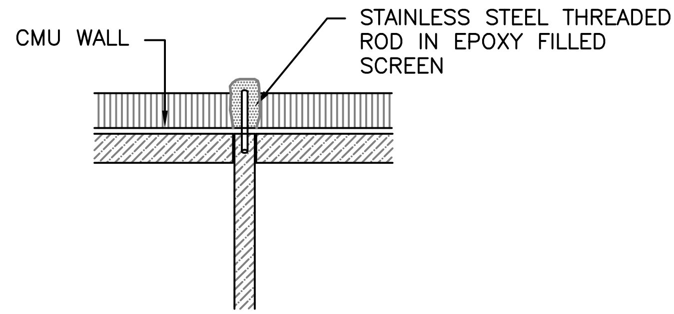
DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 16-D-9

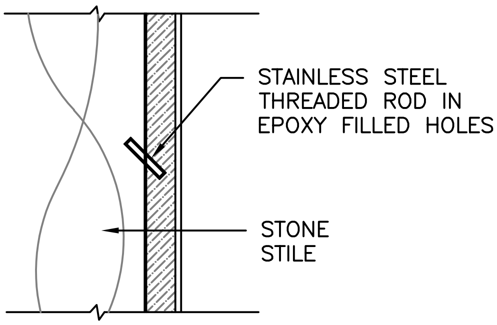
SCALE: ⅜" = 1'-0"



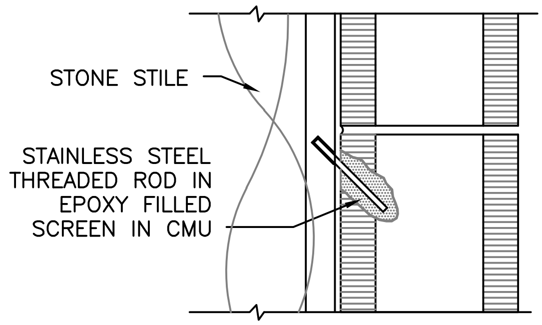
PLAN 1
DOWEL MOUNTED



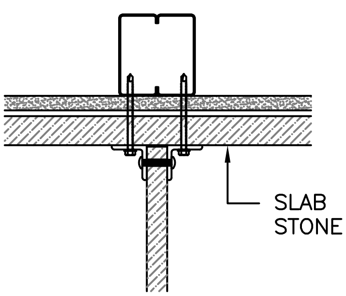
PLAN 2
DOWEL MOUNTED



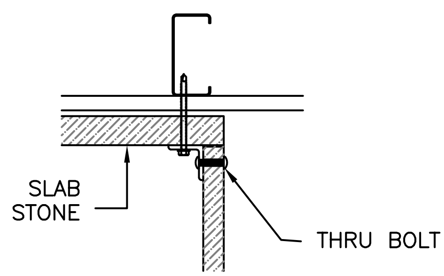
SECTION 3
DOWEL MOUNTED



SECTION 4
DOWEL MOUNTED



PLAN 5
HARDWARE MOUNTED



PLAN 6
CORNER

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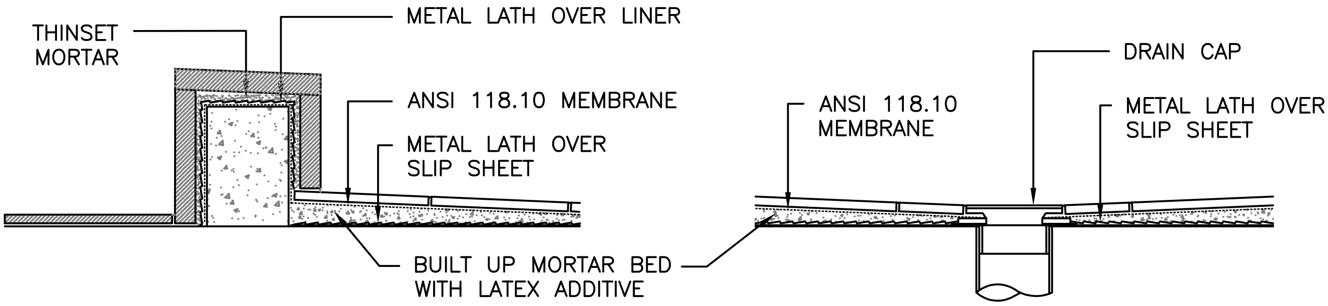
STONE SHOWER PARTITIONS

DIMENSION STONE DESIGN MANUAL 2022

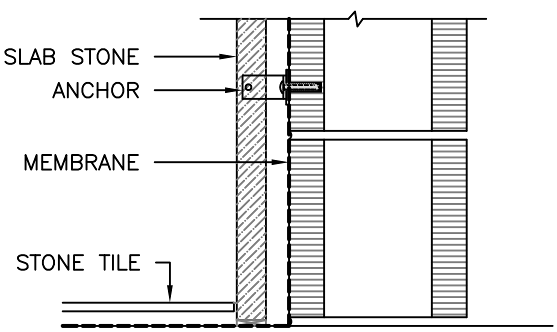
DRWG NO: 16-D-10

SCALE: 1½" = 1'-0"

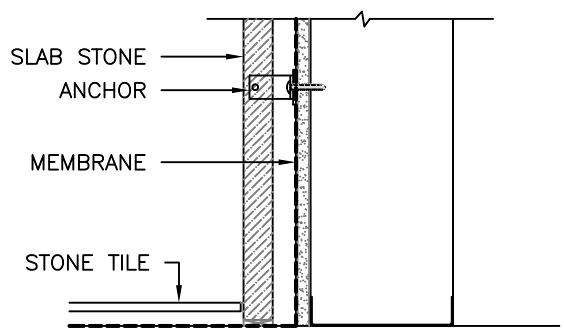


SECTION 7
SHOWER STALL CURB

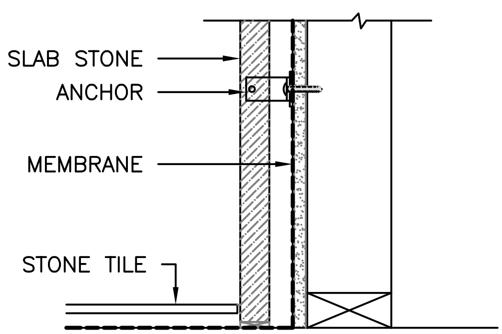
SECTION 8
SHOWER STALL DRAIN



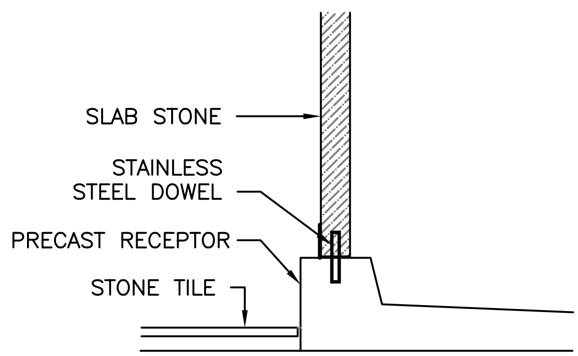
SECTION 9
BOTTOM OF STONE AT CMU



SECTION 10
BOTTOM OF STONE AT METAL STUDS



SECTION 11
BOTTOM OF STONE AT WOOD STUDS



SECTION 12
BOTTOM OF STONE AT PRECAST RECEPTOR

NOTE: REFER TO TCNA HANDBOOK FOR CERAMIC, GLASS, AND STONE TILE INSTALLATION FOR ADDITOINAL DETAILS

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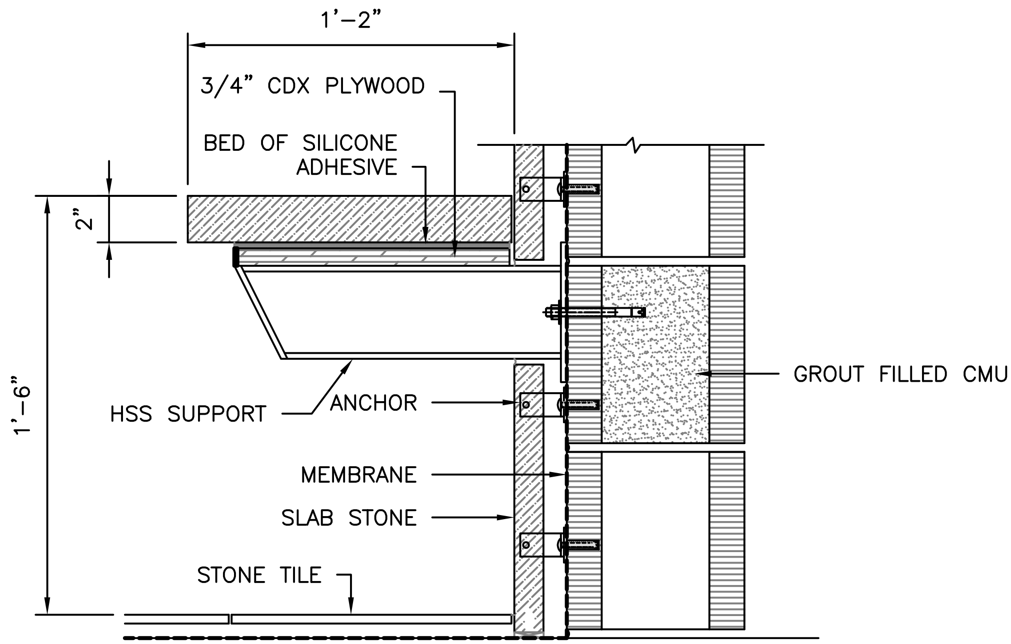
STONE SHOWER PARTITIONS

DIMENSION STONE DESIGN MANUAL 2022

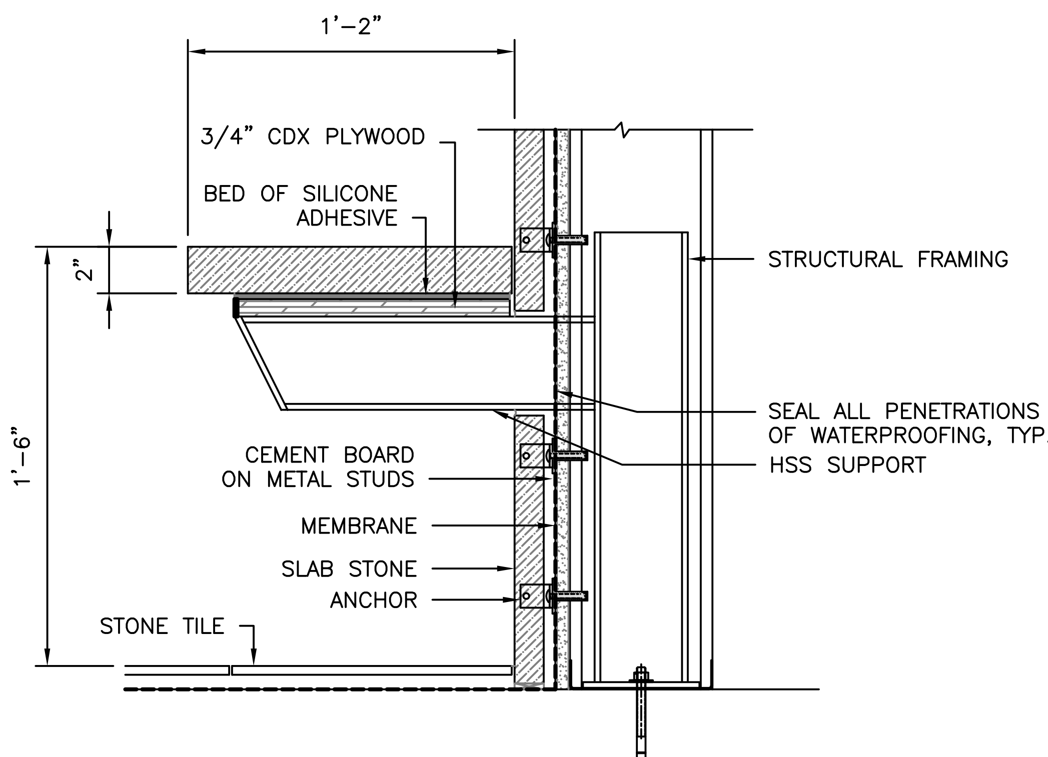
DRWG NO: 16-D-11

SCALE: 1½" = 1'-0"



SECTION 13

STONE SEAT AT CMU WALL



SECTION 14

STONE SEAT AT METAL STUD WALL

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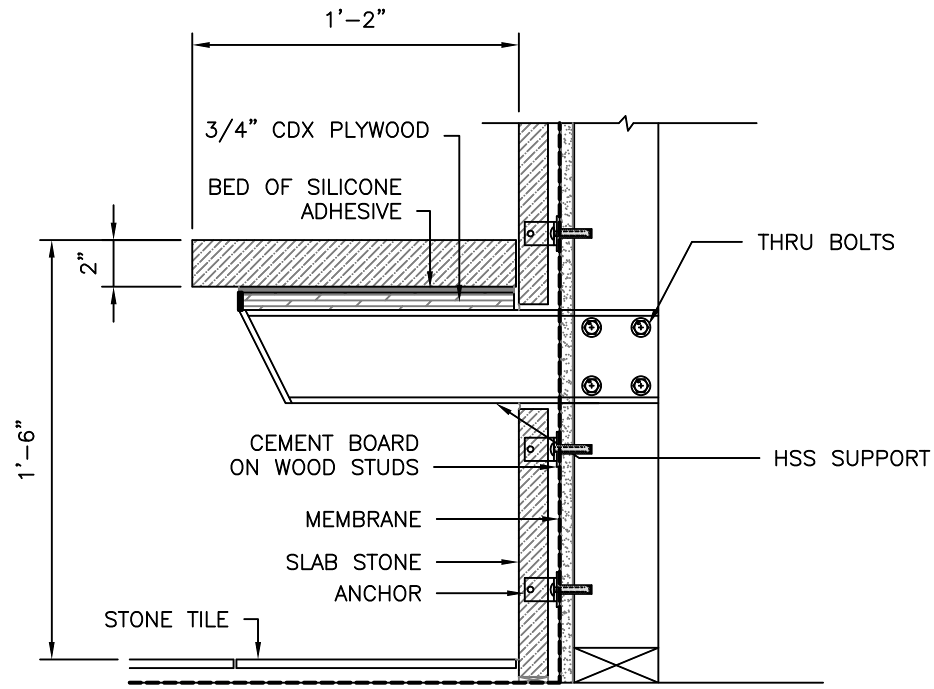
STONE SHOWER PARTITIONS

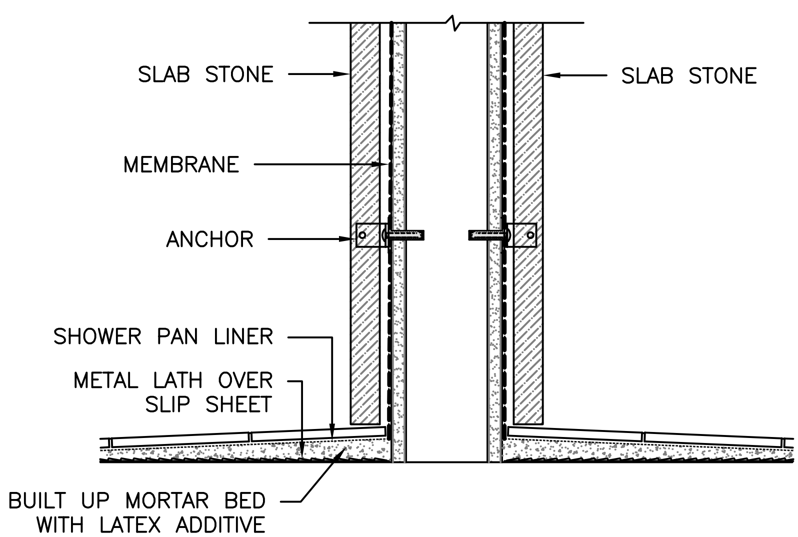
DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 16-D-12

SCALE: 1½" = 1'-0"



SECTION 15
STONE SEAT AT WOOD STUD WALL



SECTION 16
STONE CLAD SHOWER DIVIDER WALL

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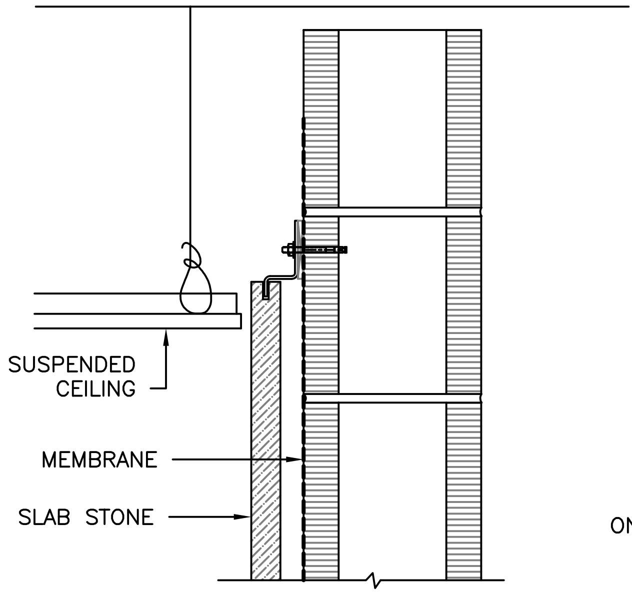
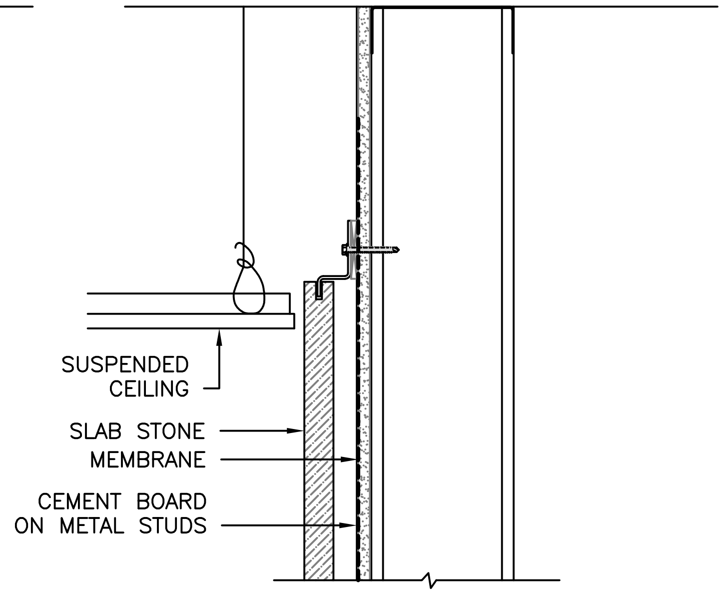
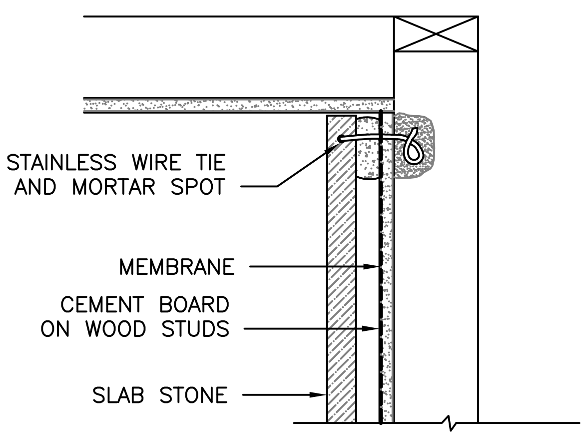
0	MAR 2022	STONE SHOWER PARTITIONS
		DIMENSION STONE DESIGN MANUAL 2022
		DRWG NO: 16-D-13 SCALE: 1½" = 1'-0"



SECTION 17
TOP OF STONE AT CMU



SECTION 18
TOP OF STONE AT METAL STUDS



SECTION 19
TOP OF STONE AT WOOD STUDS

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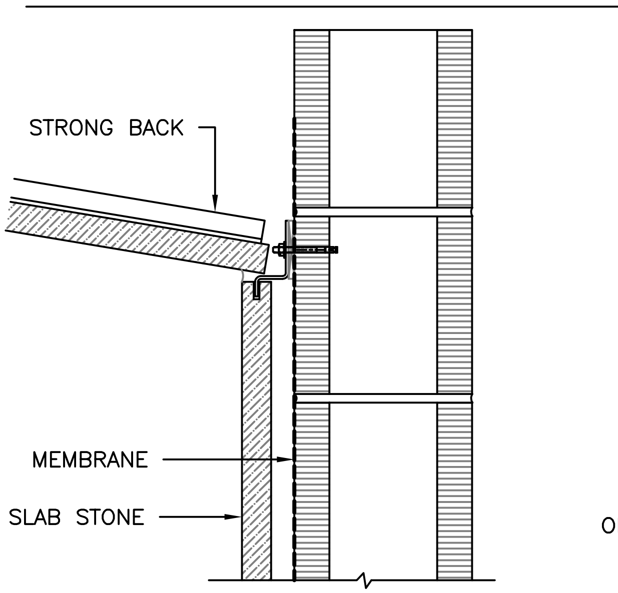
STONE SHOWER PARTITIONS

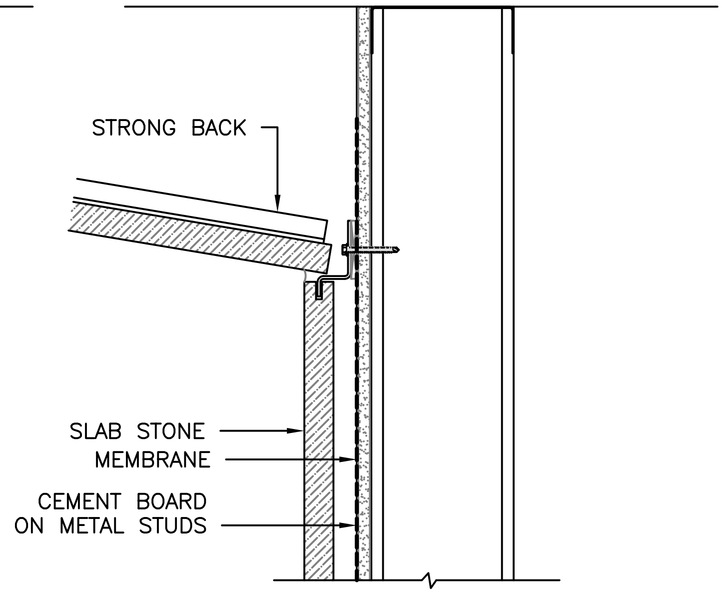
DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 16-D-14

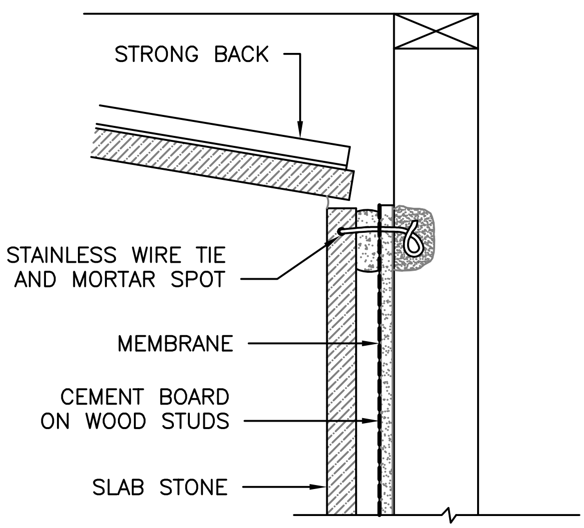
SCALE: 1½" = 1'-0"



SECTION 20
SLOPING STONE CEILING AT CMU



SECTION 21
SLOPING STONE CEILING AT METAL STUDS



SECTION 22
SLOPING STONE CEILING AT WOOD STUDS

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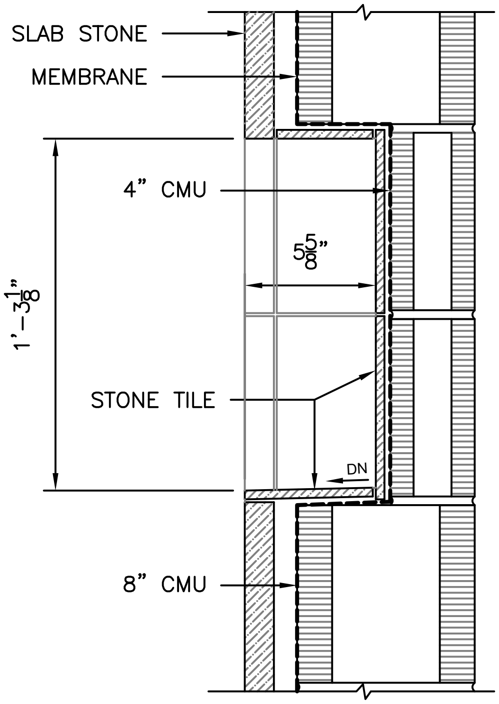
STONE SHOWER CELINGS

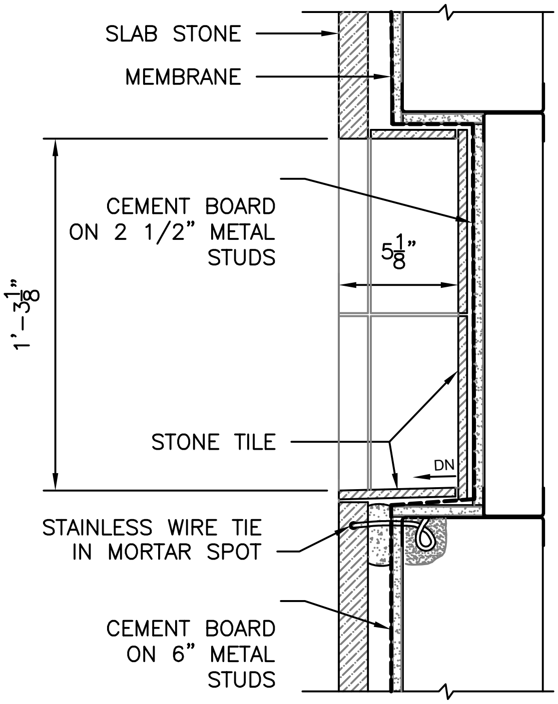
DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 16-D-15

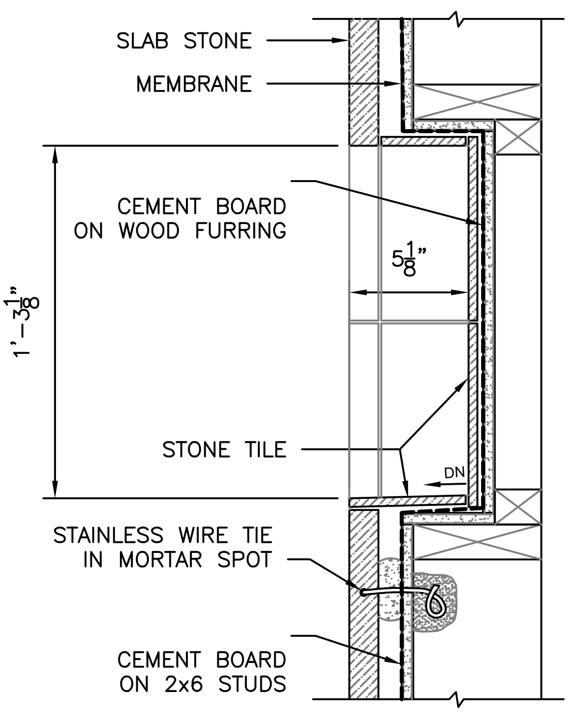
SCALE: 1½" = 1'-0"



SECTION 23
ACCESSORY NICHE AT CMU



SECTION 24
ACCESSORY NICHE AT METAL STUDS



SECTION 25
ACCESSORY NICHE AT WOOD STUDS

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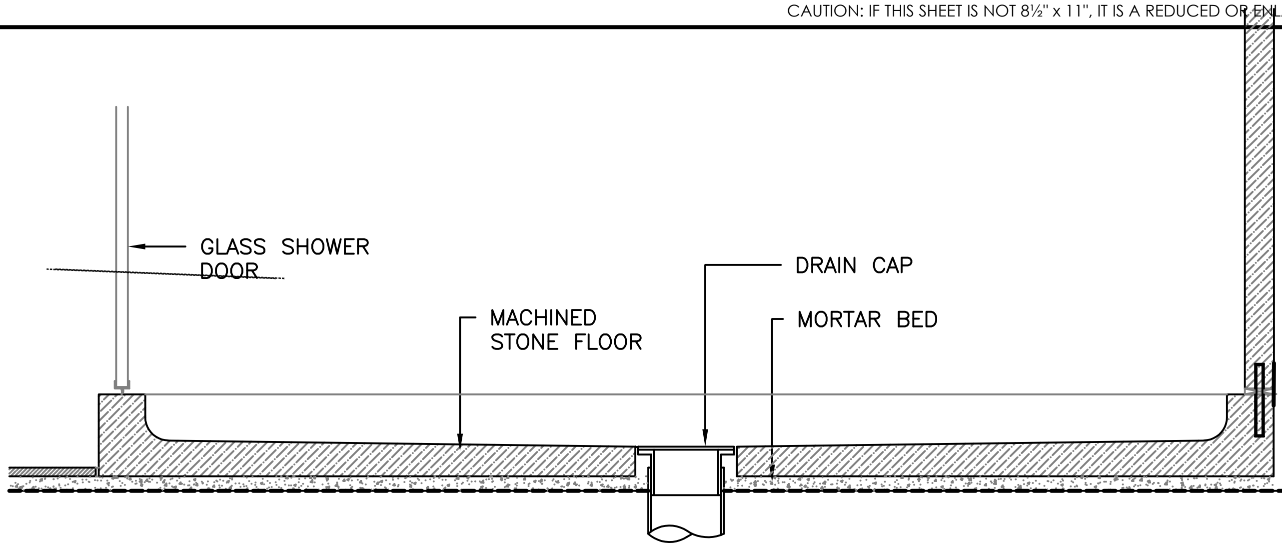
STONE SHOWER ACCESSORY NICHE

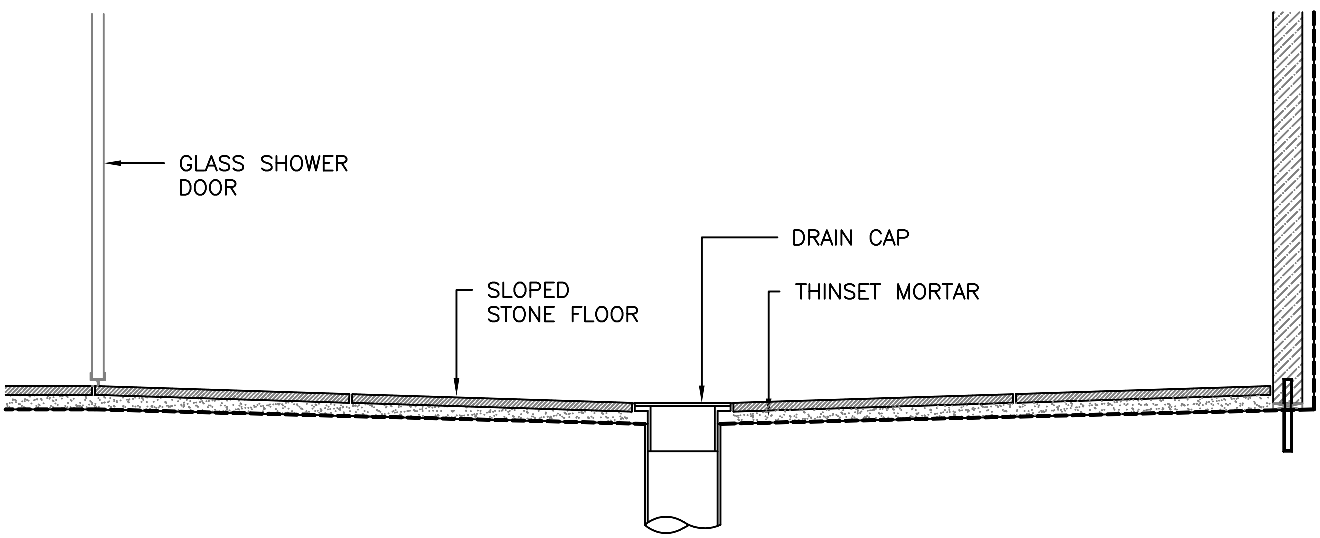
DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 16-D-16

SCALE: 1½" = 1'-0"



SECTION 26
MACHINED SHOWER FLOOR



SECTION 27
BARRIER FREE SHOWER FLOOR

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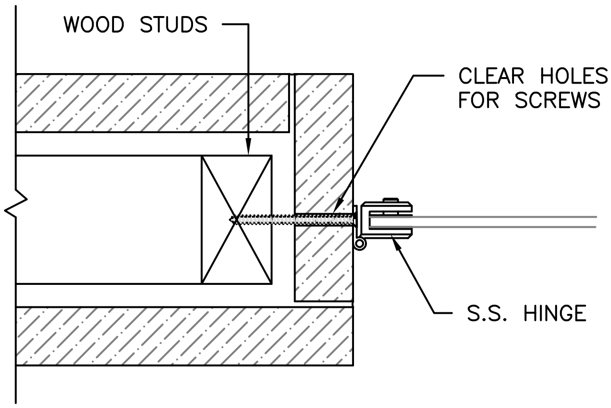
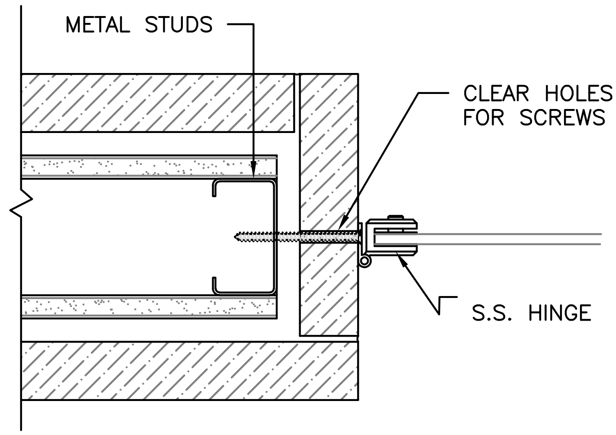
	0	MAR 2022	
			DRWG NO: 16-D-17 — SCALE: 1½" = 1'-0"



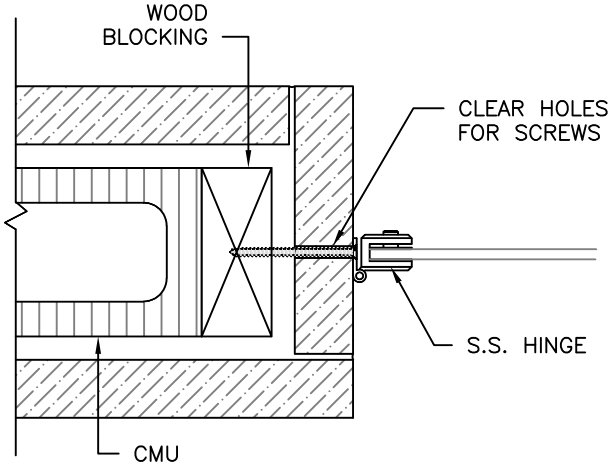
PLAN SECTION 28

JAMB AT SHOWER DOOR HINGE



PLAN SECTION 29

JAMB AT SHOWER DOOR HINGE



PLAN SECTION 30

JAMB AT SHOWER DOOR HINGE

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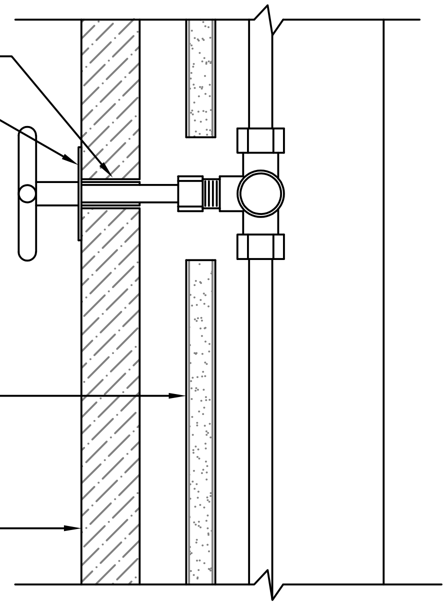
STONE SHOWER DOOR JAMBS

DIMENSION STONE DESIGN MANUAL 2022

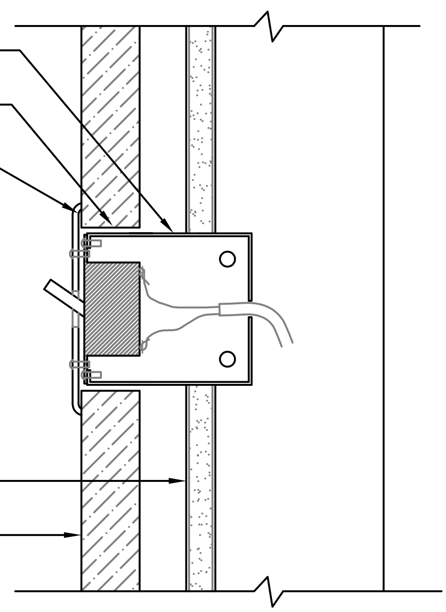
DRWG NO: 16-D-18

SCALE: 3" = 1'-0"



SECTION 31

PLUMBING CONTROL VALVE



SECTION 32

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STONE SHOWER PARTITIONS

DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 16-D-19

SCALE: 3" = 1'-0"

NOTES:

RESIDENTIAL STONE COUNTERTOP INSTALLATION

1.0 INTRODUCTION

1.1 The beauty and permanence of natural stone countertops are enjoyed by many. The full potential of these installations is realized only when the selection, design, fabrication, and installation are completed by, or with the consultation of, qualified and experienced individuals. This document has been prepared and published by the Natural Stone Institute to guide the user in the correct means and methods of using natural stone as a countertop surface.

2.0 STONE MATERIALS

2.1 Varieties. All varieties of dimension stone have been used successfully for countertop surfaces. Different types of stone have specific properties that offer advantages or disadvantages in various applications. The following is a brief overview of the common varieties of dimension stone.

2.2 Granites are undoubtedly the most popular stone type used in countertop applications today. This group of stones, in a commercial sense, includes many stone materials that are not true granites by geological definition. For example, gabbro, anorthosite, gneiss, diabase, and diorite would be commercially sold as granite due to similar working and performance properties. These are some of the hardest of the common dimension stones, offering high levels of resistance to abrasion and scratching. The primary minerals in granite materials are resistant to virtually all chemicals commonly found in a residential setting; however, there may be trace minerals present in some granites and granite-like stones that are vulnerable to some acids.

2.3 Marbles are traditionally prized for their aesthetic appeal, accentuated by pronounced veining trends and often bold colors. These stones are calcium carbonate-based, made up principally of the calcite crystal. Due to their mineralogical makeup, all marbles are vulnerable to either abrasion or chemical attack. Abrasive attack occurs most commonly from common kitchen utensils, and can be prevented with the judicious use of protective cutting boards and similar measures. The use of cleaners containing abrasives must be avoided. Chemical attack is most commonly brought about by exposure to acidic solutions, such as lemon juice, tomatoes, vinegar, etc. The use of inappropriate cleaning agents may also trigger acidic attack. Acidic solutions can permanently etch the surface of the material. The application of an impregnating sealer may reduce the vulnerability to acidic attack, but it will not eliminate it.

2.4 Serpentines are similarly prized for their veining and color. Historically, this rock type had been commercially grouped with marble. However, serpentine is not true marble geologically. See Chapter 9, Geological Classification, for distinguishing characteristics of serpentine. Due to their mineralogical difference, serpentines generally have improved abrasion and chemical resistance over true marbles.

2.5 Onyx, also prized for its color and veining, is perhaps best known for its translucent properties allowing for stunning effects when backlit in the application. Like several other rock varieties, onyx was traditionally commercialized as marble, despite its notable differences. Refer to section 1.2 of the Geological Classification section in Chapter 7 for further discussion of onyx mineralogy. Due to its cryptocrystalline grain structure, when compared to true marbles, onyx tends to have lower levels of resistance to both chemical and abrasive exposures.

2.6 Soapstone is a metamorphic rock that is comprised primarily of talc with varying amounts of dolomite, magnesite, and other minerals. Soapstone generally has a smooth feel to the touch. It is used for countertops and other various building aspects such as sinks and heaters. Soapstone is a very popular choice for countertops in laboratories and classrooms due to its high resistance to chemicals. Soapstone has limited hardness and is vulnerable to scratches from abrasives. Soapstone is typically top treated with a food grade mineral oil to retain its luster and to mask small scratches that are often common because of its talc content.

2.7 Slates, when referring to true slates, have high resistance to chemicals. Traditionally slates were frequently used as chemistry laboratory tops due to this chemical resistance. Caution is advised, however, in that not all materials marketed as slates are in fact true slate, and therefore may not demonstrate the superior chemical resistance that has been associated with this stone variety. Being of metamorphic origin, slates are of limited hardness and therefore the vulnerability to scratching or other abrasive attack should be noted. The same precautions applying to marbles with regard to abrasive damage should be applied to slates.

2.8 Limestones and travertines used in countertop applications, being of calcium-based makeup, will have the same chemical attack vulnerabilities as marbles. Abrasion damage is also a concern, particularly if the stone is provided with a polished finish. Many varieties of these stone types have high absorption rates, and commonly, a sealer will be applied to retard the rate of water absorption into the stone.

2.9 Stone tiles can be used as a countertop surface material, and the finished surface will carry the same precautions as the particular stone type from which it is made. The joint filler, whether grout, elastomeric sealant, epoxy or polyester resin, may have specific requirements for protection and maintenance. Follow the recommendations of the Manufacturer of the material.

3.0 STONE FINISHES

There are several finishes available for natural stone countertops and new finishes appear in the market regularly keeping pace with consumer demands. A description of a few of the finishes commonly available follows:

3.1 Polished: A high gloss, mirror like finish with sharp reflections. This finish is achieved using multiple grinding heads and progressively finer abrasives. A polished finish intensifies the color and pattern of natural stone.

3.2 Honed: A non-reflective, satin-like finish. This finish is achieved using multiple grinding heads and progressively finer abrasives stopping short of a polish. A honed finish shows fewer scratches.

3.3 Brushed / Antique / Leather: The use of this series of names is not fully standardized within the industry. From some sources, they are used interchangeably, while from other sources, they are distinctly different processes. Most commonly, they describe a finish that has been achieved by abrading a smooth (or honed) surface with an abrasive, often diamond, brush. The resultant finish can have varying levels of sheen and relief. The hardness of the mineral matrix within the stone to which it is applied will also affect the final product.

4.0 CUSTOMER COMMUNICATION

4.1 Documentation. As dictated by standard practices of good business, communications with the customer should be documented in writing.

4.1.1 As all natural stones are unique, with pits, fissures, cracks, corrosive minerals, or other features that the customer may find objectionable, these should be acknowledged when samples and/or slabs are being viewed. The customer must be made aware that some of these features may become more or less noticeable when the position (vertical or horizontal) of the slab is changed, or when the lighting intensity is changed.

4.2 Customer and Subcontractor Responsibilities. Those items that are required to be completed by the customer, or by subcontractors coordinated by the customer, should be specifically addressed (e.g., cabinetry installation, plumbing rough-in and electrical rough-in).

4.3 Shop Drawings (or facsimile) can effectively communicate exact cutting information to the customer. A shop drawing is a highly detailed document that will identify all aspects of the finished product installation. The shop drawing is to be prepared by the fabricator, showing the layout of the stone pieces, location and size of all seams, and details clarifying all corner and edge treatment conditions. This document can be reviewed by the customer prior to commencement of fabrication. Time constraints of some projects, particularly multi-unit projects, may not allow for the formal shop drawing preparation and approval processes. In such cases, a copy of the field measuring technician's sketch and notes may be used in place of the shop drawing. This document shall be signed by the field measurer upon completion of the field measurement.

4.4 Stone Slab Layout. When working with highly variegated materials, it may be necessary to invite the customer to participate in the layout of the actual stone slabs.

5.0 CONTRACTS

5.1 Examples of residential supply contracts can be found in the Introduction of this Manual and *Customer & Sales Forms* in the NSI Management Tool Kit Series.

6.0 CABINET AND SUBSTRATE REQUIREMENTS

Cabinets to receive stone countertops must be permanently affixed in their final position prior to field measuring for countertops.

6.1 Measurement Tolerances. Refer to Chapter 22 for allowable substrate tolerances. When cabinets are not within these tolerances, a notice to proceed with the installation shall be obtained from the customer (or authorized representative). Installations done on cabinetry that is outside of these tolerances will have excessive shim spaces and wide regions of filler material. Any required aesthetic improvement to conceal this condition (e.g., additional wood trim) is the responsibility of others.

6.2 Subtops. Fragile stone varieties may require a full subtop to support the stone. Generally, sound varieties of granites and marbles falling within soundness classifications A or B can be used in thicknesses of 20 mm or greater without the use of a subtop. The presence of unsound veins, cracks, or excessive fissuring will mandate the use of a subtop, regardless of thickness. Appropriate materials for subtops are marine-grade plywood, exterior-grade plywood, waterproofed medium-density particle board, or furring strips. Excessive load-carrying requirements, such as the use of heavy cast-iron sinks, may require the use of either a subtop or auxiliary framing to carry the weight of the sink and its contents.

6.3 Cabinet doors, end panels, and hardware shall be installed when the field measurements are made.

7.0 FIELD MEASUREMENTS

7.1 Cabinet Components. Field measurements are to be taken once all cabinets have been installed in their permanent positions. The following related components must be available to the technician at the time of measurement:

7.1.1 Cabinet Doors

7.1.2 End Panels

7.1.3 Cabinet Hardware

7.1.4 Sinks (and manufacturer-supplied templates)

7.1.5 Plumbing Fixtures

7.1.6 Cook Tops

7.1.7 Exhaust Vents (when full-height splash is required)

7.1.8 Electrical Outlets (roughed in)

8.0 DESIGN CONSIDERATIONS

8.1 Joinery Layout. The layout of the joinery of the countertops is extremely important to the overall appearance upon completion. Being products of nature, slabs of natural stone are limited by the yields of the quarry in addition to the limitations of the equipment used in their processing. Most, but not all materials marketed for use as countertops will be available in lengths up to ±8 ft (± 2.5 m), and some materials are available in lengths of 10 ft (3 m) or slightly greater. Seam location and frequency is therefore influenced by the available stock for selected species of material. Details on drawings 17-D-1, 17-D-2, and 17-D-3 show a variety of joinery schemes.

8.2 Spans and Cantilevers. In designs where part of the countertop is spanning between supports, the length of the span shall be limited to 2'-0" (600 mm) for ¾" (20 mm) stone thicknesses and 3'-0" (900 mm) for 1¼" (30 mm) stone thicknesses. In designs where the countertop is cantilevered beyond the supports (overhanging), the cantilever shall be limited to 6" (150 mm) for ¾" (20 mm) thick countertops and 10" (250 mm) for 1¼" (30 mm) countertops, but in no case may the cantilevered portion represent more than 1/3 of the width of the countertop. Cantilevered countertops exceeding these dimensions will require corbelled supports beneath the stone. The exposed underside of cantilevered portions of countertops will be sawn or otherwise unfinished surfaces. NOTE: Stones of lesser soundness may require corbelled supports for cantilevers that are less than those specified herein.

8.3 Sink Mounts. Sinks are supplied in one of several types: top mount (or self-rimming), undermount and "farm-home." In the case of the top-mounted sinks, the weight of the sink and its contents are transferred to the top surface of the stone counter via the rim of the sink. Undermount sinks can be anchored to the underside of the stone countertop or carried by a subtop or auxiliary frame. A subtop or auxiliary framing may be required for either design when stones of lesser soundness are used, or when the sink (with contents) is excessively heavy. Refer to details on drawings 17-D-8 through 17-D-11 for examples of sink mounting.

8.4 Edge profiles. Whether shaped by a router or a Computer Numeric Control (CNC) machine, edge profiles add elegance to the finished project. Edge profiles with narrow projections and sharp corners are more susceptible to chipping than those with large radii. Examples of edge profiles commonly used are included on drawing 17-D-16. With machinery and tooling available to modern fabrication shops, many custom profiles can be created which are not shown in this document.

8.5 Corner Embellishments. Corners of stone countertops can be cut square, cut to a radius, or projected. Some hand grinding may be required with projected corner designs.

8.6 Backsplashes. Partial backsplashes usually range from 4" to 8"(100 to 200 mm). Full-height backsplashes cover the entire area between the countertop and the upper cabinets. Backsplashes are normally made of the same thickness as the countertop material. The narrow strips will aid in the layout efficiency and allow for better color match. It also provides the fabricator better yield. Mixing materials of two different thicknesses requires using stone slabs sawn from two different blocks, and color variation can be pronounced.

9.0 FABRICATION METHODS

9.1 Safe Work Practices. All technicians involved in the handling and working of stone materials must receive training in the safe work practices (Refer to NSI videos on stone shop and slab handling safety).

9.2 Layout and Sawing. The layout should be marked on the stone slabs using a temporary mark or by laying physical templates on the slab. This will roughly indicate the location and orientation from which the finished panels will be sawn. The actual finished dimensions of the sawn slabs will be controlled by the sawyer, and depending on the sophistication of the available equipment, may be a digitally controlled process. The slab thickness is to be sawn through its full depth, in single or multiple passes as required by the equipment used. Blade type, rim speed, saw travel rate, and downfeed rates are to be adjusted to provide the smoothest cut with the least amount of chipping possible.

9.3 Finishing of Edge Profiles. Edge profiles shall be constant in section along the entire length of the countertop. The shaping of the edge is normally done with hand-held routers or with CNC machinery. Some hand grinding is frequently required at inside corner conditions to create a sharp line of reprise. Edges are to be finished to the same type and quality of surface as the top, unless a contrasting edge surface has been specified for accent purposes. In the case of resin treated slabs, some alteration to the color of the edge surface is required to be completed in the fabrication shop. In some cases exact color match between the edge surface and the top surface may not be achievable.

9.4 Cutouts for auxiliary equipment can be made with hand-held or automated tools. Cutouts shall conform to equipment templates, with allowable tolerances. In the interest of safe handling, some cutouts will be partially or completely performed in the field after installation of the stone.

9.5 Crating and Protection for Transport. The stone materials are to be crated or otherwise protected for transport to the project site. Local transportation laws shall be researched to ascertain tie-down and clearance requirements when transporting stones.

10.0 INSTALLATION METHODS

10.1 Safe Handling. All technicians involved in the handling and working of stone materials must receive training in safe work practices.

10.2 Dry Assembly. At the project site, it is recommended that all stone pieces be “dry assembled” in place to verify satisfactory fit prior to the application of adhesive.

10.3 Shims are commonly employed to level the stone countertops. Shim material may be wood or plastic. Shims must be placed over portions of the cabinet that are rigid enough to support it, not over some trim filler portion. Maximum spacing between shims is 2'-0" (600 mm). Alternatively, longer spacing between shims may be used if the stone is supported with a noncompressible filler material (usually epoxy or polyester resin). This practice is often referred to as “hard packing.”

10.4 Adhesive. The stone countertops are to be secured to the substrate with a nonstaining adhesive. Common construction adhesives or silicone sealant are the most popular materials used. Construction adhesives generally provide greater bond strength, while silicone sealants offer slightly more forgiveness for movements in the substrate. The adhesive material must have a cure rate that is slow enough to allow final positioning of the stone countertop units. Apply adhesive to within 3" (75 mm) of all edges and at 6" (150 mm) maximum center-to-center spacing when installing over a subtop. When installing to the cabinet frame without a subtop, apply adhesive to all frame members that contact the stone slab.

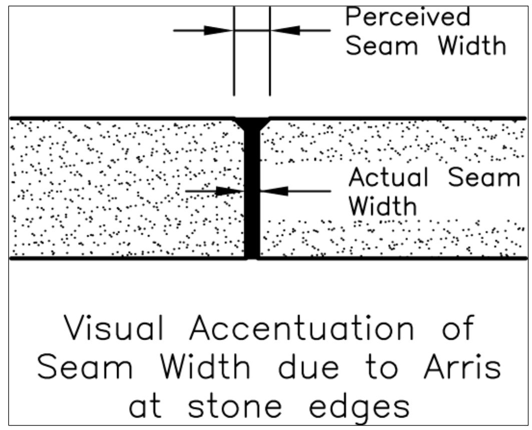
10.5 Final Positioning and Joint Filling. Final positioning of the stone is done either manually or with the aid of commercially available stone-alignment tools. The filling of the seams is normally completed prior to final positioning of the stone units, allowing the filler material to extrude out of the joint as the stones are pulled into alignment. The stone surface may be masked to prevent contact by the filler material (refer to NSI *Basics of Natural Stone Countertop Installation* video).

10.6 Sealer Application. After the countertops are installed and the seams are filled, a sealer or impregnator may be applied. Refer to the Maintenance section of this chapter for further discussion of these applications. Alternatively, some fabricators prefer to apply the sealer or impregnator in the fabrication shop prior to transporting the pieces to the project site.

11.0 TOLERANCES

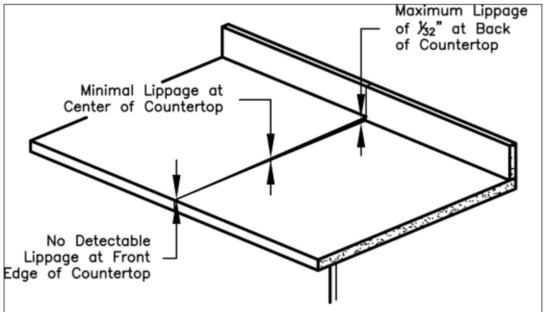
11.1 Refer to Chapter 22 for allowable fabrication and installation tolerances. The tolerances listed in this section are achieved using skilled tradesmen following standard industry workmanship practices. Due to variations in fabrication equipment and stock availability, these tolerances may not be achievable, or in some cases, closer tolerances may be achievable. Therefore, for any particular project, the supplier and customer may agree to hold tolerances that are more or less stringent than those listed herein. Such agreements must be documented in writing. Unless otherwise agreed, the tolerances listed in this document shall govern.

11.2 Joint (seam) Widths. Joint width does not include the dimension of an arris on the stone edge. When an arris is used, the perceived joint width may be greater that the actual width due to the seam filler occupying the width of the arris.

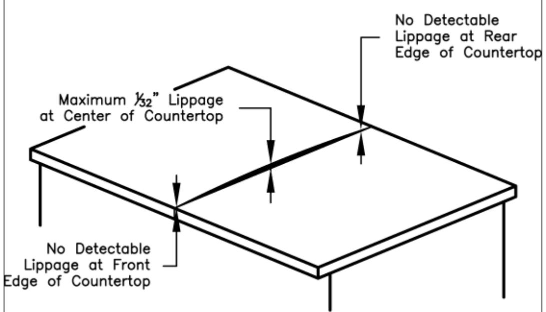


11.3 Lippage. The term "lippage," as used in the stone industry, is the planar offset of the finished surfaces of two adjacent stone units. Due to the relatively tight seams used in countertop installations, even minor amounts of lippage are noticeable. Lippage may be unavoidable due to permanent warp in the slab stock. There should be no detectable lippage at the front edge of the countertop. See sketch below for clarification.

11.4 Exposed edges of adjacent stone slabs must be matched in thickness and properly installed so that neither the top nor bottom surface exceeds lippage tolerances.



Allowable Lippage Due to Slab Warp
(For Standard Counter with Backsplash)



Allowable Lippage Due to Slab Warp
(For Island or Peninsula Counter)

12.0 ADHESIVES AND JOINT FILLERS

12.1 Types. Adhesives used for stone installation can be either standard construction adhesives or elastomeric sealant with strong bonding properties to both the stone and the substrate. Construction adhesives will normally provide greater bond strength, while elastomeric sealants will provide some forgiveness for movement within the substrate cabinet. Excessive movement of the substrate, regardless of the type of adhesive used, will result in cracking of the seams or stone units. Verify that the product used does not stain the stone material.

12.2 Seam Filler Materials. Seams in the stone countertop are usually filled to the level of the top surface. The most common filler materials are polyester resin, epoxy resin and elastomeric sealant. Elastomeric sealants can be of silicon, polyurethane, or acrylic bases. The table below identifies several advantages and disadvantages of each product.

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12 pp. color brochure (2019) available from NSI.

SEAM FILLER MATERIALS ADVANTAGES & DISADVANTAGES

Product	Advantages	Disadvantages
Polyester resin	• Accepts dyes readily, allowing a pleasing color match to stone. • Leaves joint neatly flush with counter-top surface. • Can be buffed to a glossy finish that complements the polished stone surface. • Relatively quick cure time.	• Cures to a high durometer hardness which offers little or no forgiveness for movement. • Limited pot life.
Epoxy Resin	• Leaves joint neatly flush with countertop surface. • Can be buffed to a glossy finish that complements the polished stone surface. • Provides stronger bond than polyester resin. • Long pot life.	• Cures to a high durometer hardness which offers little or no forgiveness for movement. • More difficult to achieve accurate color match than polyester resin. • Long cure time. • The stone fabric will fail before the seam, which is more difficult to repair.
Grout	• Simple to use. • Long pot life. • Relatively easy to dye for color matching.	• Color may not be consistent between batches. • Cracks easily due to movement. • Coarse texture contrasts with polished stone. • High porosity can be a sanitation concern.
Elastomeric Sealant (Silicone, polyurethane, or acrylic)	• Relatively low durometer hardness provides significant extension and compression capability, hence the greatest accommodation for movement of any filler material. • Cures to a glossy surface that compliments the polished stone surface	• Limited to available colors. • Some sealant products contain plasticizers that can migrate into and stain the stone.

13.0 STONE TILE COUNTERTOP INSTALLATION

13.1 Subtops. Stone tile countertops must have a subtop made of minimum ¾" exterior-grade plywood or ½" cementitious backer board. Subtop must be flat to within 1/8" in 10'-0" (3 mm in 3 m).

13.2 Edge Treatment. Exposed edges of the countertop may be finished by providing an edge profile strip of stone, wood, or metal. Where stone is employed, it is to be used as an apron to the top surface stone, which limits stress on the countertop/apron joint.

13.3 Stone tile tolerances for all stone types must be 1/32" (1 mm) in length, width, and thickness.

13.4 Joint Widths. Unless otherwise agreed, joint widths for stone tile countertops must conform to the following: Stone-to-wall joints must be 1/8" (3 mm) in width. Stone-to-stone joints must be 1/16" (1.5 mm) minimum, 3/32" (2 mm) maximum, and uniform from stone to stone. Stone-to-cabinetry joints must be 1/8" (3 mm) in width.

13.5 Vein Trend. When using stone tiles with obvious trend, all tiles shall be installed with vein trend running in the same direction unless otherwise specified.

13.6 Shading Variation. Stone tiles are subject to manufacturing processes different from structural stone. There is great latitude in the acceptability of shaded stones. Installers are cautioned to lay out the stone for inspection and obtain approval from the Owner or Specifying Authority prior to installation.

13.7 Tile Widths. No tile shall be employed that is less than ½ the width of the stone tile, except at the front of cutouts, unless previously discussed with the client.

13.8 Cutouts should be prepared for drop-in appliances and sinks. Avoid undermounted sinks, stove tops, etc.

13.9 Aprons. Where a stone apron is employed and the countertop is designed to have a radial corner, the apron may be staved to fit the radius.

13.10 Flat Installation. Stone tiles must be installed flat, side by side, within 1/32" (0.8 mm) maximum lippage.

13.11 Splashes must be of stone tile, minimum of 4" high. On stones with obvious vein trend, the vein trend of the splash must be identical to the countertop below unless otherwise specified.

13.12 Back buttering of all stone tiles is required. This technique applies a portion of the installation material to the back face of the stone. It requires placement of one-half of the setting material in the case of thin-set mortar, epoxy, or nonwater-soluble adhesive, or a lesser quantity of very rich mortar in the case of portland cement, to the back of the stone, while the balance of the setting material is applied to the bed. Application should be performed so that one pass is completed in a north-south direction, while the second pass is performed in an east-west direction, thus ensuring, as close as possible, 100% contact of the stone to the installation bed.

13.13 Tile Reinforcement. A common reinforcement for stone tiles of limited soundness is to adhere a fiberglass mesh to the back surface of the tile. The adhesive used in this application is commonly an epoxy or polyester resin. When this type of reinforcement is adhered to the tiles, the Installer must use a thin-set material that will bond to the resin-impregnated backer. Most often this will require an epoxy-based, rather than a portland-based, thin-set compound.

Mohs Scale
In 1812, the Mohs Scale of mineral hardness was devised by the German mineralogist Friedrich Mohs (1773-1839), who selected the ten minerals because they were common or readily available. The scale is not a linear scale, but a relative scale.

Hardness	Mineral
1	Talc or Mica
2	Gypsum
3	Calcite
4	Fluorite
5	Apatite
6	Orthoclase
7	Quartz
8	Topaz
9	Corundum
10	Diamond

Source:
American Federation of Mineralogical Societies, Inc.

14.0 RESIN-IMPREGNATED SLABS

The application of resin to the surfaces of stone slabs has become an ever-increasing practice. The intent of this procedure is to fill pits, cracks, and fissures of natural stones with a glossy resin to enhance the appearance of the polished slab. When received, the resin treatment is usually easily detected by viewing the raw edges of the slab. Evidence of excess resin is usually visible on the edges of the slab if the stone has been treated.

14.1 Description of Procedure. The process involves screeding the resin on the surface of the cleaned, sawn slab. This is frequently done in an automated process, although some suppliers will do this manually. Depending on the equipment used, the slab may be placed over a large vacuum table to draw the resin deeper into the stone. The resin is allowed to cure, which may or may not be accelerated with heat application. Once the resin has cured, the slab is polished. The polishing grinds most of the resin from the stone surface, so that it remains only in depressions and some intercrystalline regions of the slab. The amount of surface area that remains as resin varies due to the natural features of the material, but it is usually a fraction of one percent.

14.1.1 The resin used in this process is typically an epoxy, but polyester and acrylic-based polymers may be used.

14.2 Design Considerations. While the intent of this process is to provide a cosmetically more attractive surface, these are several characteristics of which the fabricator should be aware:

14.2.1 Color. The resin application normally makes the color of the stone somewhat darker than an untreated slab. This becomes an issue when finishing the edges of the countertop, as the color of the edge will be lighter in appearance than the color of the face surface. Several products are marketed in the industry for the darkening of the edge, but none have been found to be universally successful.

14.2.2 Interaction with Sealers. There have been cases of incompatibility between a given resin and fabricator-applied sealer combination. This usually results in a "cloudy" or "blotchy" appearance after the sealer product has been applied.

14.2.3 Structural Flaws. The resin process can hide cracks or other blemishes which are structurally influential features of the material. Assessment of the structural worthiness of the material can be made more difficult as a result.

14.2.4 UV Light Exposure. Nearly all of the resins currently in use are vulnerable to color change or surface degradation when exposed to ultraviolet light. These materials are therefore not suitable for exterior applications.

15.0 REINFORCEMENT TECHNIQUES

As products of nature, stones have varying strength and behavioral properties. Stones of lesser soundness or stones that have had substantial areas removed from the slab (e.g., sink cutouts) will benefit from reinforcement by a variety of techniques.

15.1 Fiberglass Mesh. A common reinforcement for stone slabs of limited soundness is to adhere a fiberglass mesh to the back surface of the slab. The party doing the sawing of the slabs normally completes this process. The adhesive used in this application is commonly an epoxy or polyester resin.

15.2 Liner Blocks. Although not frequently used in stone countertop construction, a liner block of stone material can be adhered to the underside of the stone slabs (when no subtop is used) to reinforce seams or other vulnerable areas. The liner block need not be of the same type of stone material as the countertop.

15.3 Splines. Seams, particularly those between narrow stone pieces, are often splined together with a steel or stainless steel key. Commonly, a large washer is used as the spline key. The metal is fully encapsulated with polyester or epoxy resin and fitted to closely cut slots in the stone, similar to the "biscuit" joint reinforcements used in woodworking.

15.4 Rodding. A commonly seen method of countertop reinforcement is the technique referred to as "rodding." Rodding may be beneficial to narrow strips of stone material, such as those in front or behind sink or cook top cutouts. This technique requires a shallow kerf in the underside of the stone slab (See details on drawing 17-D-5). The kerf is then closely fitted with a metal or fiberglass rod, which is then fully embedded in epoxy. The rod, having greater tensile strength than the stone, helps prevent concave flexure of the stone surface. Closely matching the rod size to the kerf size and careful preparation of the rod, including cleaning or abrading the bonding surface, are required to get the maximum benefit from this technique. A strip of fiberglass mesh backing is often adhered over the rodded region for additional reinforcement. See detail on drawing 17-D-5.

16.0 ALLOWABLE REPAIR

Repair of stone countertops must be performed by competent, experienced artisans to achieve the desired results. Repair of the stone is permitted when the repaired region is not in a structurally significant area of the countertop, and when it can be accomplished skillfully so that the repair is consistent in color and texture with unrepaired regions of the slab.

16.1 Fissures occur naturally in many stone types. A fissure is defined by the American Geological Institute as, "An extensive crack, break, or fracture in the rock, which may contain mineral-bearing material." The term "fissure" is used commercially in the stone industry to describe a visible separation along intercrystalline boundaries. This separation may start and stop within the field of the stone or extend through an edge. A fissure differs from a crack in that it is a naturally occurring feature in the stone that may be found in other areas of the same slab or other slabs of the same material.

16.2 Cracks occur in stones as a result of manmade mechanically induced stresses during handling, fabrication, transport, or installation. When cracks are detected in slab material prior to fabrication, the best method is to simply avoid including them in the product through culling during the layout process. In stones with lesser soundness properties, this option may not be practical, or possible. When working with such stones it is common practice to repair cracks by cementing them together with epoxy or polyester resin, either with or without dowel reinforcement. Cracks that occur as a result of handling-induced stresses are often more difficult to repair, as they commonly include chipping in addition to the crack. Repair is frequently performed by injection of a penetrating resin adhesive, which may be dyed to match the stone, and then rebuffing the area after curing of the resin. In many cases, the entire stone must be repolished to make the repair unnoticeable. If the repair is attempted but unsuccessful, the stone is to be replaced with a new piece.

16.3 Chips can occur in stones either as a result of sawing operations or handling and restraint devices. Particularly in the igneous stone varieties, the exiting portion of the diamond blade will create many small chips. A small chamfer, called an "arris," of approximately 1/16" x 1/16" (1.5 x 1.5 mm) can be used to eliminate most of these small chips. The use of an arris will make the seam appear wider than its actual dimension when filled (see section 11.2, above). Larger chips may be repaired with epoxy or polyester resin if the completed repair is consistent in color and texture with unrepaired areas of the slab. In many materials, the resin used in the repair will appear more natural if it is not dyed.

16.4 Pitting of the countertop surface, particularly in granite material, is a commonly seen characteristic on natural stone. Granites are made up of several different minerals, each mineral having a different hardness. Granites contain quartz, feldspars, biotite, amphibole, ferrous titanium oxides, and other mineral combinations. On the Mohs Scale (see chart above), diamonds are the hardest mineral, with a rating of 10. Quartz and feldspar have a hardness of 6.5 to 7 and are very durable. Biotite (small, black minerals throughout the slab) on the other hand is very soft (2.5) and flakes easily. All true granites have biotite in their composition. Because biotite is relatively soft and flaky, the first few layers are often removed during the polishing process, causing pits throughout the slab. Some granites have more biotite throughout their composition than others. The higher the biotite content of the stone, the more pits it will have. Most polished igneous rocks will have varying degrees of pits, depending on the amount of biotite, muscovite, and phlogopite in their composition.

The pits do not make the granite less durable or otherwise inferior, and do not in themselves qualify the slab for replacement. Pits are common in all granites and should be expected when dealing with a natural, polished stone containing several types of minerals with different hardnesses. It is usually best to not attempt repair of pits, as most repair techniques will not cosmetically improve the countertop.

17.0 MAINTENANCE

17.1 Application of Sealers. The application of a topical sealer or impregnator is a common step in decreasing the vulnerability of the stone to stains.

17.2 Topical sealers cure as a film on the stone surface. Since the material is actually covering the stone, the appearance of the stone surface may be altered by the application of this type of product. This material will provide somewhat of a sacrificial layer over the stone and will absorb most of the wear on the countertop. Since the sealer is softer than the stone, normal use of the countertop will result in abrasion of the sealer surface and dictate reapplication to maintain the original luster of the surface. A properly applied topical sealer will normally reduce, although not eliminate, the vulnerability of calcareous stones to attack from mildly acidic solutions.

17.3 Impregnators will penetrate the stone and cure a few millimeters below the surface, residing in the intercrystalline boundary areas and pores of the stone. These products do not actually "seal" the stone and are more correctly referred to as a repellent rather than a sealer. As such, they are formulated to prevent transmission of liquids, while allowing transmission of vapor. Since they reside below the actual surface of the stone, the change to the appearance of the stone surface is minimal.

Impregnators will be either hydrophobic, in that they repel water-based fluids only, or oleophobic, repelling both oil and water-based fluids. The manufacturer of the impregnator product will recommend a reapplication interval.

17.4 General Precautions. When any surface protection product is used, care must be taken to read and follow the manufacturer's written instructions accurately. This will provide the greatest benefit from the application and will guarantee safe handling of the product.

17.5 Care and cleaning practices of the stone countertop are to be thoroughly discussed with the client upon completion of the installation. Refer to the NSI brochure *Care & Cleaning for Natural Stone Surfaces* for more information.

18.0 OUTDOOR KITCHENS

18.1 General Precautions. An increasingly popular area for stone countertops is in outdoor kitchens. The installation of natural stone countertops in these areas creates additional challenges from the installation of indoor countertops for suppliers and installers. Due to extreme temperature changes, possible freeze/thaw cycling, UV exposure and varying moisture levels, typical installation methods along with certain materials cannot be used.

18.2 Customer Communication. In addition to the prescriptions state earlier in this chapter, customers should be made aware that due to the use of resins in the finishing process of natural stone, they will most likely experience some fading in their countertops. Nearly all resins used in the fabrication process are subject to color change and surface degradation when exposed to UV light See section 14.2.4.

18.3 Materials. It is recommended that only sound stones with minimal geological flaws or voids be used for these areas. Stones that contain these voids or fissures may harbor contaminants which allow the growth of mold and mildew. Additionally, the loosening of filler materials and in some cases, cracking and separating due to thermal and/or freeze/thaw cycling.

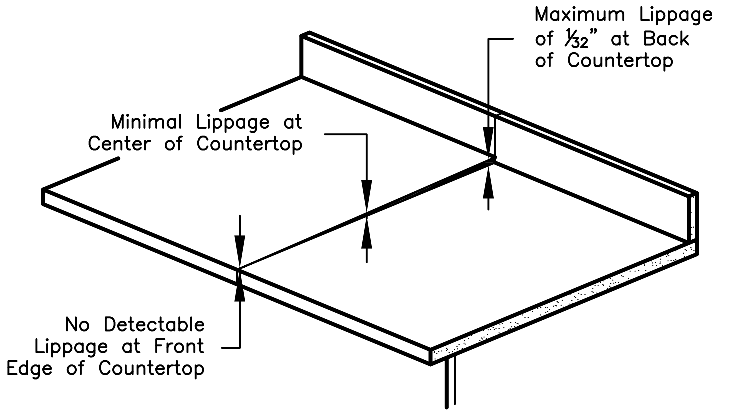
18.4 Subtops. All areas that are to receive stone countertops should have a sub top or auxiliary frame made of cement board or mortar bed. The subtop or auxiliary framing should include only materials which are rated for exterior exposure.

18.5 Adhesives. All adhesives to be used must be suitable for exterior installations. Since silicone is frequently used on outdoor kitchens, care must be taken to ensure that staining does not result from plasticizer migration of some silicone products. Polyester adhesives should be avoided in an exterior environment.

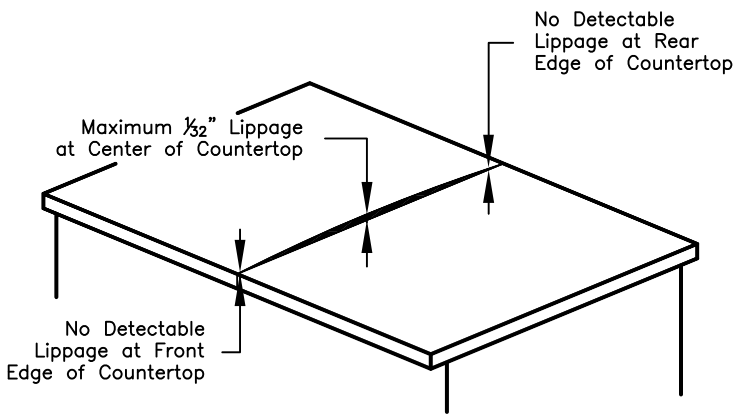
18.6 Seam Filler Materials. All materials that are to be used for seam filler must be suitable for exterior installations and allow for some movement. Joint widths between adjacent stone units may be as small as nominal 1/16" (1.5 mm), but ample accommodation for differential movement due to thermal expansion and contraction must be made at the perimeter of the stone installation.

18.7 Undermount sinks can be anchored to the underside of the stone countertop or carried by a subtop or auxiliary frame. A subtop or auxiliary framing may be required and should be rated for exterior use.

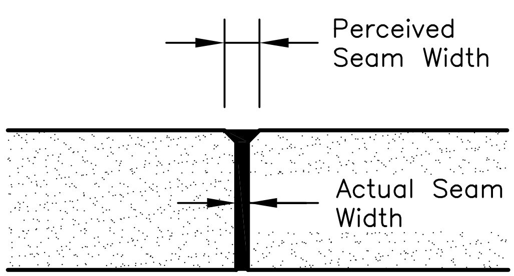
NOTES:



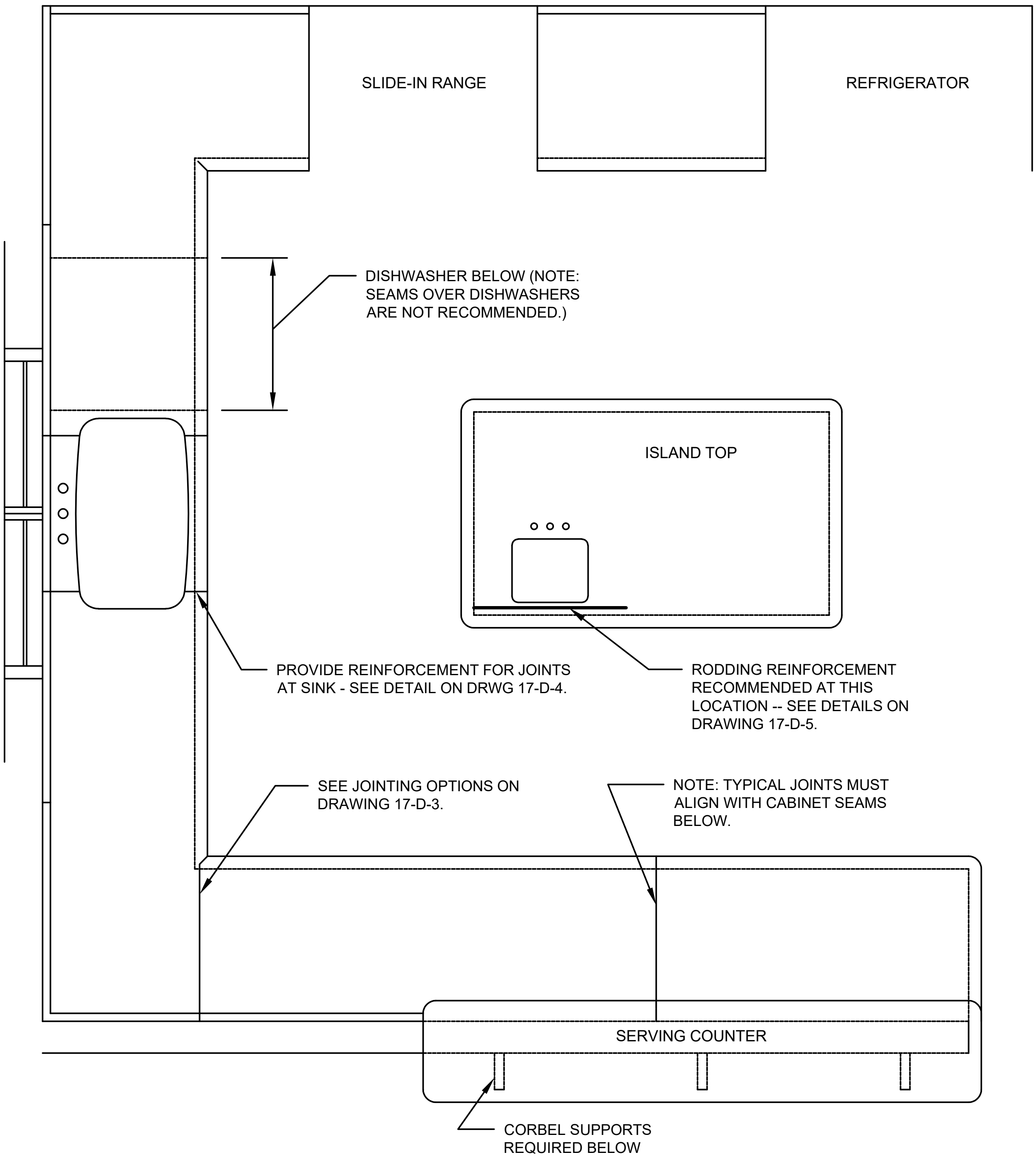
Allowable Lippage Due to Slab Warp
(For Standard Counter with Backsplash)



Allowable Lippage Due to Slab Warp
(For Island or Peninsula Counter)



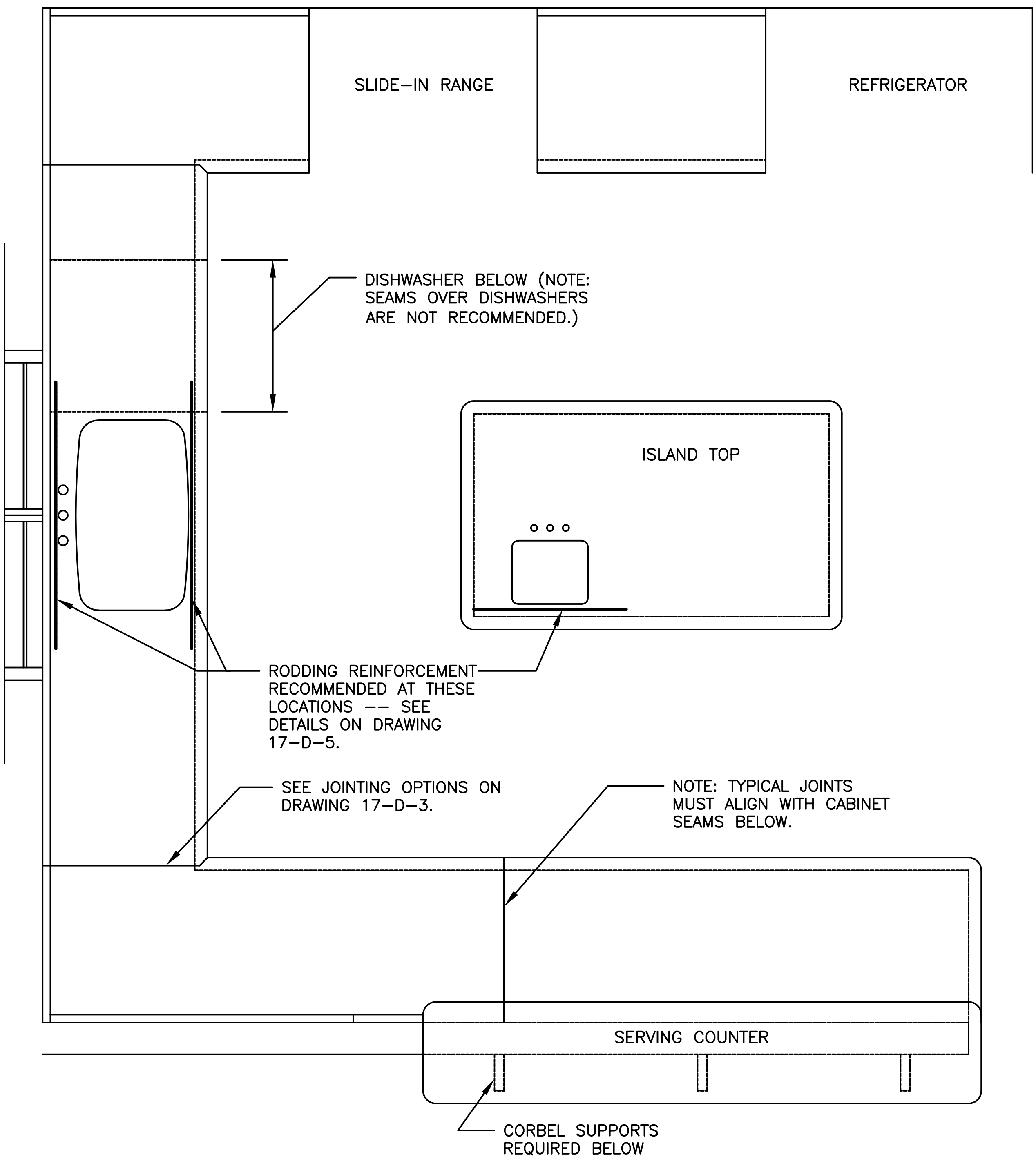
Visual Accentuation of
Seam Width due to Arris
at stone edges



TYPICAL KITCHEN LAYOUT
(WITH JOINTS AT SINK)

NATURAL STONE INSTITUTE
380 East Lorain Street, Oberlin, OH 44074 USA
www.naturalstoneinstitute.org

REV	DATE	
0	MAR 2022	TYPICAL KITCHEN LAYOUT
		DIMENSION STONE DESIGN MANUAL 2022
		DRWG NO: 17-D-1 — SCALE: ½" = 1'-0"



TYPICAL KITCHEN LAYOUT
(WITH JOINTS AT CORNERS IN LIEU OF SINK)

NATURAL STONE INSTITUTE
380 East Lorain Street, Oberlin, OH 44074 USA
www.naturalstoneinstitute.org

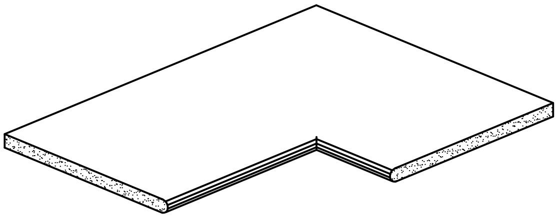
REV	DATE
0	MAR 2022

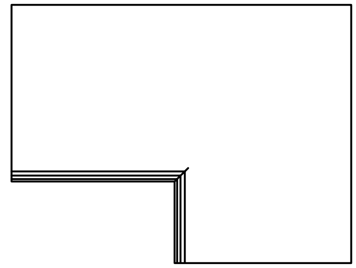
TYPICAL KITCHEN LAYOUT

DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 17-D-2

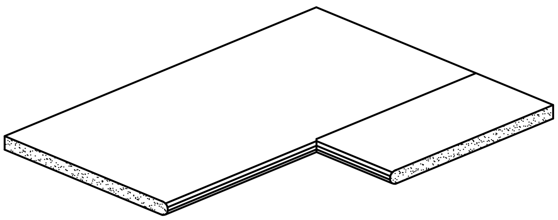
SCALE: ½" = 1'-0"

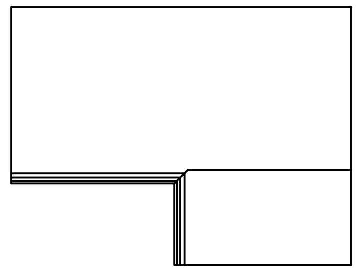




NO JOINT IN CORNER

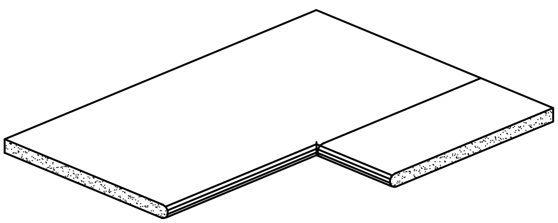
THIS IS PERHAPS THE MOST PREFERRED DETAIL VISUALLY, AS IT PROVIDES THE CLEANEST–LOOKING RETURN. SOME HAND GRINDING WILL BE REQUIRED AT THE INTERIOR CORNER. THE LOSS OF YIELD IN THE STONE SLAB ADDS TO THE COST OF THE PROJECT. THIS DETAIL IS SOMEWHAT MORE SUSCEPTIBLE TO CRACKING IF THE COUNTERTOP IS NOT SHIMMED UNIFORMLY, OR IF THERE IS MOVEMENT IN THE CABINETS AFTER THE INSTALLATION OF THE COUNTERTOP.

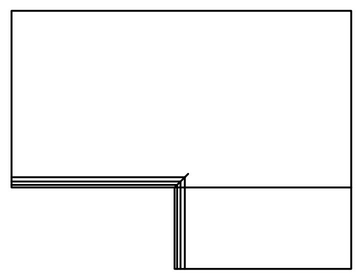




MITER JOINT THROUGH BULLNOSE EDGE DETAIL

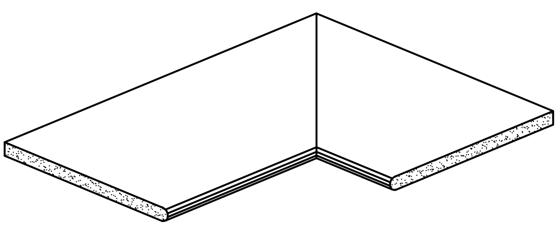
THIS DETAIL IS WELL SUITED FOR EDGING MACHINES, AS IT REQUIRES NO HAND GRINDING OF THE BULLNOSE.

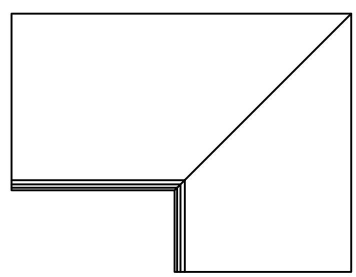




COMMON JOINT WITH BULLNOSE RETURN CORNER

THIS DETAIL WILL REQUIRE SOME HAND GRINDING OF THE BULLNOSE RETURN.





MITER JOINT THROUGH ENTIRE COUNTERTOP SURFACE

THIS DETAIL IS NOT RECOMMENDED. SLAB YIELD IS REDUCED BECAUSE BOTH PIECES NEED TO BE CUT TO FULL LENGTH. THE SHARP CORNERS ARE VERY FRAGILE. LEVELING OF THE COUNTERTOPS IS DIFFICULT DUE TO THE LENGTH OF THE SEAM AND UNACCEPTABLE LIPPAGE OFTEN RESULTS. HOWEVER, THE USE OF A STONE MATERIAL WITH A HEAVY, LINEAR VEINING TREND MAY MAKE THIS DETAIL AESTHETICALLY PREFERABLE TO THE PREVIOUS DETAILS.

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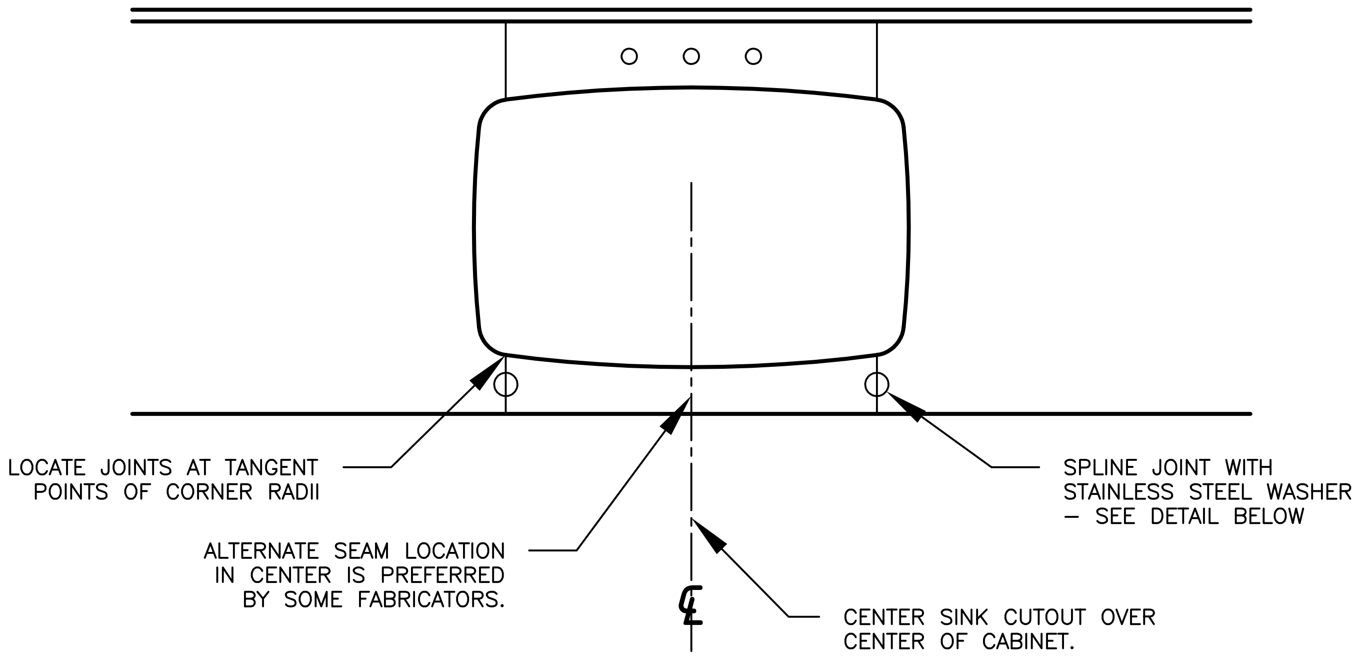
CORNER JOINERY EXAMPLES

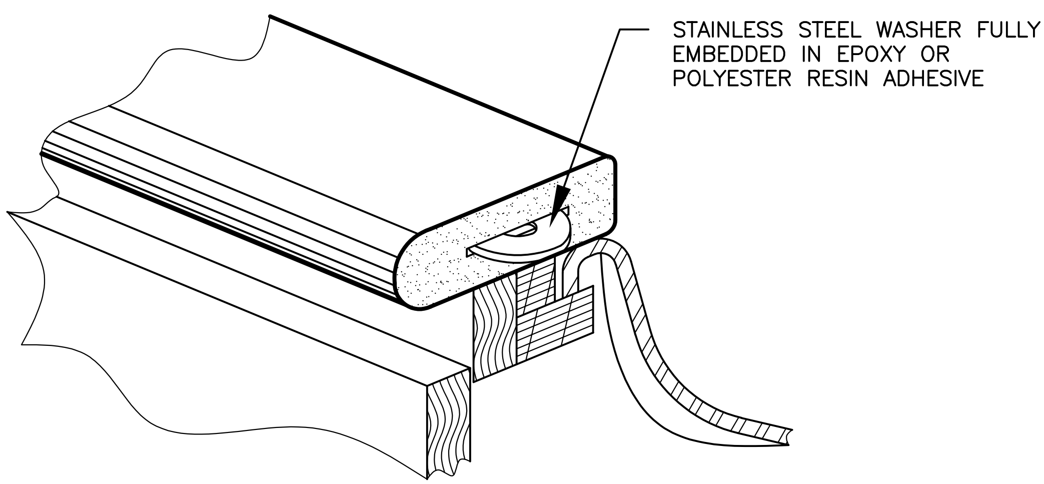
DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 17-D-3

SCALE: ½" = 1'-0"



PARTIAL PLAN WITH JOINTS LOCATED AT SINK



DETAIL OF SPLINE JOINT REINFORCEMENT

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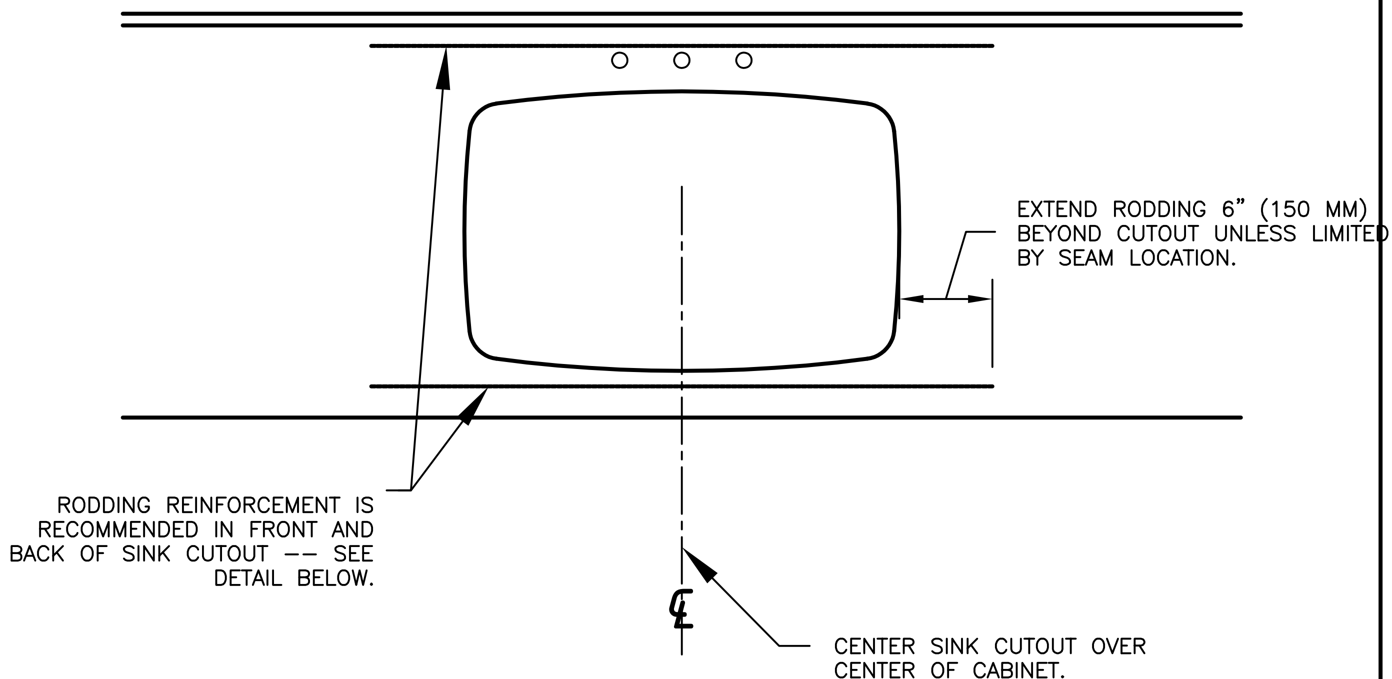
0	MAR 2022

TYPICAL JOINERY @ KITCHEN SINK

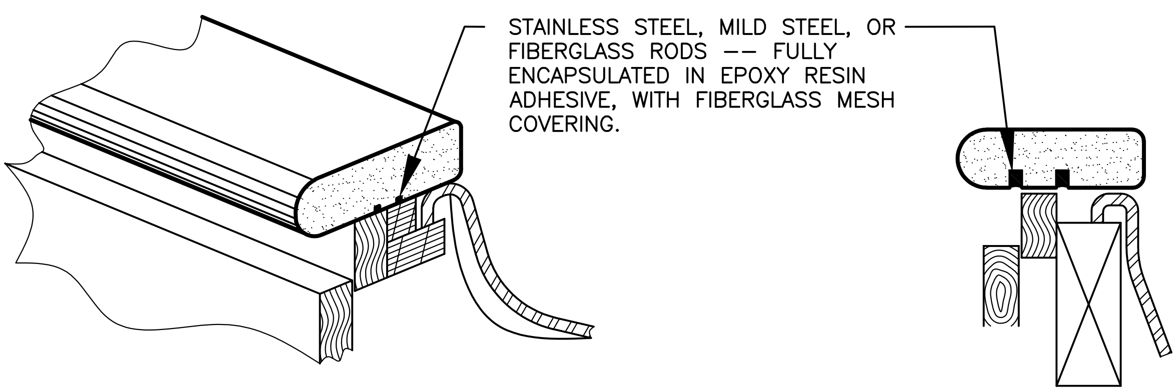
DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 17-D-4

SCALE: 1" = 1'-0"



PARTIAL PLAN WITH NO JOINTS AT SINK



DETAIL OF RODDING REINFORCEMENT

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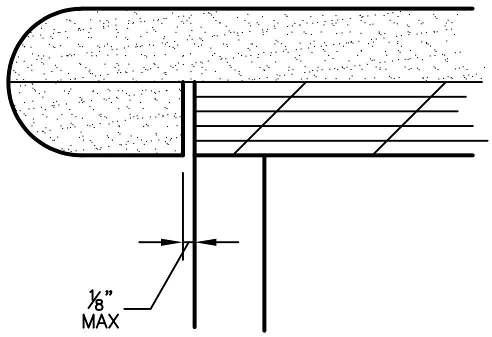
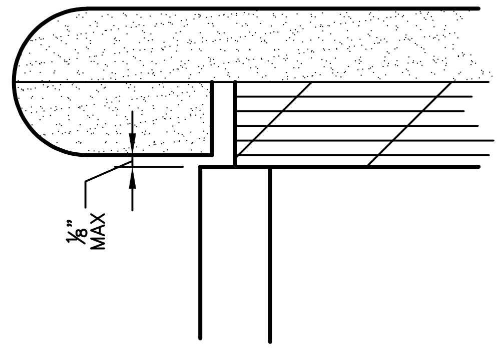
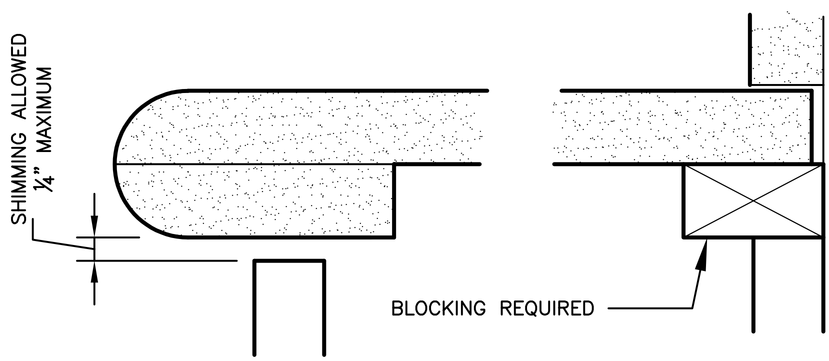
	0	MAR 2022	DIMENSION STONE DESIGN MANUAL 2022
			DRWG NO: 17-D-5 — SCALE: 1" = 1'-0"



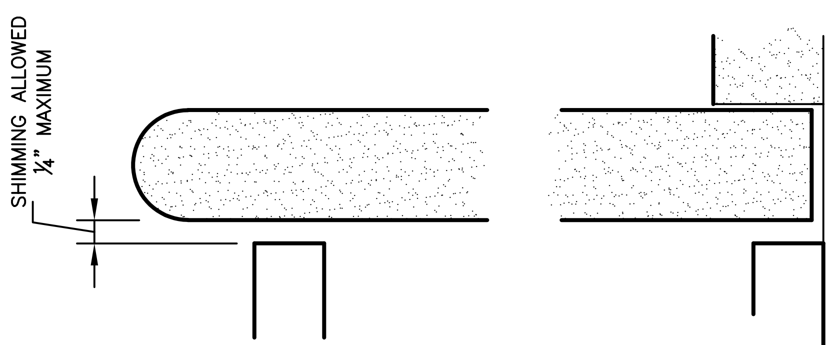
TYPICAL DETAIL AT
FLUSH SUBTOPS



TYPICAL DETAIL AT
SETBACK SUBTOPS



TYPICAL DETAIL WITH NO SUBTOPS
LAMINATED 20 MM STONE



TYPICAL DETAIL WITH NO
SUBTOPS -- 30 MM STONE

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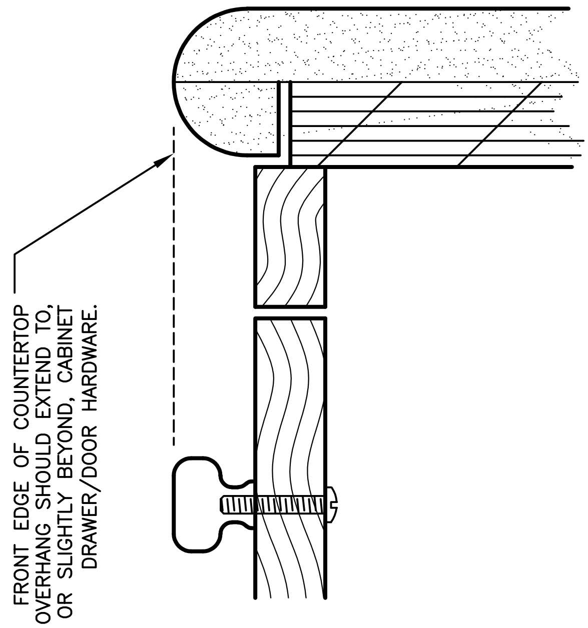
COUNTERTOP SUPPORT DETAILS

DIMENSION STONE DESIGN MANUAL 2022

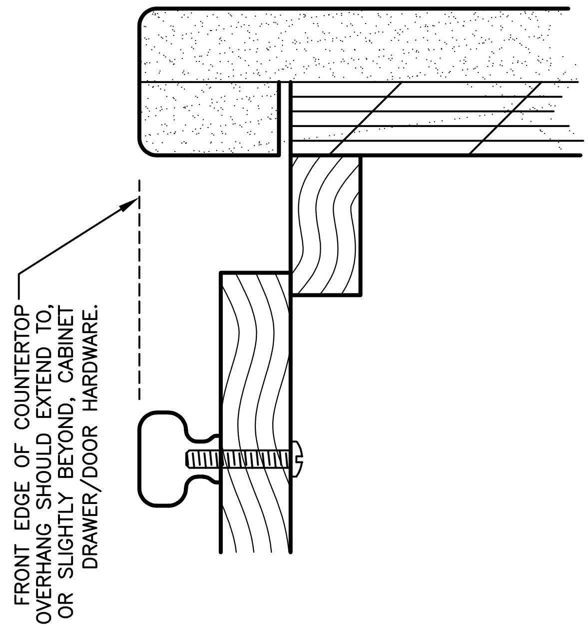
DRWG NO: 17-D-6

SCALE: 6" = 1'-0"

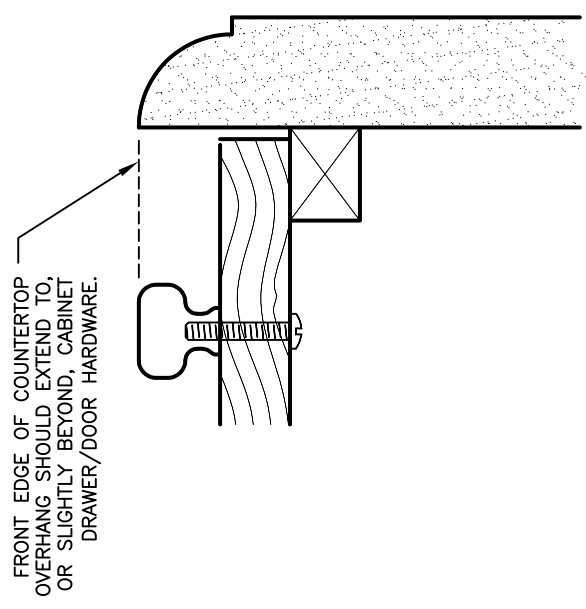
CAUTION: IF THIS SHEET IS NOT 8½" x 11", IT IS A REDUCED OR ENLARGED PRINT



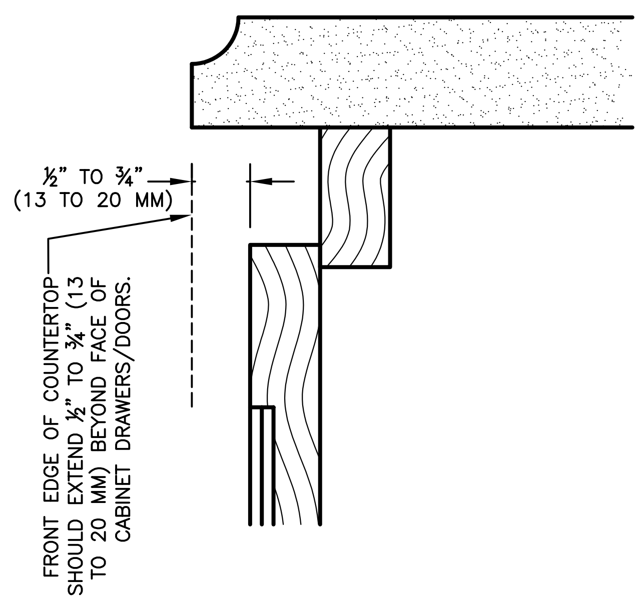
DOORS FLUSH WITH CABINETS



DOORS OVERLAPPING CABINETS



DOORS COVERING CABINETS



RECESSED OR FLUSH HARDWARE

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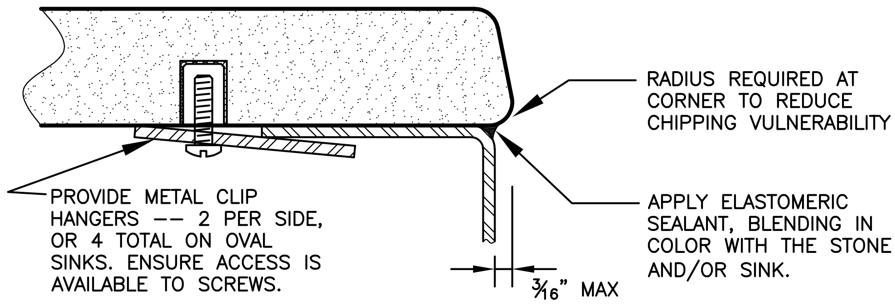
COUNTERTOP OVERHANG RECOMMENDATIONS

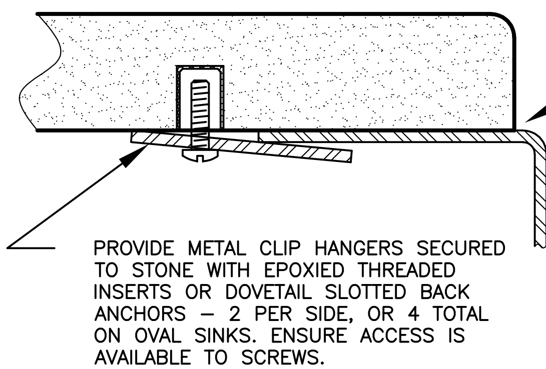
DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 17-D-7

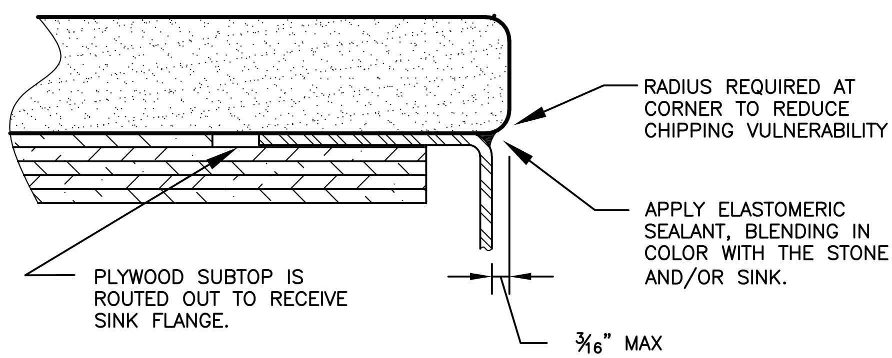
SCALE: 6" = 1'-0"



DETAIL WHEN COUNTERTOP OVERHANGS EDGE OF SINK



DETAIL WHEN COUNTERTOP SETS BACK FROM SINK EDGE



DETAIL OF SUBTOP ROUTED OUT TO RECEIVE SINK FLANGE

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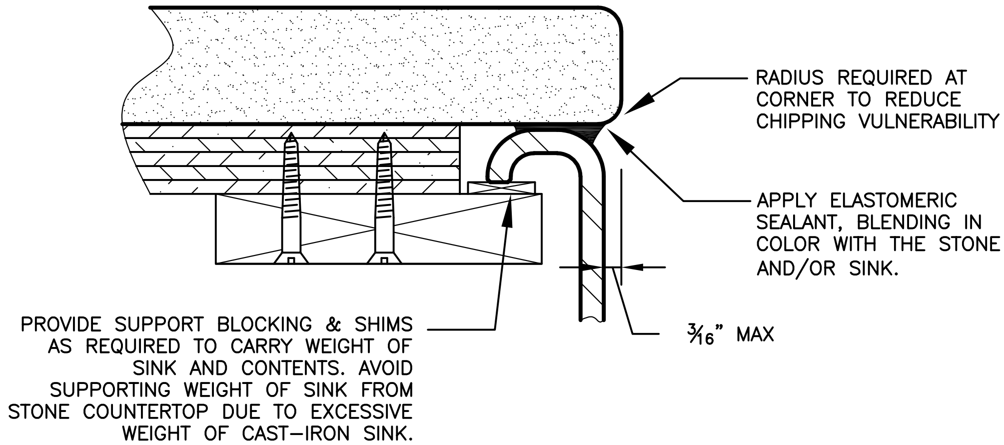
UNDERMOUNT SINK SUPPORT DETAILS

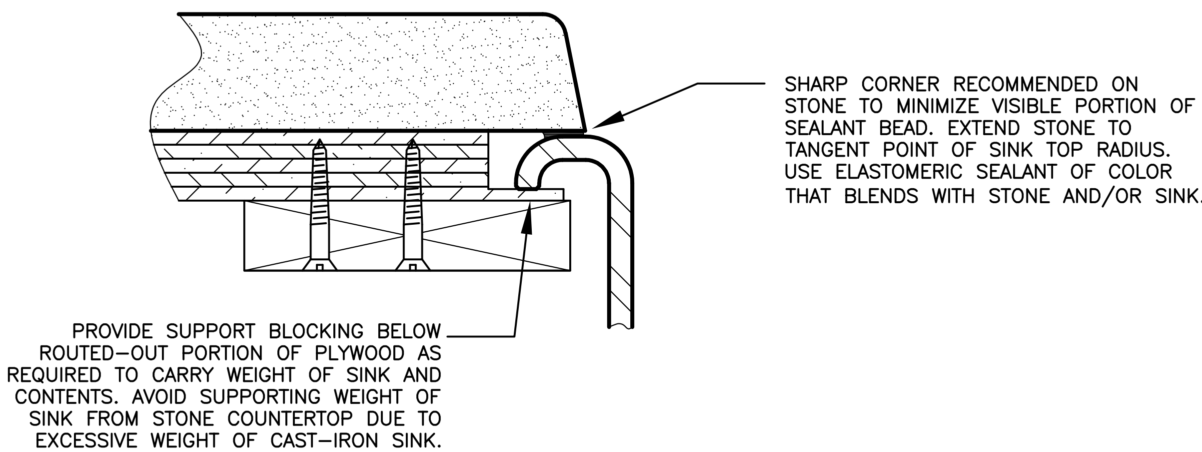
DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 17-D-8

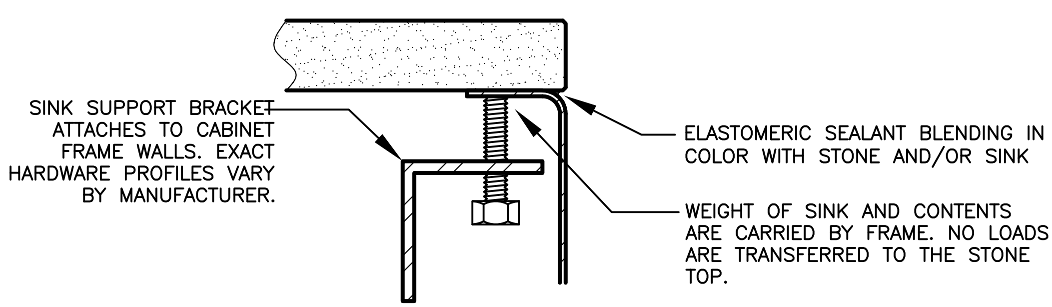
SCALE: 6" = 1'-0"



DETAIL FOR COUNTERTOP OVERHANGING SINK EDGE



DETAIL FOR SINK EXTENDING PAST COUNTERTOP CUTOUT



DETAIL FOR SINK SUPPORTED BY HARDWARE KIT

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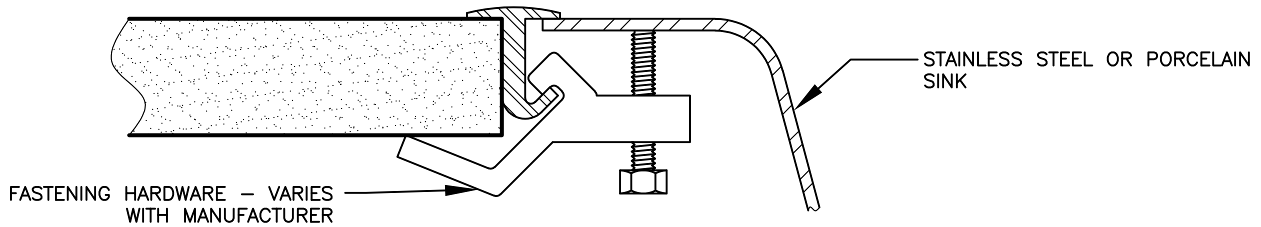
SUPPORT DETAILS FOR HEAVY (ENAMELED CAST IRON) SINKS

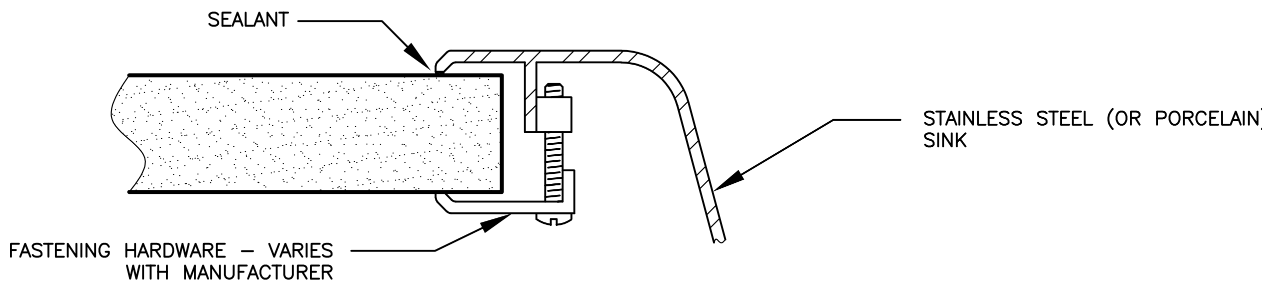
DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 17-D-9

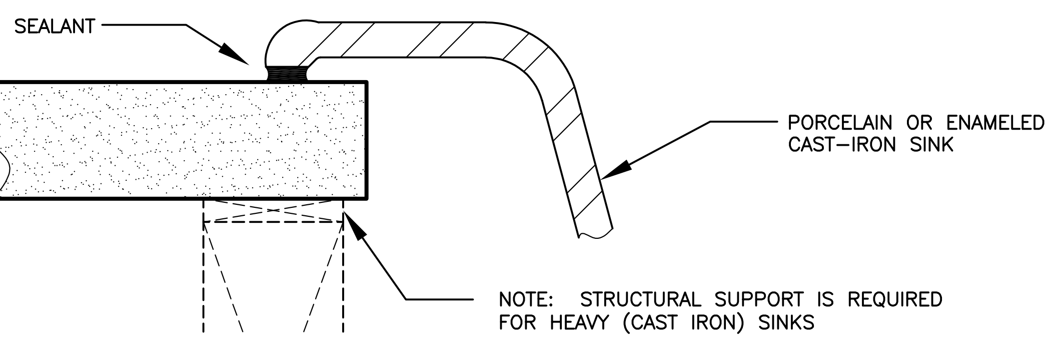
SCALE: 6" = 1'-0"



DETAIL FOR SINK SUPPORTED BY METAL FRAME



TYPICAL DETAIL FOR STAINLESS STEEL SINKS



DETAIL FOR SINK SUPPORTED BY METAL FRAME

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SUPPORT DETAILS FOR RIMMED (DROP-IN) SINKS

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DRWG NO: 17-D-10

SCALE: 6" = 1'-0"

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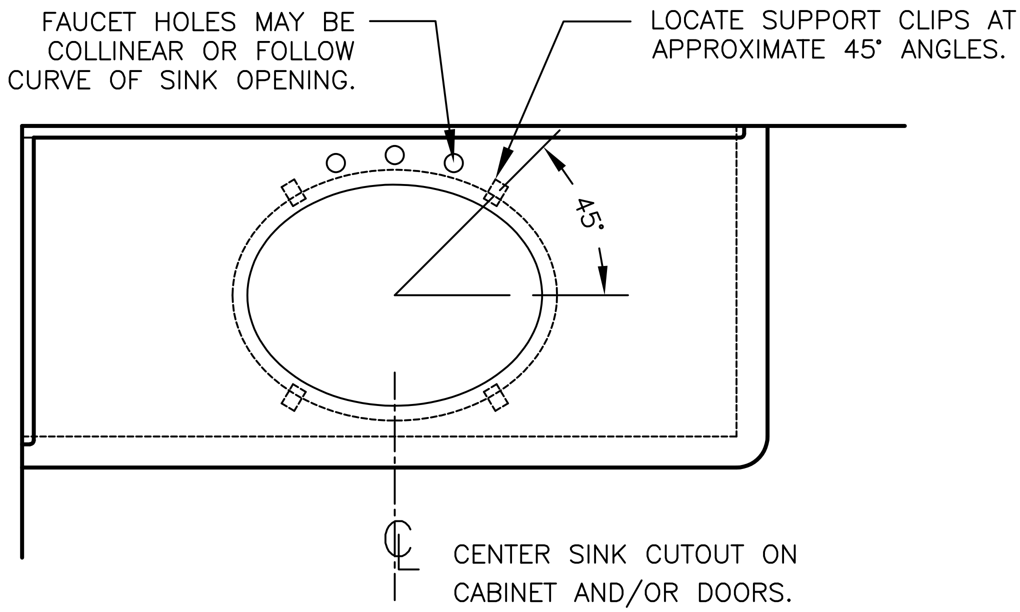
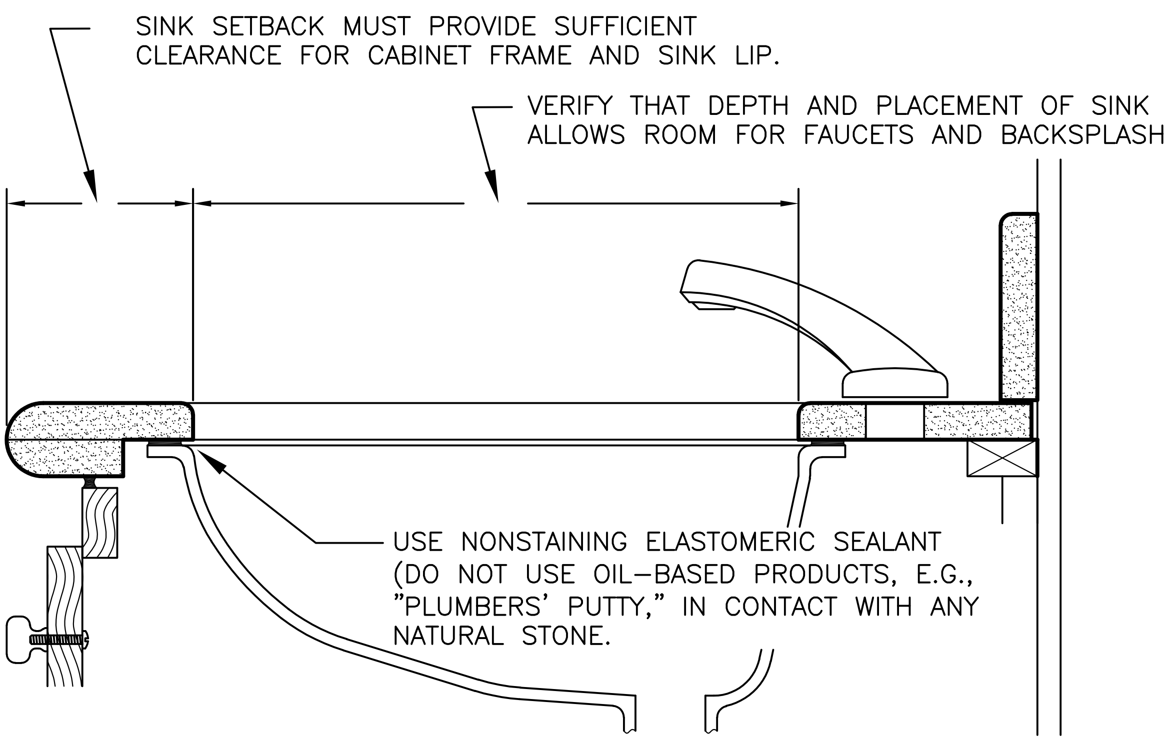


PLAN VIEW OF TYPICAL VANITY



SECTION THROUGH VANITY COUNTER

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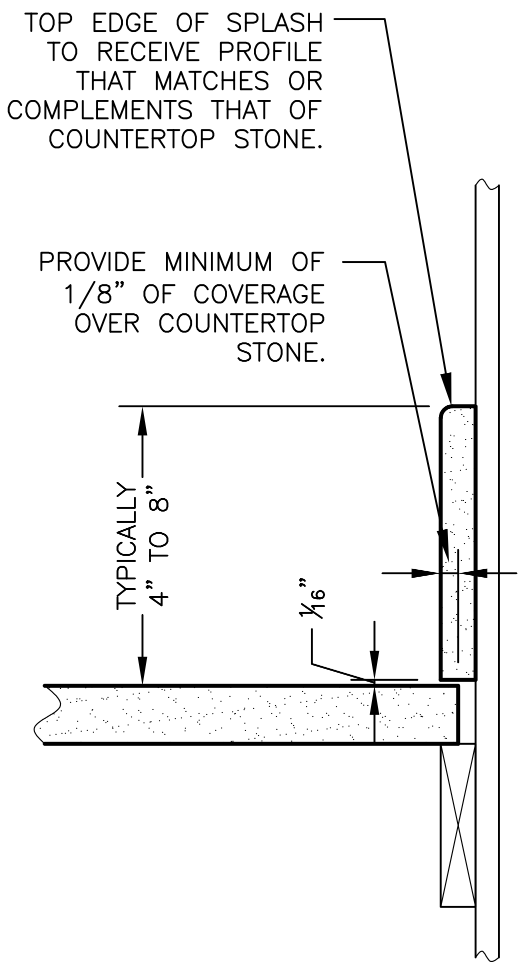
VANITY TOP DETAILS

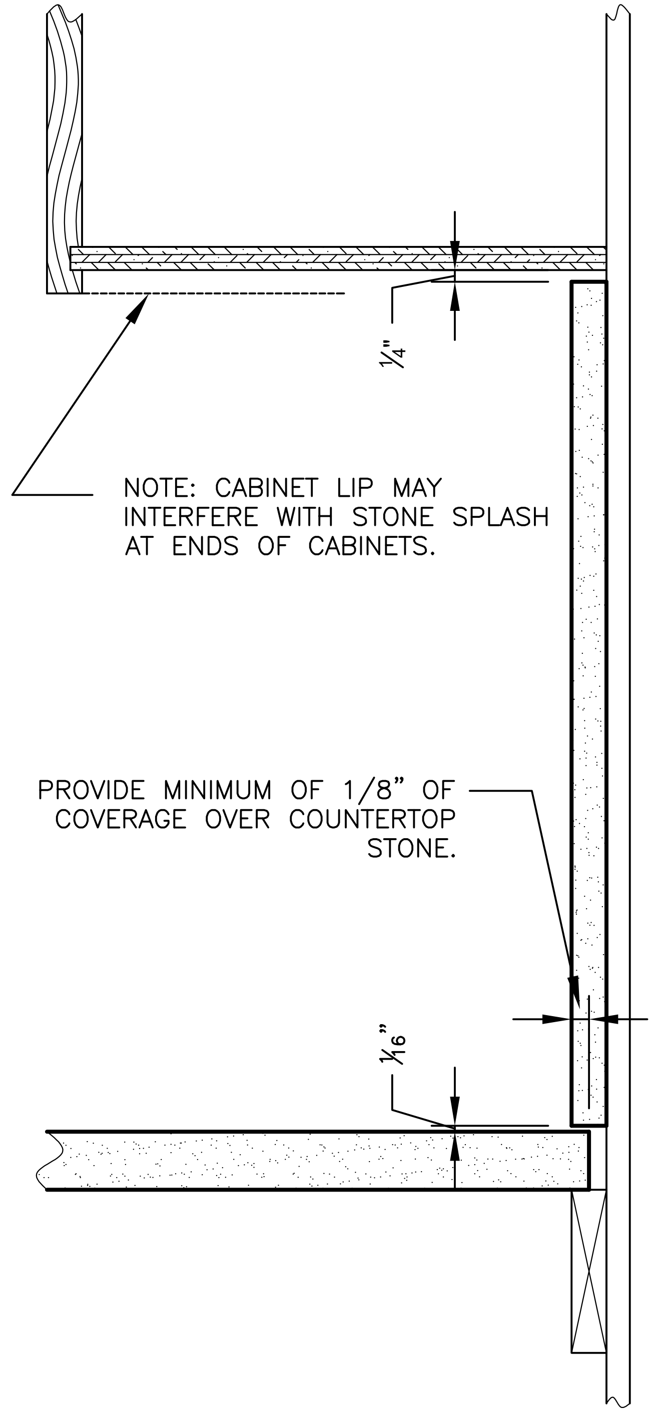
DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 17-D-11

SCALE: 3" = 1'-0"



SECTION THROUGH PARTIAL-HEIGHT BACKSPLASH



SECTION THROUGH FULL-HEIGHT BACKSPLASH

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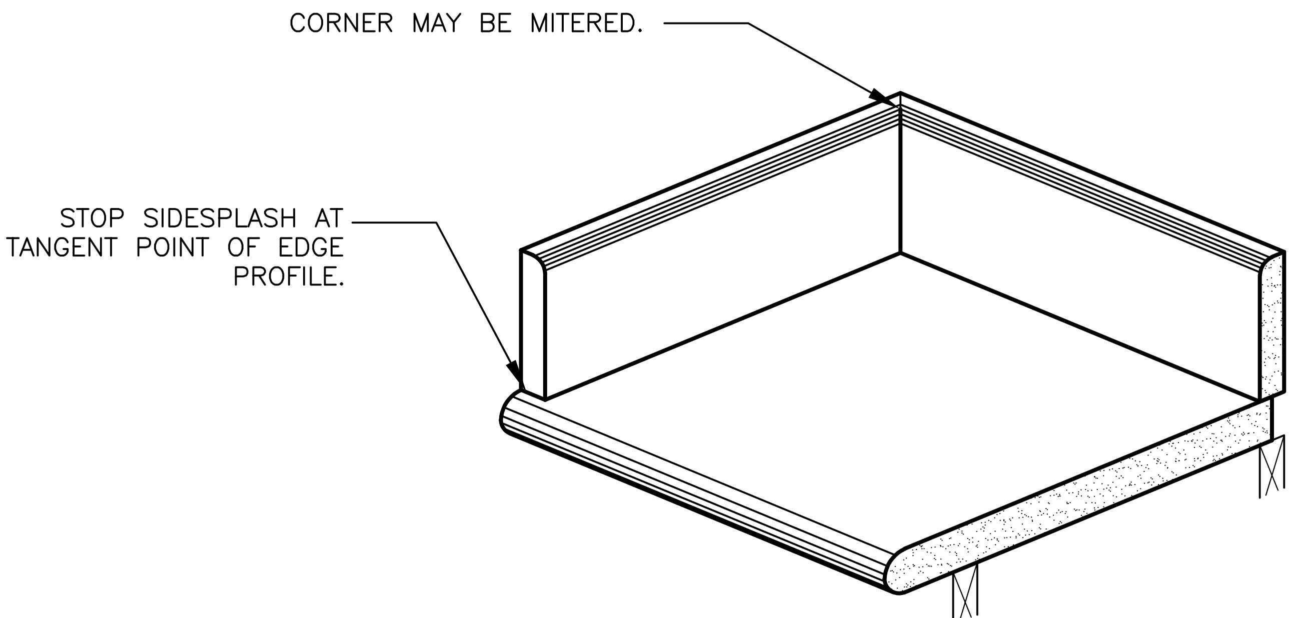
BACKSPLASH DETAILS

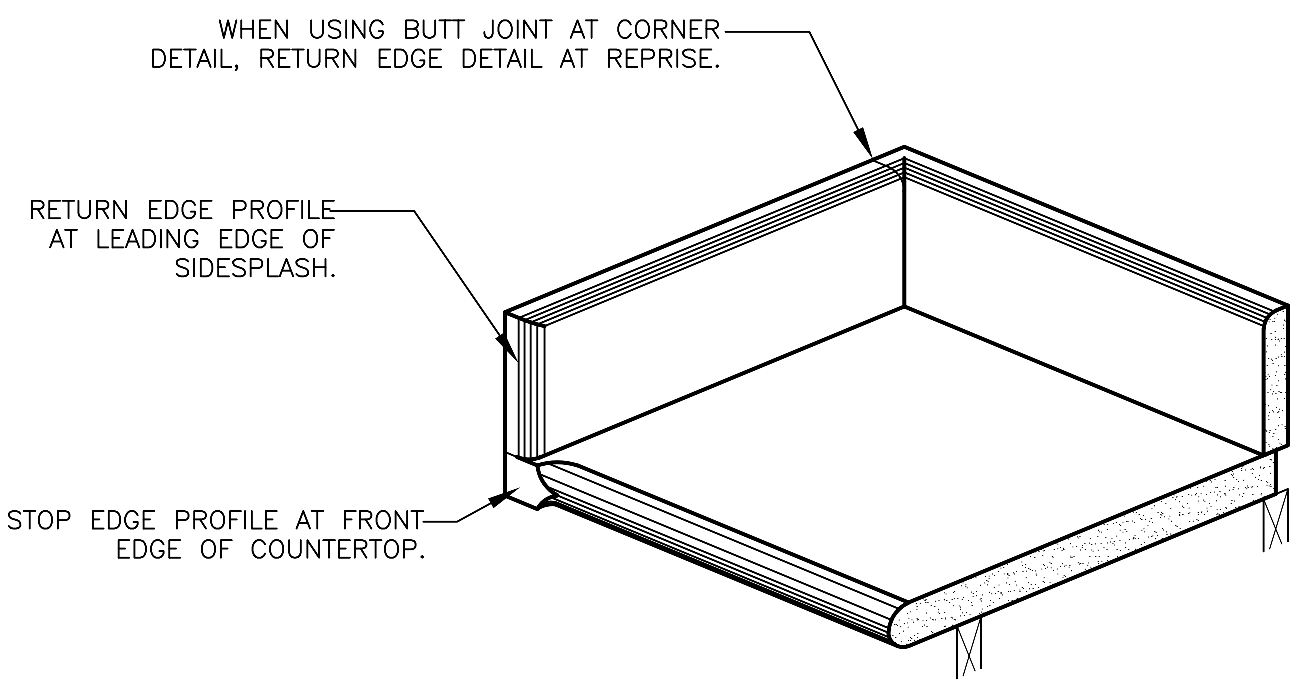
DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 17-D-12

SCALE: 3" = 1'-0"



VIEW OF COUNTERTOP WITH FULL– LENGTH NOSING PROFILE



VIEW OF SIDESPLASH CONTINUING TO EDGE OF COUNTERTOP

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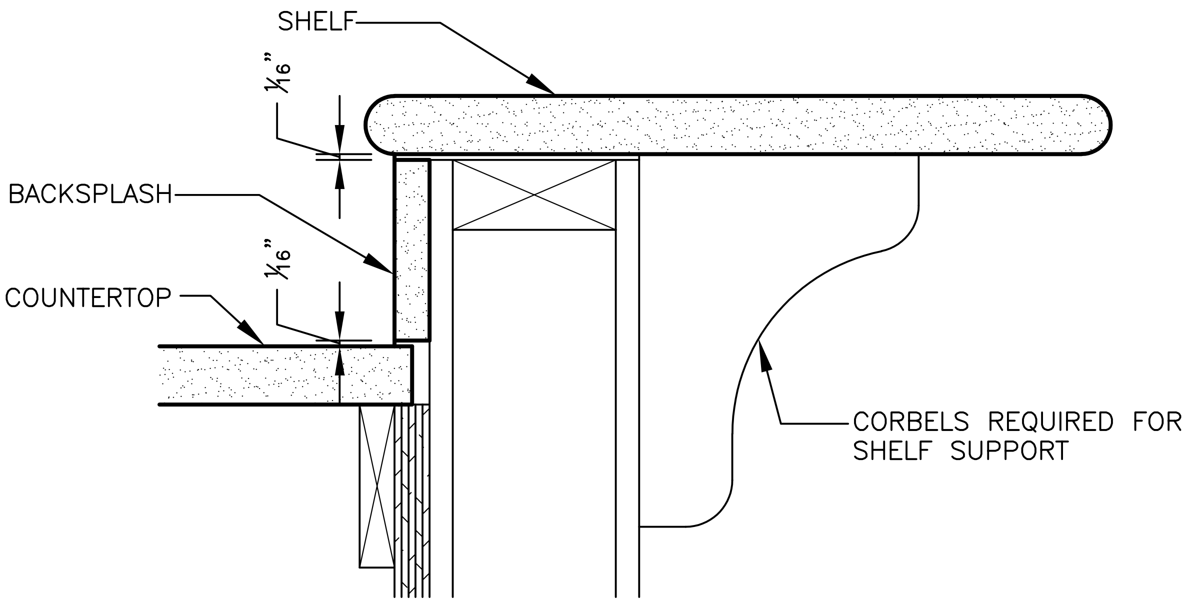
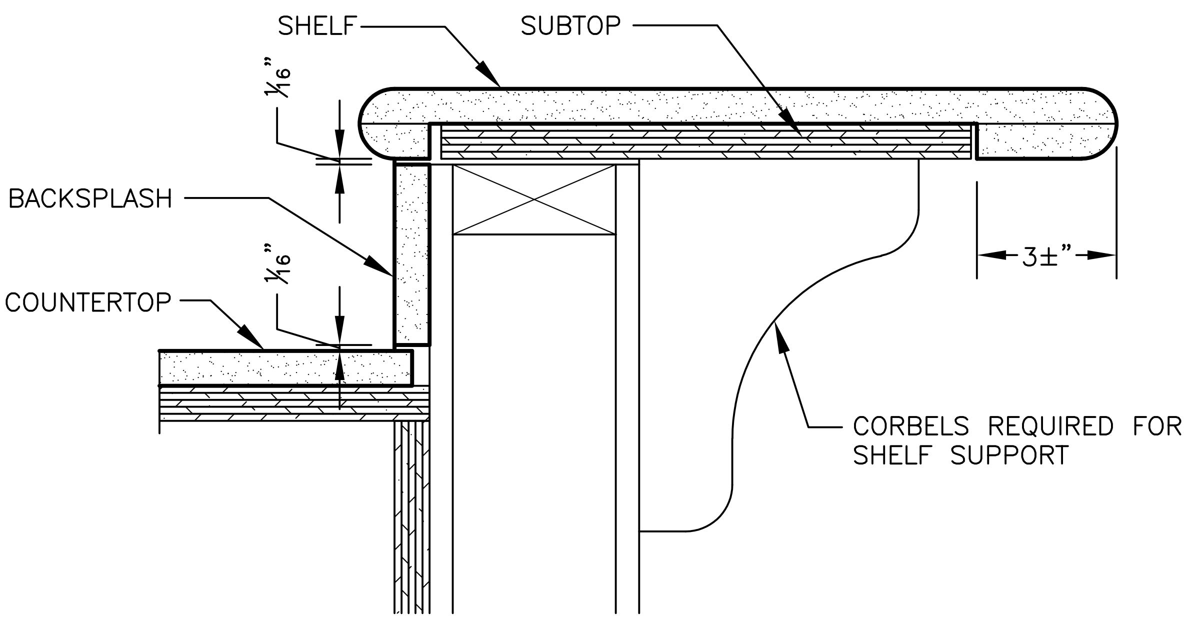
	0	MAR 2022	DIMENSION STONE DESIGN MANUAL 2022
			DRWG NO: 17-D-13 — SCALE: 3" = 1'-0"



DETAIL OF STONE SHELF WITHOUT SUBTOP



DETAIL OF STONE SHELF WITH SUBTOP

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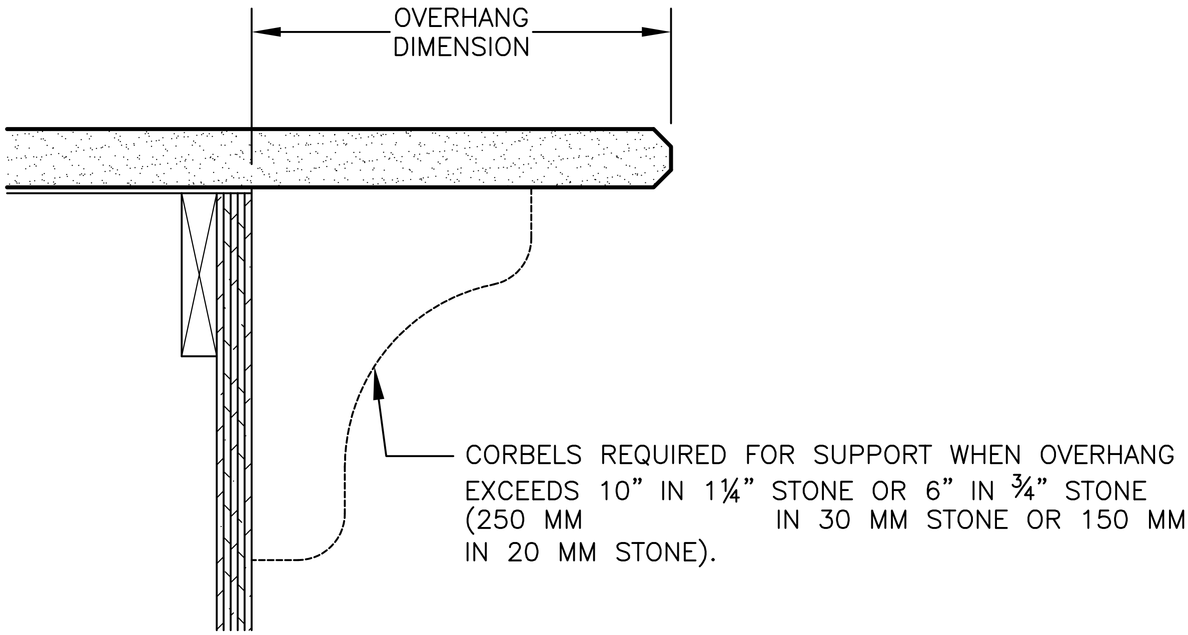
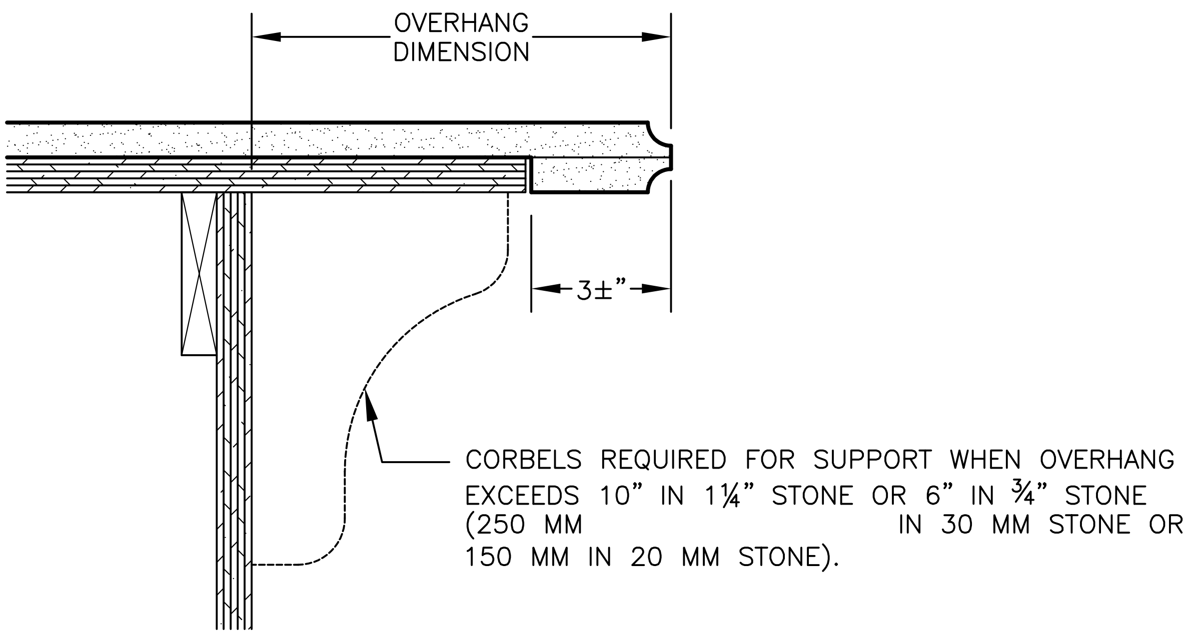
	0	MAR 2022	
			DRWG NO: 17-D-14 — SCALE: 3" = 1'-0"



DETAIL OF COUNTERTOP OVERHANG WITHOUT SUBTOP



DETAIL OF COUNTERTOP OVERHANG WITH SUBTOP

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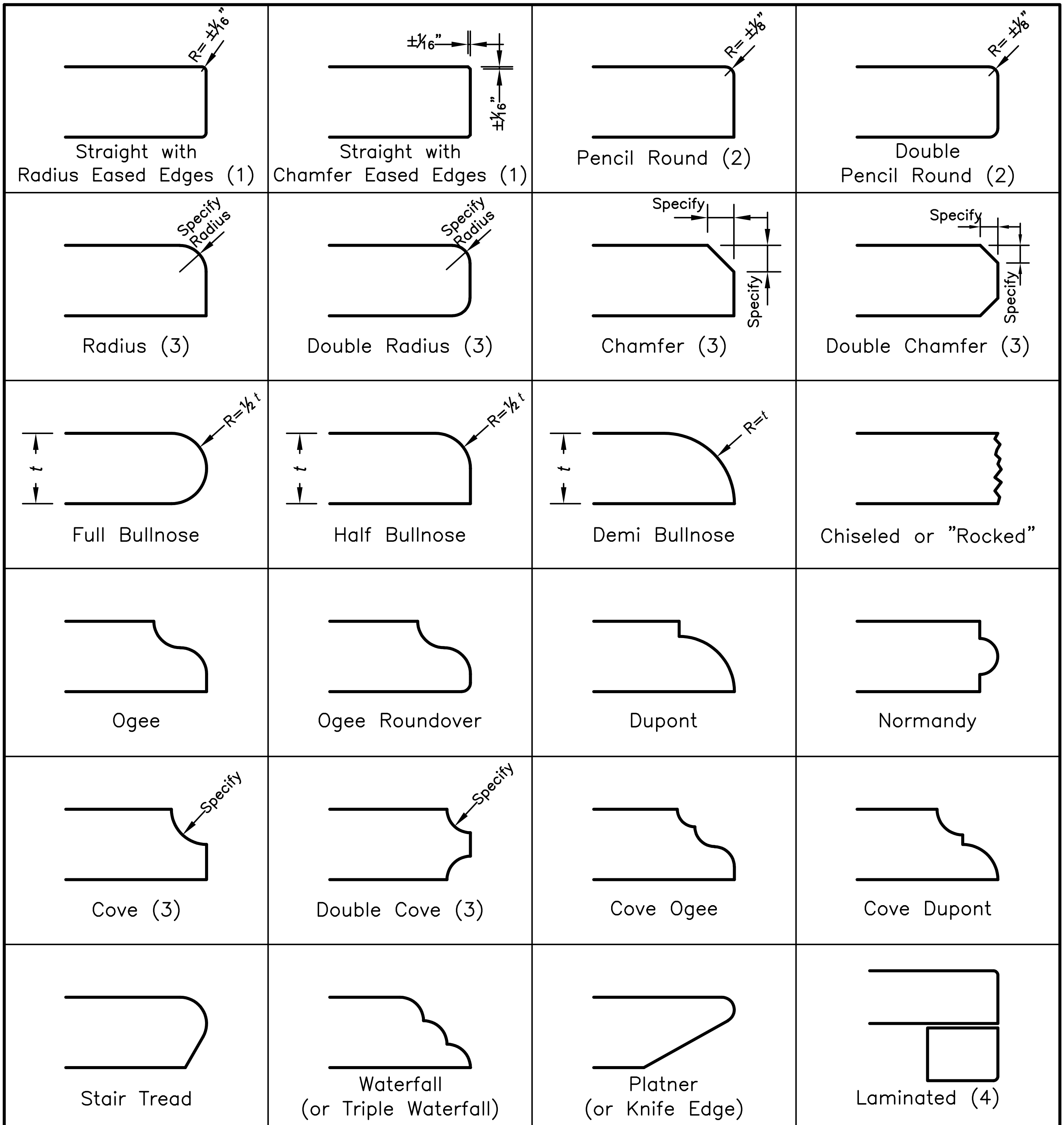
	0	MAR 2022	DIMENSION STONE DESIGN MANUAL 2022
			DRWG NO: 17-D-15 — SCALE: 3" = 1'-0"



Notes:

1. The term "Eased Edge" more commonly refers to a slightly radiused profile than a slightly chamfered profile, although the use of the term varies regionally and/or with specific fabricators. In either case, the edge treatment is slight, and normally does not exceed 1/16" (1.5 mm).
2. "Pencil Round" generally refers to a radius near that of a standard pencil, approximately 1/8" to 5/32" (3 to 4 mm).
3. Radius, Chamfer, or Cove edge profile can be any dimension. The actual dimension should be specified at the time of sale. Chamfers are most commonly 45°, although not necessarily so.
4. Many of the profiles shown on this drawing can be done with laminated edge details.

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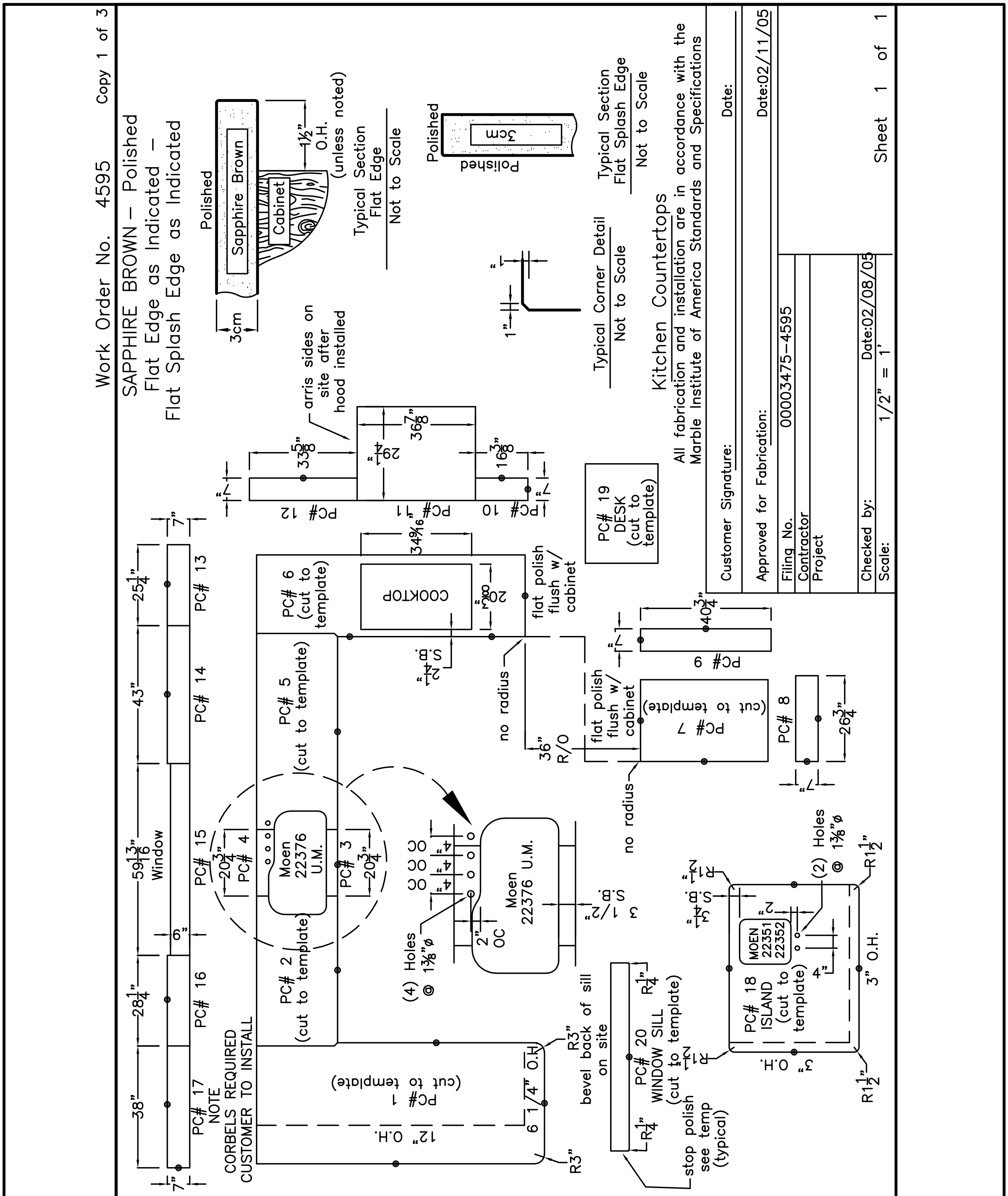
EDGE PROFILE NOMENCLATURE

DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 17-D-16

SCALE: NOT TO SCALE



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SHOP DRAWING EXPAMPLE

DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 17-D-17

SCALE: ½" = 1'-0"

COPING AND STOOLS -
EXTERIOR CUBIC STONE COPING AND WALLS

1.0 INTRODUCTION

1.1 Installation Method. There are several methods by which cubic coping and walls can be installed. Consideration should be given to the various features of each method in making a selection for a specific installation. See information about installation methods in this section's Data Sheet, Part 3, and illustrations of examples at the close of this section.

2.0 DESIGN CRITERIA

2.1 Physical Property Values. Final design should always be based on specific physical property values for the stone to be used. These values may be obtained from the Stone Supplier.

2.2 Backup Walls. When exterior cubic stone is set in conjunction with masonry load-bearing walls, the masonry backup should be solid brick or concrete. If hollow load-bearing concrete block is used to support and anchor stone, it must be reinforced with brick, concrete, or by filling the voids full of concrete two block courses in each story height.

2.3 Bonding. It is recommended for exterior coping that there be 100% coverage of bonding material between the stone and the substrate.

2.4 Bond Stones. For cubic walls, the effectiveness of bonding is improved when bond stones are staggered at random. The number or percentage of bond stones depends on design; from 25% to 30% is generally sufficient. Bond stones should bear on floors and beams. Provide an open joint at intervals for expansion gasket.

2.5 Corrosion-Resistant Metals. All metals that contact the stone must be corrosive-resistant.

2.6 Oil-based putty and sealants should never be used in contact with stone.

2.7 White portland cement is recommended for light-colored granite and marble. White portland cement with a low alkali content is recommended for limestone.

For additional information, refer to Chapter 13, Horizontal Surfaces and Chapter 14, Vertical Surfaces.

2.8 Geographic Methods. Some installation methods and materials are not recognized and may not be suitable in some geographic areas because of local trade practices, building codes, climatic conditions, or construction methods. Therefore, while every effort has been made to produce accurate guidelines, they should be used only with the independent approval of technically qualified persons.

DATA SHEET
EXTERIOR CUBIC STONE COPING AND WALLS

1.0 PRODUCT DESCRIPTION

1.1 Basic Use. Exterior masonry walls, caps, copings, and other cut stonework.

1.2 Fabrication. Exterior cubic stone units are precut and prefinished to dimensions specified on shop drawings, and are delivered to the job site ready to install.

1.3 Finishes. Abrasive, honed, and rough sawn finishes may be used for exterior cubic stone applications.

1.4 Colors. Most of the commercially available varieties are suitable.

2.0 TECHNICAL DATA

2.1 Each stone variety used for cubic stone coping and walls should conform to the applicable ASTM standard specification and the physical requirements contained therein. The specification for each stone type follows:

2.1.1 Granite: ASTM C615, Standard Specification for Granite Dimension Stone

2.1.2 Limestone: ASTM C568, Standard Specification for Limestone Dimension Stone

2.1.3 Marble: ASTM C503, Standard Specification for Marble Dimension Stone

2.1.4 Quartz-based Stone: ASTM C616, Standard Specification for Quartz-based Dimension Stone

2.1.5 Serpentine: ASTM C1526, Standard Specification for Serpentine Dimension Stone

2.1.6 Slate: ASTM C629, Standard Specification for Slate Dimension Stone

2.1.7 Soapstone: No ASTM Standard exists at this time

2.1.8 Travertine: ASTM C1527, Standard Specification for Travertine Dimension Stone

3.0 INSTALLATION

3.1 Preparatory Work. Exterior cubic stone may be installed against an existing backup or concurrently with the backup wall. It is recommended that the General Contractor install continuous flashing for stone coping.

3.1.1 When ready for installation, stones should be cleaned on all sides, and all dirt and foreign material removed from all surfaces.

3.2 Methods. Stones should be set in a full bed of mortar with the vertical joints full of mortar. Joints should be raked out to a depth equal to the width of joint, and later pointed or sealed with an approved, nonstaining sealant.

3.2.1 Expansion joints should be provided as required and kept free of mortar. Joint width may be maintained by using nonstaining, resilient cushions recessed 1" (25 mm) from exterior face. Joints should be at least 1-1/4" (30 mm) wide, except at control joints, where greater widths may be required.

3.2.2 All anchors, cramps, dowels, pins, supports, and similar items that contact the stone should be corrosion-resistant metals and should be securely attached to the structure and to the stone.

3.3 General Precaution. During construction, the General Contractor shall protect all stone from staining and damage.

3.3.1 Oil-based putty and sealants should never be used in contact with stone.

COPING AND STOOLS - THIN STONE STOOLS AND CUBIC SILLS

1.0 INTRODUCTION

1.1 Installation Methods. There are several methods by which stone window stools can be installed. Consideration should be given to the various features of each method in making a selection for a specific installation. See information about installation methods in this section's Data Sheet, Part 3, and illustrations of examples at the close of this section.

2.0 DESIGN CRITERIA

2.1 Oil-based putty or sealants should never be used in contact with stone.

2.2 Corrosion-resistant Metals. All metals that contact the stone must be corrosive-resistant.

2.3 Bonding. There must be 100% coverage of bonding material between stone window stools and substrate.

2.4 White portland cement is recommended for light-colored granite and marble. White portland cement with a low alkali content is recommended for limestone.

For additional information, refer to Chapter 13, Horizontal Surfaces and Chapter 14, Vertical Surfaces.

2.5 Geographic Methods. Some installation methods and materials are not recognized and may not be suitable in some geographic areas because of local trade practices, building codes, climatic conditions, or construction methods. Therefore, while every effort has been made to produce accurate guidelines, they should be used only with the independent approval of technically qualified persons.

DATA SHEET
THIN STONE STOOLS AND CUBIC SILLS

1.0 PRODUCT DESCRIPTION

1.1 Basic Use. Interior window stools and exterior cubic sills.

1.2 Fabrication. Stone window stools and cubic sills are precut and prefinished to dimensions specified on shop drawings, and are delivered to the job site ready to install.

1.3 Finishes. Exposed surface and edges of thin stone stools shall be polished or honed. Cubic sills shall be abrasive, honed, or rough finish.

1.4 Colors. Most of the commercially available varieties are suitable.

1.5 Sizes. Thin stone stools shall have thicknesses of ¾" (20 mm) and 1¼" (30 mm), or as specified. Cubic sills shall be as specified.

2.0 TECHNICAL DATA

2.1 Each stone variety used for thin stone stools and cubic sills should conform to the applicable ASTM standard specification and the physical requirements contained therein. The specification for each stone type follows:

2.1.1 Granite: ASTM C615, Standard Specification for Granite Dimension Stone

2.1.2 Limestone: ASTM C568, Standard Specification for Limestone Dimension Stone

2.1.3 Marble: ASTM C503, Standard Specification for Marble Dimension Stone

2.1.4 Quartz-based Stone: ASTM C616, Standard Specification for Quartz-based Dimension Stone

2.1.5 Serpentine: ASTM C1526, Standard Specification for Serpentine Dimension Stone

2.1.6 Slate: ASTM C629, Standard Specification for Slate Dimension Stone

2.1.7 Soapstone: No ASTM Standard exists at this time

2.1.8 Travertine: ASTM C1527, Standard Specification for Travertine Dimension Stone

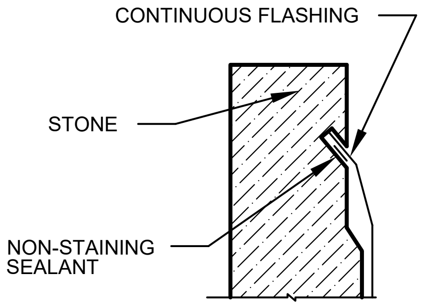
3.0 INSTALLATION

3.1 Methods: Stone window stools are installed either by the standard or thin set method. Cubic sills are installed in a full portland cement mortar bed with dowels.

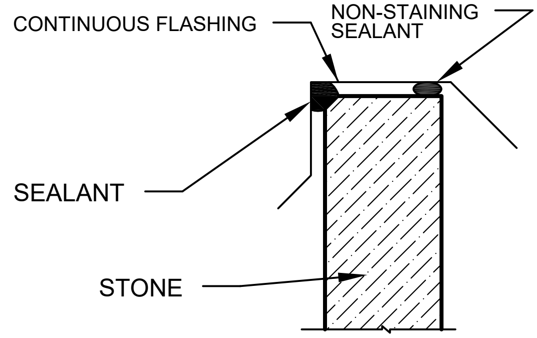
3.2 General Precautions: During construction, the General Contractor shall protect all stone from staining and damage.

3.2.1 Oil-based putty and sealants should never be used in contact with the stone.

NOTES:

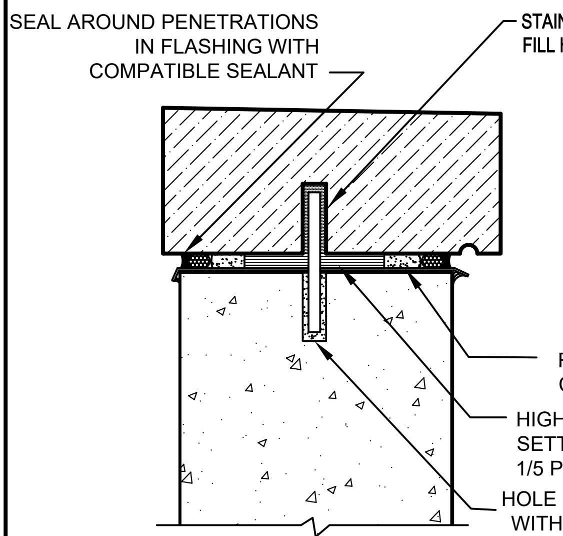


1 PARAPET DETAIL

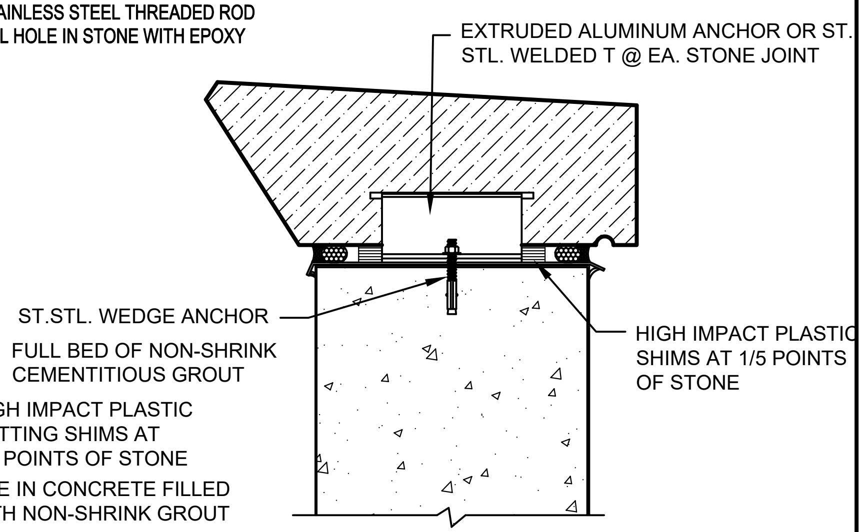


2 PARAPET DETAIL

NOTE: MINUMUM RECOMMENDED STONE THICKNESS FOR THESE DETAILS IS 1-1/4".



3 COPING DETAIL



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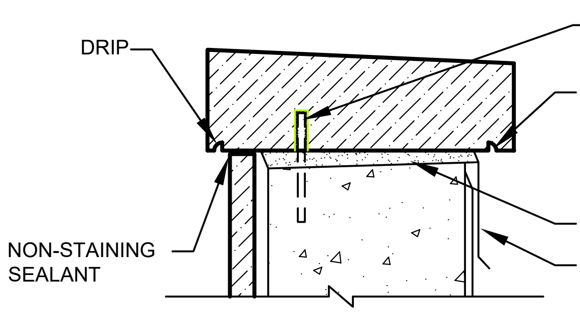
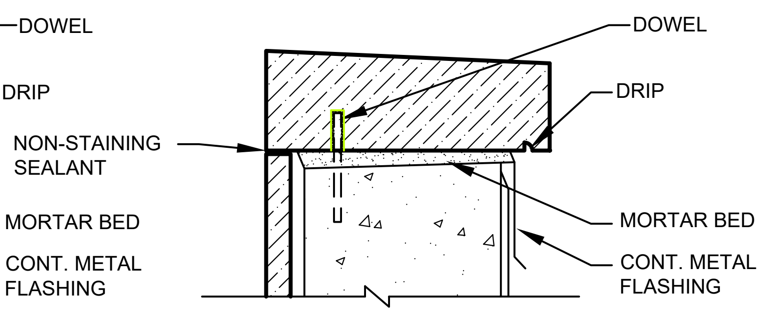


5 COPING DETAIL



6 COPING DETAIL

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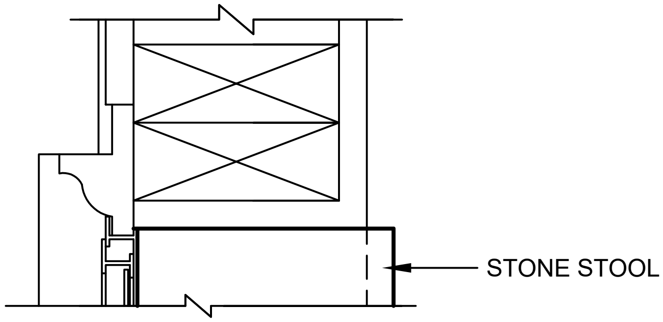
EXTERIOR STONE VENEER
FLASHING & COPING DETAILS

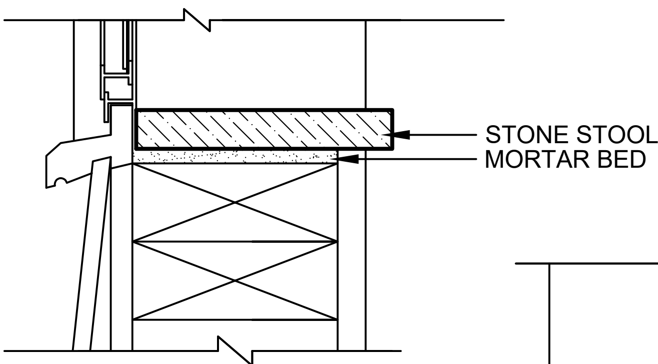
DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 18-D-1

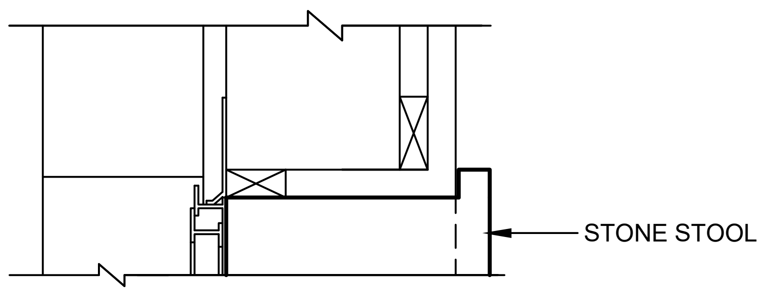
SCALE: 3" = 1'-0"



1 PLAN SECTION
(WOOD FRAME CONSTRUCTION)

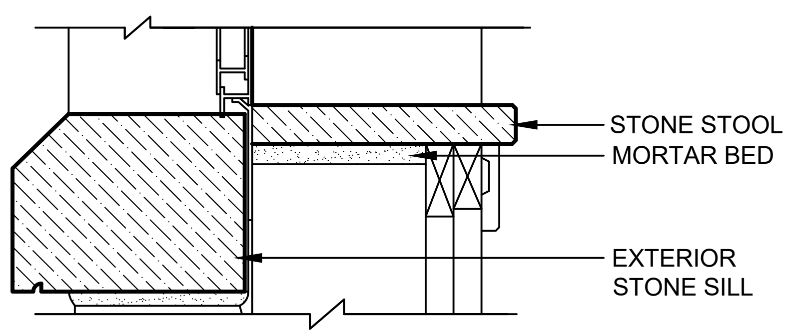


2 SECTION
(WOOD FRAME CONSTRUCTION)



3 PLAN SECTION
(MASONRY CONSTRUCTION)

NOTE: USE 100% COVERAGE OF MORTAR BED MATERIAL BETWEEN STOOL AND SUBSTRATE.



4 SECTION
(MASONRY CONSTRUCTION)

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STONE SILL & STOOL DETAILS

DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 18-D-2

SCALE: 3" = 1'-0"

STONE FURNITURE - STONE FURNITURE AND TOPS

1.0 INTRODUCTION

1.1 Installation Methods. There are several methods by which stone furniture can be fabricated and installed. Consideration should be given to the various features of each method. Refer to recommendations furnished by NSI Members specializing in furniture and top construction. See information about installation methods in this section's Data Sheet, Part 3, and illustrations of examples at the close of this section.

2.0 DESIGN CRITERIA

2.1 Sealers. Furniture or tops may be sealed or unsealed depending upon location and conditions of usage.

2.1.1 If sealed, follow Manufacturer's re-commendations for cleaning, stripping, and resealing.

2.1.2 If tops are used for food preparation, make certain sealer applied is nontoxic and safe for food preparation areas.

2.2 Base Design. Adequate support of stone should be designed into the base to prevent accidents and fracturing of the stone after assembly or installation.

2.3 Unsupported Spans and Overhangs. The size of any unsupported span or overhang depends upon the thickness and type of stone used.

2.3.1 It is not recommended to project any unsupported stone past the base more than 6" 150 mm) for stone of ¾" (20 mm) or less thickness.

2.3.2 When using some of the more fragile stones, including Soundness Classification Groups C and D marbles, the use of an unsupported stone overhang of any dimension may not be feasible.

2.3.3 Stone thicker than ¾" (20 mm) can have a greater unsupported span.

2.3.4 Overhangs can be increased if other stone, such as Soundness Classification Group A marble, slate, or travertine, ¾" (20 mm) thick exterior plywood, or other structural support is provided for the finished stone.

2.4 Exposed stone edges must be gauged to the thickness specified.

2.5 Dimensions of bevel and quirk miters and radius of rounded edges should be specified.

2.6 Laminated Aprons. When fabricating laminated aprons and double thicknesses, all jointed edges and horizontal surfaces must be sanded or ground to eliminate irregularities and ensure 100% contact.

2.7 Oil-based putty and sealants cannot be used in contact with stone.

For additional information, refer to Chapter 13 Horizontal Surfaces, Chapter 14 Vertical Surfaces, and Chapter 17 Residential Countertops.

2.8 Geographic Methods. Some installation methods and materials are not recognized and may not be suitable in some geographic areas because of local trade practices, building codes, climatic conditions, or construction methods. Therefore, while every effort has been made to produce accurate guidelines, they should be used only with the independent approval of technically qualified persons.

DATA SHEET

STONE FURNITURE & TOPS

1.0 PRODUCT DESCRIPTION

1.1 Basic Use. Furniture and tops.

1.2 Fabrication. Stone furniture and tops are precut and prefinished to dimensions specified on shop drawings, and are delivered to the job site ready to install or place in a predetermined location.

1.3 Finishes. Polished, honed, natural cleft, and rough.

1.4 Colors. Most of the commercially available varieties are suitable.

1.5 Sizes. Custom according to design requirements and size limitations of selected stone.

2.0 TECHNICAL DATA

2.1 Each stone variety used for stone furniture and tops should conform to the applicable ASTM standard specification and the physical requirements contained therein.

2.2 These specifications are as follows:

2.2.1 Granite: ASTM C615, Standard Specification for Granite Dimension Stone

2.2.2 Limestone: ASTM C568, Standard Specification for Limestone Dimension Stone

2.2.3 Marble: ASTM C503, Standard Specification for Marble Dimension Stone

2.2.4 Quartz-based Stone: ASTM C616, Standard Specification for Quartz-based Dimension Stone

2.2.5 Serpentine: ASTM C1526, Standard Specification for Serpentine Dimension Stone

2.2.6 Slate: ASTM C629, Standard Specification for Slate Dimension Stone

2.2.7 Soapstone: No ASTM Standard exists at this time

2.2.8 Travertine: ASTM C1527, Standard Specification for Travertine Dimension Stone

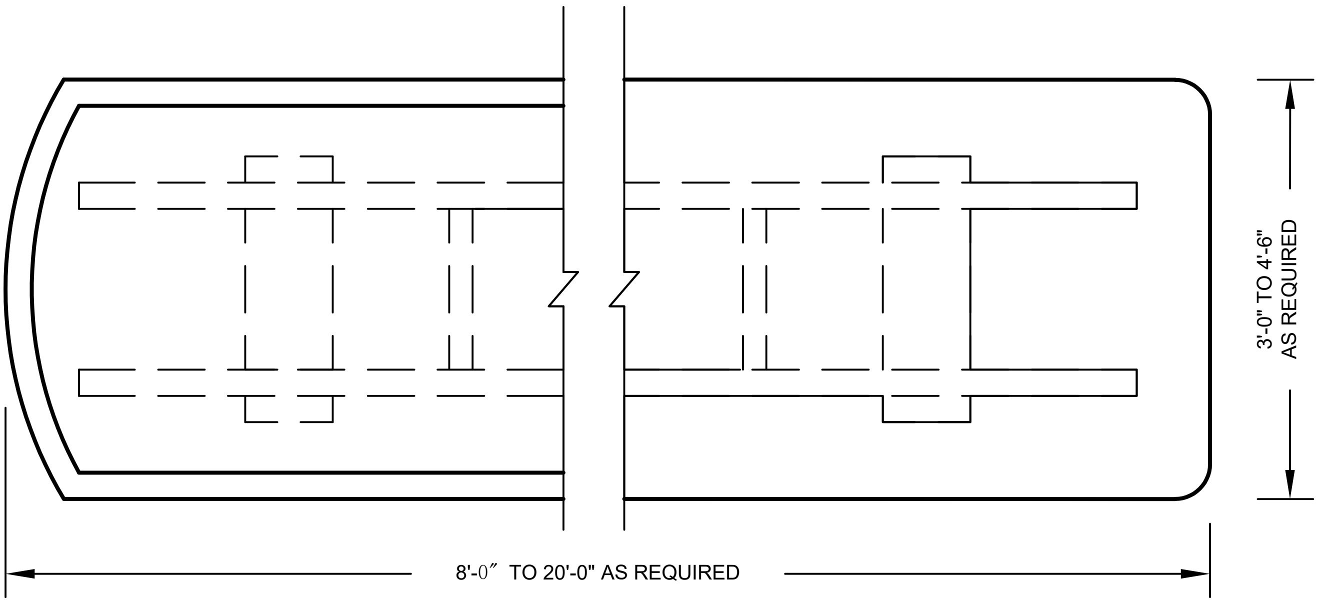
3.0 INSTALLATION

3.1 Methods. Furniture is usually pre-assembled in the Fabricator's shop.

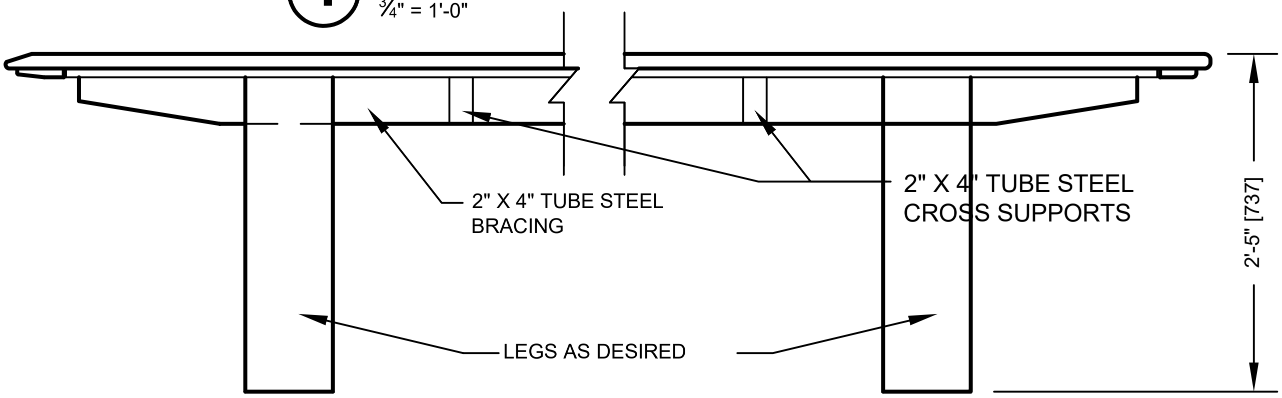
3.1.1 Tops are anchored to the supporting base with dowels, pins, nonstaining adhesive, or a combination of these.

3.2 General Precautions: During construction, the General Contractor shall protect all stone from staining or damage.

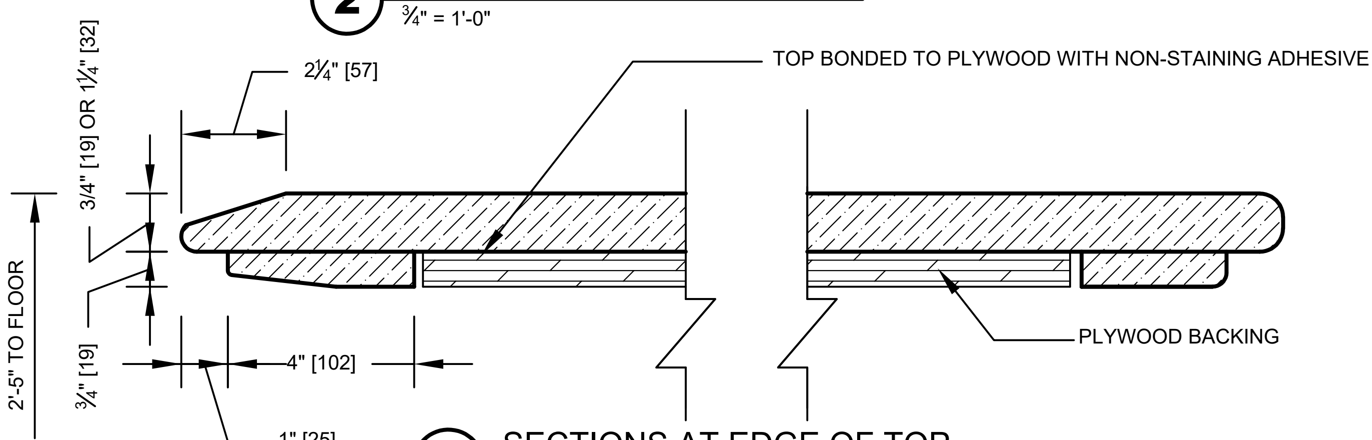
3.2.1 Oil-based putty and sealants should never be used in contact with stone.



1 PLAN VIEW
¾" = 1'-0"



2 ELEVATION
¾" = 1'-0"



A SECTIONS AT EDGE OF TOP
3" = 1'-0"

NOTE: DIMESIONS IN [ ] ARE IN MILLIMETERS

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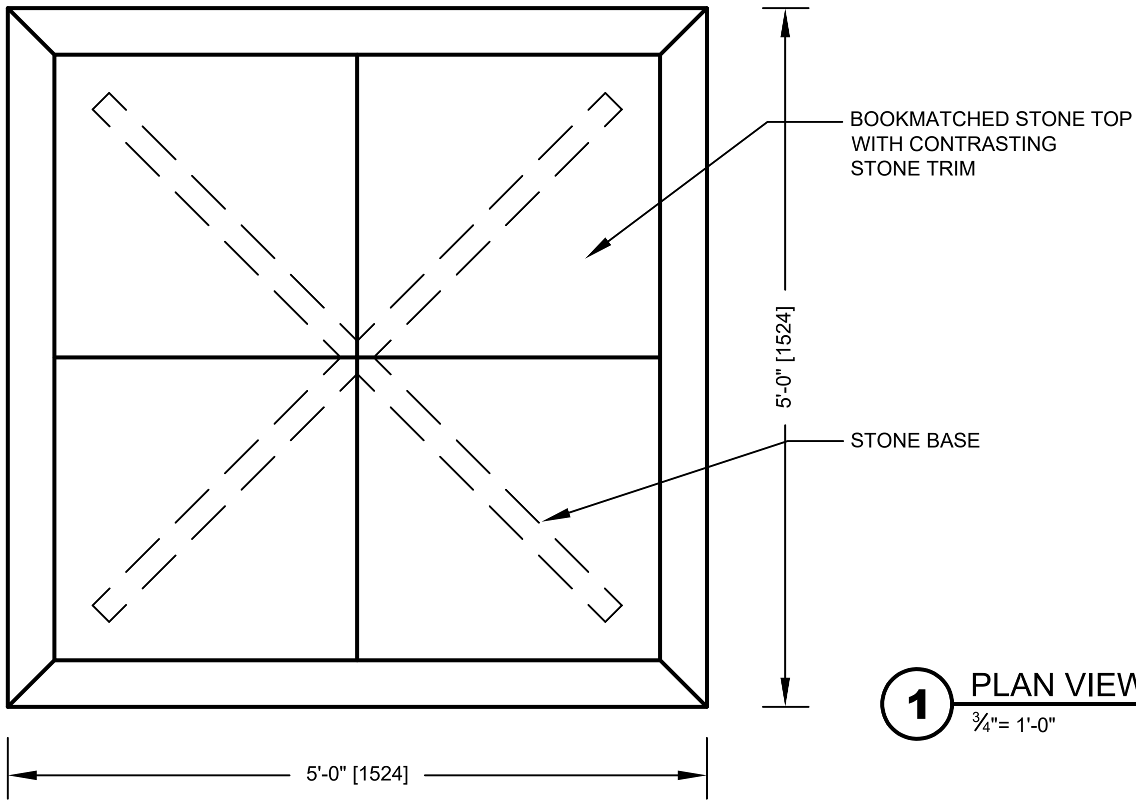
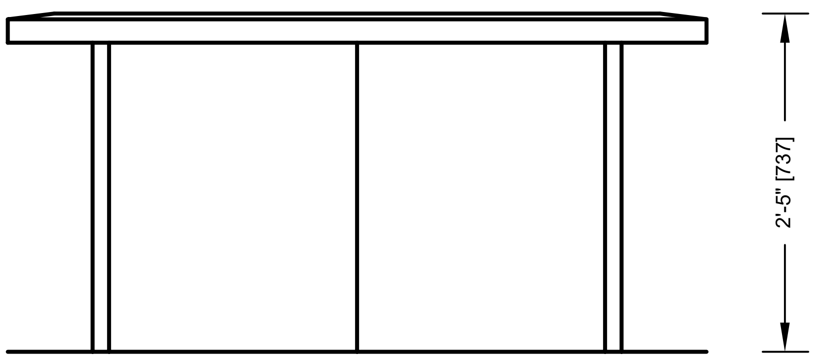
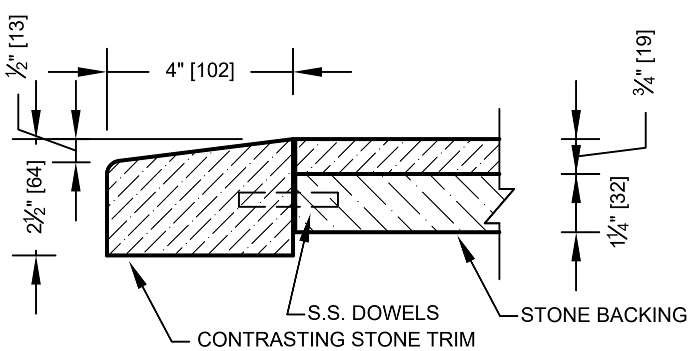
			DRWG NO: 19-D-1 — SCALE: AS NOTED



1 PLAN VIEW
¾"= 1'-0"



1 ELEVATION
¾"= 1'-0"



NOTE:
BOND STONE PIECES TOGETHER WITH A TWO-PART, 100% SOLIDS EPOXY. GRIND AND POLISH TOP AND EDGES AFTER ASSEMBLING TO ACHIEVE SMOOTH, UNIFORM SURFACES.

A SECTION AT EDGE
6"= 1'-0"

NOTE: DIMESIONS IN [ ] ARE IN MILLIMETERS

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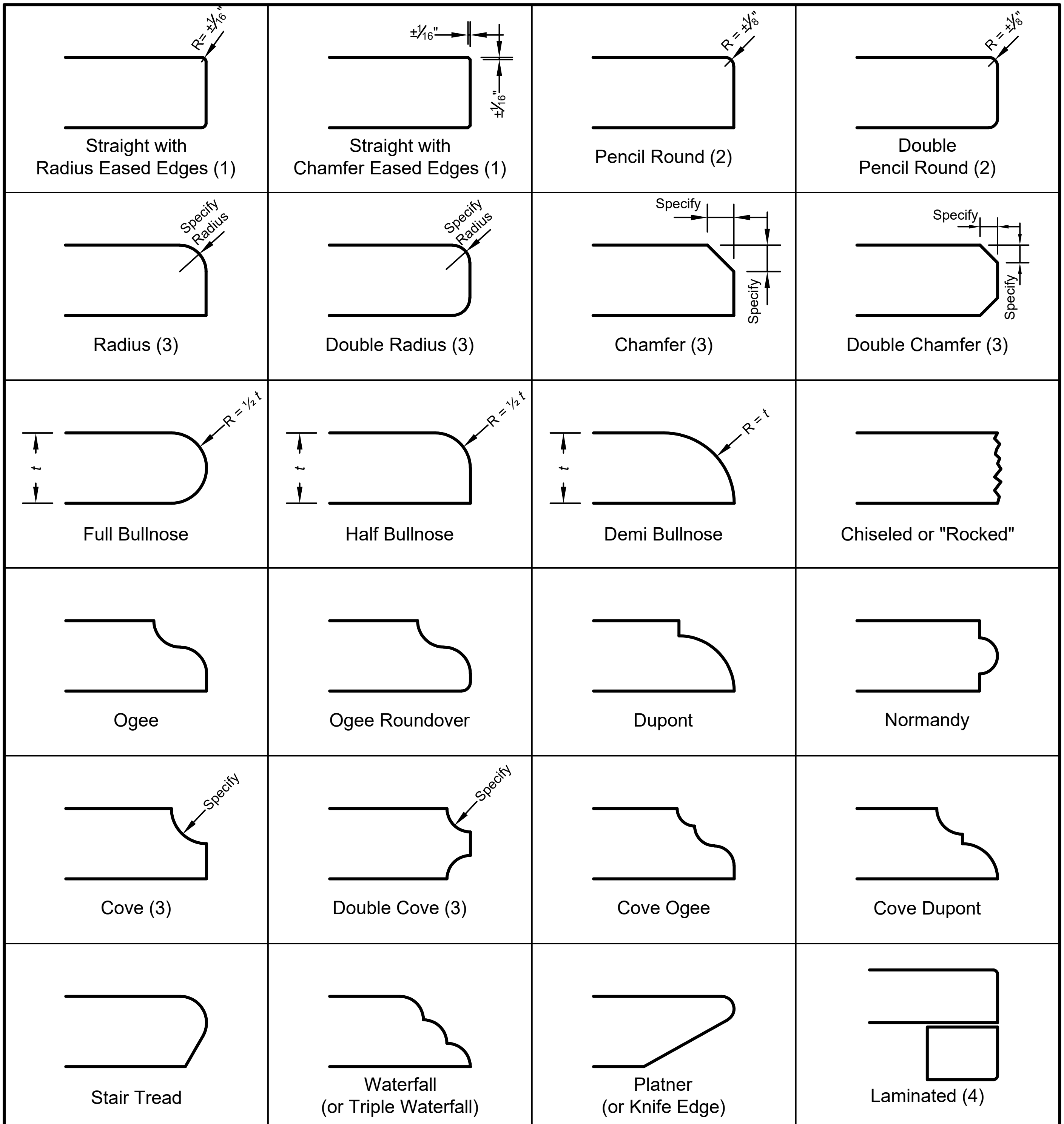
			DRWG NO: 19-D-2 SCALE: AS NOTED



Notes:

1. The term "Eased Edge" more commonly refers to a slightly radiused profile than a slightly chamfered profile, although the use of the term varies regionally and/or with specific fabricators. In either case, the edge treatment is slight, and normally does not exceed 1/16" (1.5 mm).
2. "Pencil Round" generally refers to a radius near that of a standard pencil, approximately 1/8" to 5/32" (3 to 4 mm).
3. Radius, Chamfer, or Cove edge profile can be any dimension. The actual dimension should be specified at the time of sale. Chamfers are most commonly 45°, although not necessarily so.
4. Many of the profiles shown on this drawing can be done with laminated edge details.

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STONE TOILET PARTITIONS
(FLOOR-SUPPORTED)

DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 19-D-3

SCALE: NOT TO SCALE

NOTES:

STONE-FACED VENEER PRECAST CONCRETE PANELS

1.0 Physical Properties. When using precast panels, careful attention should be given to ensuring the necessary strength and serviceability requirements, with particular attention given to the physical properties of the stone, anchorage of the stone to the concrete, safety factors, and effect of finishes on the strength of the stone.

1.1 The physical properties of the stone facing material must be compared with the properties of the concrete backup. These properties include:

1.1.1 Tensile (axial and flexural), compressive, and shear strength.

1.1.2 Modulus of elasticity (axial tension, flexure, and axial compression).

1.1.3 Coefficient of thermal expansion.

1.1.4 Volume change.

1.2 Testing mockups should be built to test wall, window, and joint performance under the most severe wind and rain conditions.

1.3 Coordinator. It is recommended that a qualified person be engaged to coordinate delivery, scheduling, and color uniformity of the panels (to satisfy samples or mockup) among the General Contractor, Stone Fabricator, and Precast Supplier.

1.4 Detailed recommendations can be obtained from:
Prestressed Concrete Institute
8770 W Bryn Mawr Ave., Suite 1150
Chicago, IL 60631
Phone: (312) 786-0300
Fax: (312) 786-0353
https://www.pci.org/

1.5 Geographic Methods. Some installation methods and materials are not recognized and may not be suitable in some geographical areas because of local trade practices, building codes, climatic conditions, or construction methods. Therefore, while every effort has been made to produce accurate guidelines, they should be used only with the independent approval of technically qualified persons.

DATA SHEET

STONE-FACED VENEER PRECAST CONCRETE PANELS

1.0 PRODUCT DESCRIPTION

1.1 Basic Use. Exterior precast panels.

1.2 Limitations. The physical properties of the stone veneer facing should be compared with those of the concrete, including tensile (axial and flexural), compressive and shear strength, modulus of elasticity (axial tension, flexure, and axial compression), coefficient of thermal expansion, and volume change. Refer to the Prestressed Concrete Institute Handbook for detailed information.

1.3 Finishes. Polished, honed, thermal, bush-hammered, rough, abrasive, and natural cleft. Polished finish is not recommended for marble and limestone.

1.4 Colors. Most of the commercially available varieties are suitable.

1.5 Sizes. Stone veneer panels generally are 1", 1¼", 1½", 2" (25 mm, 30 mm, 40 mm, 50 mm), or thicker as specified. Refer to PCI Handbook for detailed information.

2.0 TECHNICAL DATA

2.1 Each stone variety used for veneer precast panels should conform to the applicable ASTM standard specification and the physical requirements contained therein. The specification for each stone type follows:

2.1.1 Granite: ASTM C615, Standard Specification for Granite Dimension Stone

2.1.2 Limestone: ASTM C568, Standard Specification for Limestone Dimension Stone

2.1.3 Marble: ASTM C503, Standard Specification for Marble Dimension Stone

2.1.4 Quartz-based Stone: ASTM C616, Standard Specification for Quartz-based Dimension Stone

2.1.5 Serpentine: ASTM C1526, Standard Specification for Serpentine Dimension Stone

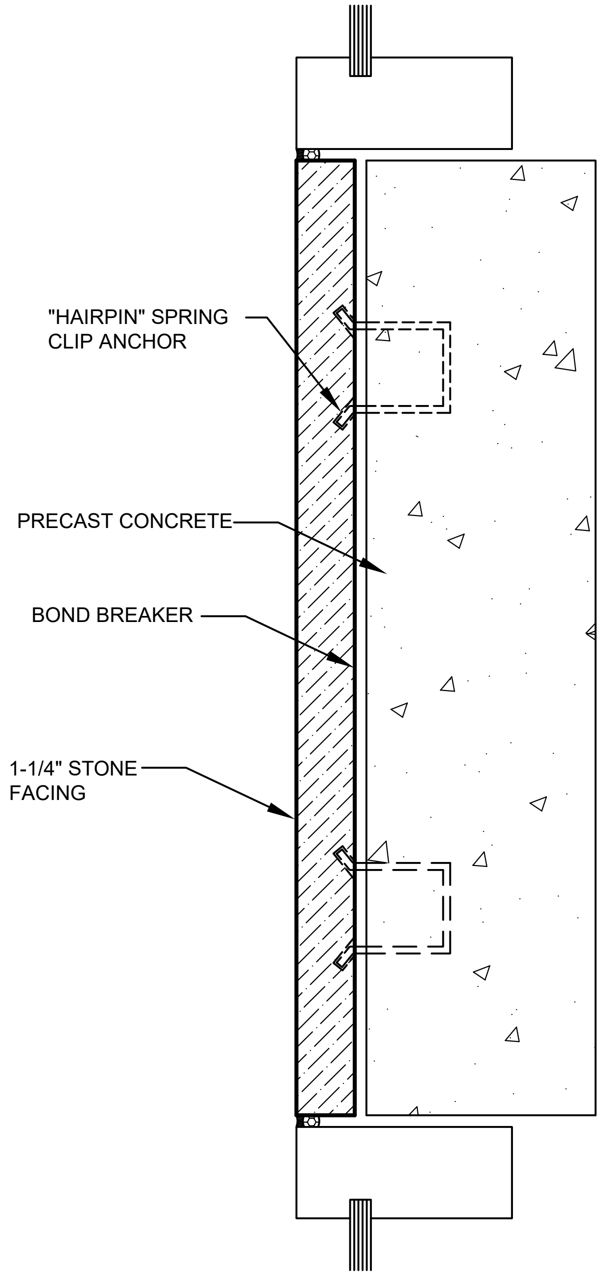
2.1.6 Slate: ASTM C629, Standard Specification for Slate Dimension Stone

2.1.7 Travertine: ASTM C1527, Standard Specification for Travertine Dimension Stone

3.0 INSTALLATION

3.1 Methods: Precast panels are generally installed by the General Contractor. Refer to PCI Handbook or contact Precast Producer for detailed information.

3.2 General Precaution: Contact Precast Producer or review the PCI Handbook for detailed information.



1 TYPICAL SECTION

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STONE VENEERED PRECAST CONCRETE DETAILS

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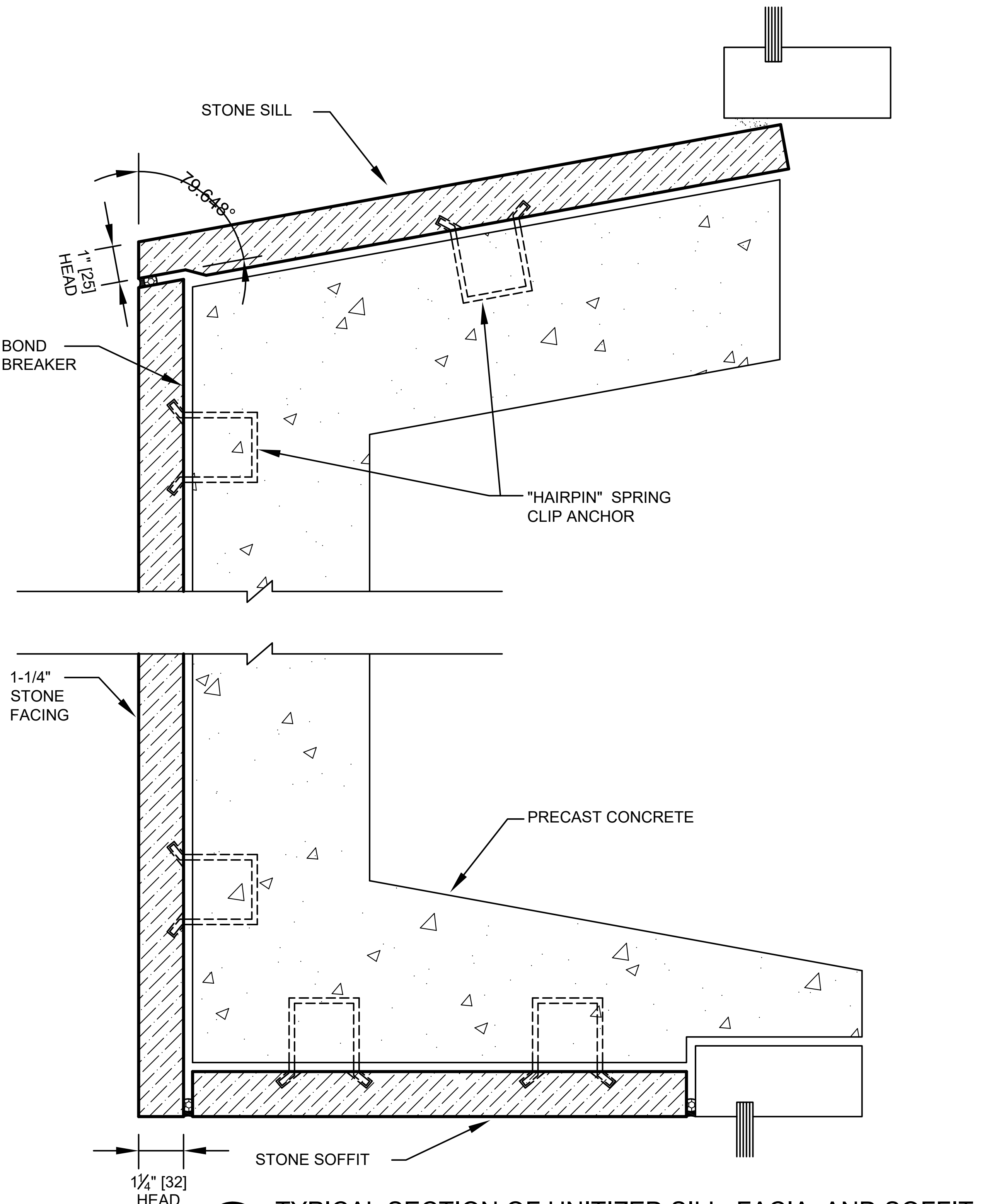
DRWG NO: 20-D-1

SCALE: 3" = 1'-0"



1 TYPICAL SECTION OF UNITIZED SILL, FACIA, AND SOFFIT

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			DRWG NO: 20-D-2 — SCALE: 3" = 1'-0"

RESTORATION AND MAINTENANCE – STONE GEOLOGY

1.0 INTRODUCTION

1.1 One cannot effectively participate in the field of stone restoration without at least a rudimentary understanding of the geological sciences. Stone composition is a far more complex issue than is commonly thought, and the in-service performance and behavior of the stone can be significantly influenced by even minor constituents of its composition. This issue is further complicated by the fact that while geologists and petrographers identify hundreds of different rock types, the stone industry uses much broader definitions of stone types than the scientific community. In doing so, the industry includes similar materials into various stone groups despite the fact that the stone does not technically and scientifically belong to that group. As practical examples, popular stones such as Crema Marfil and Rojo Alicante are commercially identified as "marble," even though they are not geologically marble, and would be scientifically classified as "hard, compact, dense limestone." Paradiso and Uba Tuba are commercially considered granite, yet they are actually "gneiss" and "charnockite," respectively. The differences in composition, behavior, and performance between these rocks and those rocks that scientifically belong in these classifications are generally slight, and negligible in most commercial issues. But to the restoration professional, such differences can be significant. Reference is made to the Natural Stone Institute's *Dimension Stone Design Manual* Chapter 1 and Chapters 5 through 12. While a brief introduction of stone geology is offered here, a far more comprehensive discussion of the subject can be found in those chapters. The reader is strongly encouraged to study those sections thoroughly to gain a greater understanding of the subject matter.

2.0 STONE FORMATION

2.1 Thousands of stone deposits exist throughout the world. Yet all stones have been formed by one of three methods, and therefore all stones can be classified into one of three groups: Sedimentary, Metamorphic, and Igneous.

2.2 The term **Sedimentary** comes from the Latin word *sedimentum*, which means "sinking" or "settling." It is used to describe stone deposits that are formed when sediment is collected over geological periods of time, causing individual grains, or "clasts," to be cemented together by another agent. Common cementing agents, in descending order of preference, include silica, carbonate, iron oxides, and clay. Limestone and sandstone are examples of sedimentary rocks.

2.2.1 There also exist sedimentary stones which are not created from the settling of clasts, but are **chemical sedimentary stones**. Onyx is an example of a chemical sedimentary stone.

2.3 **Metamorphic** is a term used to describe stones that have undergone a change in structure. The term originates from two Greek words: *meta*-, meaning change, and *morphic*, meaning structure. Perhaps the best known example of a metamorphic rock is marble, which has changed its structure from a sedimentary limestone to a recrystallized rock fabric known as marble due to intense heat and pressure.

2.4 The term **Igneous** comes from the Latin word *ignis*, meaning fire. This term describes stones that were melted deep within the earth by thermal energy released from the decay of radioactive minerals within the earth's core. These stones, eventually cooled and solidified, have been harvested for a variety of uses. Commercially, the most common of these rock types used is granite, yet many other igneous rock types exist in commercial trade.

3.0 STONE MINERALOGY

3.1 Siliceous and Calcareous Stones. Geologists have identified roughly 3,500 different minerals found in the earth's composition, yet only about a dozen of these minerals are commonly found in commercially-used stone varieties. As previously stated, however, even minerals found in trace levels of a rock fabric can influence the behavior and performance of the stone. Minerals that make up stone are commonly divided into two groups: siliceous, or silicate minerals, and calcareous, or calcium carbonate minerals. Stones that are comprised of siliceous minerals include granite, slate, and serpentine, while stones that are comprised of calcium carbonate components include marble, limestone, and travertine.

3.2 Mineral hardness is an extremely important consideration for the restoration professional. Mineral hardness determines how the stone will perform in service when subjected to abrasion, such as stones used for walking surfaces. Mineral hardness is also an important measurement in predicting how easily a stone can be resurfaced, as the grinding operation can be significantly slowed when hard minerals make up the stone fabric. In addition to the absolute hardness of a mineral, one must take into account the variability of mineral hardness within an installation. A patterned floor, using granite bands and travertine fields, can pose an extreme challenge to the restoration professional attempting to refinish it. The hardness of the granite requires aggressive abrasives to effectively work the material, yet these same abrasives can create uncontrollable dishing and gouging in the much softer travertine portions of the floor. Variability in mineral hardness can also exist within one stone. Such variability can create the same challenges in achieving a uniform level of grinding, and can also prevent a uniform level of gloss from being achieved due to the difference in the light reflectivity of the two portions of the stone.

3.2.1 Mineral hardness has long been measured by means of the **Mohs Scale of Relative Hardness**. In 1822, Friedrich Mohs, an Austrian mineralogist, published a paper on mineral hardness based on the scratch resistance of each of 10 minerals when tested against the other 9 minerals in his study. His published paper listed the 10 minerals in order of their relative scratch resistance. As simple as this study appears, almost two centuries later, we are still using Mohs' research and findings as the basic rank of mineral hardness. The ten stones included in Mohs' scale include:

Hardness	Mineral
1	Talc or Mica
2	Gypsum
3	Calcite
4	Fluorite
5	Apatite
6	Orthoclase
7	Quartz
8	Topaz
9	Corundum
10	Diamond

3.2.2 There are two common misconceptions regarding the Mohs scale. The first is that many do not clearly understand that **the scale is relative, not absolute**. Relative simply means that "4" on the scale is harder than "3," and both of them are harder than "2." The scale offers no absolute information regarding how much harder, or whether the interval between 4 and 3 is greater or less than the interval between 3 and 2. A mineral with a hardness of 4 **IS NOT** twice as hard as a mineral with a hardness of 2. It is more than 10 times harder! Today, we have the instrumentation available to measure absolute hardness. If the Mohs scale reported absolute hardness, it would look like the table below:

Mineral	Relative	Absolute
Diamond	10	1600
Corundum	9	400
Topaz	8	200
Quartz	7	100
Orthoclase	6	72
Apatite	5	48
Fluorite	4	21
Calcite	3	9
Gypsum	2	2
Talc	1	1

3.2.3 The second area of confusion regarding the Mohs scale is that **it is a hardness scale of minerals, not stones**. Since nearly all stones are polymineralic, each mineral within the stone's composition has its own unique properties, including hardness. Oftentimes we see marketing literature for a certain stone that lists a "Mohs Hardness" for the stone. This is a technical inaccuracy, since the stone is comprised of a variety of minerals and each mineral has a unique hardness value. To ask, "What is the Mohs' hardness of this stone?" is the equivalent of asking, "What is the flavor of Neapolitan ice cream?" It depends on which part of the stone, or which part of the ice cream, we are talking about.

3.3 Chemical Resistance. There are a variety of chemicals that can attack the fabric of a stone, but acidic chemicals are the cause of most frequent concern. Acidic chemicals are commonly found in both commercial and residential settings, through food and beverages, as well as many common cleaners and detergents. One of the most frequent inadvertent acid exposures encountered in both residential and commercial settings is urine, which is quite acidic and has been responsible for the attack of many stone floors.

3.3.1 Acidic content is measured with the pH scale. The pH scale ranges from 0 to 14, although there are some exceptionally acidic substances that can actually be below zero on the pH scale. A value of 7 is neutral; anything lower than 7 is acidic, while anything above 7 is alkaline. The pH scale is not a linear scale, but a logarithmic scale. This means that a substance with a pH of 5 is 10 times more acidic than a substance with a pH of 6.

3.3.2 Generally speaking, **all calcareous stones are subject to acid attack**, even from the mild acids found in household settings. The most common result of acid exposure is etching, which is generally visible as a dull spot in an otherwise high gloss polished surface. Depending on the acidity of the attacking agent, the dwell time that the attacking agent was allowed on the stone surface, the vulnerability of the specific stone to acid reaction, and the number of repetitions allowed to occur, the result can be much more severe than a simple dull spot.

3.3.3 Siliceous stones are far more acid resistant than their calcareous counterparts. This does not mean that they are necessarily acid proof. Many siliceous stones include minerals of minor to trace levels of concentration which are acid vulnerable. Additionally, certain acid types will attack silicates. One of the better known examples is hydrofluoric acid (HF). This is a common component found in rust-removing stain removers and rust-removing laundry stain removers. Accidental exposure of stone to compounds containing low concentrations of HF is fairly common.

3.3.4 Degradation due to salt attack is included in this section, but despite the fact that salt is a chemical, its mode of attack on natural stone is not actually chemical, but mechanical. Salt is readily soluble in water, and when in solution, can penetrate the pores of medium to highly porous stone fabrics. When the water evaporates, the salt will recrystallize within the confines of the pore cavity in the stone. The expansion caused by the recrystallization exerts significant pressure on the walls of the pore, and is great enough to cause fracturing, resulting in an exfoliation of the stone face. Salt exposure is most commonly experienced in northern climates where salt is used as a snow melting chemical. The exposure is not limited to exterior surfaces, however, as the salt is carried into the building envelope by the footwear of pedestrians. Salt attack can be evident in both commercial and residential properties, but it is far more prevalent in commercial settings due to the greater use of salts in those venues. Limestone and travertine are the two most commonly affected stones due to their pore volume and pore structure.

RESTORATION AND MAINTENANCE – STONE IDENTIFICATION

1.0 FIELD IDENTIFICATION TOOLS

1.1 Several simple field identification tools are available to measure hardness and acid sensitivity. Mohs Hardness picks can be purchased from any number of laboratory or geology supply vendors, generally for less than $100 per set. This set of picks consists of metal and/or plastic tipped instruments which are calibrated to correspond to the values on the Mohs scale. One simply attempts to scratch the stone surface with the pick. If the stone is scratched, it is softer than that value; if it is not scratched, it is harder than that value. The most common field test for acid resistance is to use a diluted concentration of hydrochloric acid (HCl), generally 5 or 10% concentration. The hardware store variety of HCl is muriatic acid, which contains about 30% HCl. Many field technicians purchase the economical muriatic acid and dilute it with water in a water to muriatic acid ratio of 5:1 to 2:1. Placing a drop of the diluted acid solution on an inconspicuous area of the stone surface will tell you if the stone is calcareous or siliceous. The acid will bubble and fizz when placed on calcareous stones, such as marble, limestone, or travertine, while it will rest on the surface of a siliceous stone, such as granite, quartzite, or slate, without any noticeable reactive activity. Remember that this is an aggressive acid, even after dilution. Safe handling practices with appropriate PPE are required at all times.

2.0 STONE FINISH IDENTIFICATION

2.1 The restoration professional must identify the finish originally applied to a stone surface. There are a variety of stone finishes in the marketplace, many of them proprietary, but the majority of stone installations will have one of the standard finishes listed below.

2.2 Polished surfaces are smooth, with a highly reflective, glossy face. The level of gloss will vary from stone to stone, and can vary between different regions of a stone. Gloss level is related to both mineral hardness and pore space, so significant variation exists. Gloss, or the level of reflectivity, can be measured with a gloss meter, but no industry consensus standard exists as to what level of gloss is required to define a surface as polished. If such a standard were to exist, it would actually be different for each stone on the market. Stone polishing is strictly a mechanical, abrasive process, with the exception of some marble varieties, in which oxalic acid might be used. It does not produce any level of pore closure, nor "mineral welding." As such, polishing does not reduce absorption of the surface. However, it does provide greater surface tension when fluids are applied to it.

2.3 Honed surfaces are typically produced with the same machinery used for polished surfaces, with only a few of the final abrasive heads removed. A honed surface has the same flatness and perceived smoothness as a polished surface, but has no or very limited reflectivity. Again, there is no industry consensus standard that establishes the limits in grit size or reflectivity that define the coarse and fine boundaries of honed finishes. It is commonly believed that honed surfaces have greater frictional properties than polished surfaces. This is true in some extremely coarse grit honed surfaces, but in the majority of honed stones available in today's marketplace, the difference in measured friction between honed and polished surfaces is statistically irrelevant.

2.4 A variety of textured surfaces can be achieved in natural stones.

2.4.1 Acid Washed, or "Acid Etched," surfaces are created by intentionally inducing an acid attack on calcareous varieties of stone, leaving a rough textured surface. The depth of relief achieved is dependent upon the concentration of acid, vulnerability of the stone fabric to acid reaction, and dwell time of the acid application.

2.4.2 Flamed, or "Thermal," surfaces are created by briefly exposing the stone surface to a propane flame. The rapid heating of the outermost crystals of stone causes significant expansion and results in a thermal desegregation of the stone minerals. This finish is typically limited to granite and granite-like igneous rock varieties, but some other stones are also capable of taking a flamed finish. The depth of relief and related profilometry of the surface is dependent upon the stone's mineralogy, stone crystal size, and the setback, speed, and angle of incidence of the flame.

2.4.3 Sanded surfaces have been textured by abrasive particles striking the stone surface at high velocities. Again, the finish profilometry is dependent upon a multitude of factors, including the stone composition and hardness, particle size and velocity, and dwell time.

2.4.4 Cleft surfaces are produced by splitting the stone fabric along its rift, or direction of preferred separation. Virtually all stones can be cleft, but a much smaller variety of stones can be cleft to produce a surface that is suitable and safe for pedestrian ambulation. The most common stone to be supplied in a cleft surface is slate, some varieties of which cleft into extremely flat and uniform sheets.

3.0 DETECTION OF SURFACE TREATMENTS

3.1 Many stone surfaces today are treated with some type of surface-applied product, and in many cases, multiple products. Recognition and identification of these products is vital, as removal (or "stripping") of them is frequently required to prevent an incompatibility with subsequently applied products. The best scenario is if the owner has retained records of what has been used on the stone during its service life, from which the manufacturer can be contacted and exact chemistry and removal protocol can be determined. Four groups of surface applied products are discussed below.

3.2 Sealers. True sealers are rarely used in stone applications, as they prevent the stone from "breathing," and often create vapor pressures, blotchiness, or other negative aspects within the stone fabric. There are a few true sealers marketed for use on stone, but most commonly when a sealer is encountered, it is a product that was not specifically formulated for stone, but intended to be used on a different surface, such as wood. Sealer application can usually be detected by a "plastic-like" sacrificial surface compound on top of the stone.

3.3 Impregnators are the most common product applied post-fabrication to stone surfaces. An impregnator can be solvent carried or water carried. In either case, the carrier evaporates after application, and the active ingredients, which may be a small percentage of the original formula, remain to treat the stone surface. An impregnator "impregnates," or penetrates, the surface and remains below the surface to a depth of a couple of millimeters, depending on the stone's porosity and density. Impregnators must be matched to the stone variety, as they are designed for optimum performance on a specific range of stone properties. Impregnators are usually detected by the stone's reaction to water droplets; the greater surface tension of an impregnated surface will cause "beading" of water droplets.

3.4 Dyes and some colored waxes are occasionally used by suppliers to alter the natural color of a stone to a color that is more desirable and in greater demand. The presence of a dye is rarely disclosed by the supplier. Some dyes can be detected with a simple cloth saturated in a solvent. Acetone, methyl ethyl ketone, and toluene are frequently used for this purpose. Not all dyes are soluble with these solvents, so while this simple test might confirm the presence of a dye, it cannot reliably confirm the absence of a dye.

3.5 Resin impregnation prior to polishing is common, especially in the countertop sector of the stone industry. The most common resin used worldwide is epoxy, but polyester and acrylic-based resins are also used.

3.5.1 Process. Though resin impregnation can be done entirely manually, most major stone slab sawyers and finishers use large, sophisticated process lines to perform this operation. The sawn, unfinished slab is screeded with the resin product. It is then placed over a vacuum table, which draws the resin deeper into the stone slab, then placed in an oven for accelerated heat curing. Once cured, the slab is sent to the polish line, where the majority of the resin is abraded from the slab. The residual resin exists only in the fissures, cracks, pits, and other surface interruptions of the slab, offering a cosmetically improved, uninterrupted reflective surface, unattainable in an untreated stone slab. The percentage of resin in the finished slab differs for each stone slab. Most overseas suppliers will not disclose the application of a resin treatment on their slab products. On rough slabs, the presence of resin treatment can usually be confirmed by observing the rough edges of the slab and noting the cured drippings of resin.

3.5.2 Problems with resin treatment. Although resin treatment does reduce the absorption of stone surfaces, it will not have the same effect as impregnator treatment. Resin treatment has long been associated with a darkening of the stone's natural color, which can present challenges in matching the color tone of an exposed polished edge to the treated surface. Some resins may also complicate the application of impregnators due to compatibility issues between the two products. No resin treatments have been proven to be 100% UV resistant. Discoloration (yellowing) of the resin is possible, though not likely. Due to the vast difference in rates of thermal expansion between cured plastics and natural stone, dislodging of resin fillers is commonly noted when such products are used in exterior settings. Degradation of exterior surfaces is likely even without freeze/thaw cycling. As such, the use of resin-treated stone materials in exterior applications is not recommended.

4.0 IDENTIFYING REPAIRS AND REINFORCEMENTS

4.1 Repairs and reinforcements are common and necessary in many stone varieties. The restoration professional must be able to detect and identify such repairs, because some modes of restorative procedures could compromise the integrity of the repair/reinforcement. A more comprehensive discussion of the allowable and anticipated levels of repair and reinforcement can be found in the Natural Stone Institute's *Soundness Classification* document.

4.2 Adhesive Repairs. Many repairs and reinforcements are adhesive, in which two portions of the stone have been re-cemented using a polymer adhesive. In some cases, this is actually an intentional fabrication technique (not a repair), such as using an adhered liner at a countertop edge to create a visually thicker edge.

4.2.1 Epoxy-based resins are best for adhesive repairs that carry any amount of load, because these products are stronger and have higher bond strengths and greater flexibility than polyester-based resin adhesives.

4.2.2 Polyester-based resin adhesives are preferred by many fabricators and installers because they typically offer lower cost, faster cure time, and more easily-attained color matches when dyed. Polyester adhesives are weaker and significantly more brittle than epoxies, making them a poor choice when high strength is required. However, this can be used as an advantage in some cases. If the seams of a kitchen countertop have been filled with epoxy, and the cabinetry moves, the stone is likely to crack, whereas as the same seam filled with polyester would have yielded prior to fracture of the stone.

4.3 Mechanical repairs. The use of adhesive alone is often inadequate to accomplish the structural augmentation desired in the stone. A mechanical device may also be incorporated into the repair or reinforcement to achieve the required stability.

4.3.1 Rodding is most commonly associated with kitchen countertop fabrication, specifically in narrow regions such as the rail in front of a kitchen sink or cooktop. Rodding is not limited to these conditions, and can also be used on facing panels. The technique involves cutting a groove, essentially a "dado," into the back surface of the stone slab that is just slightly (not more than perhaps 0.020") greater than the diameter or width of the rod. The rod, either metal or fiberglass, is fully encapsulated in epoxy (polyester is not effective in this application) within the groove. If metal is used, many choose stainless steel over mild steel, due to the quality control aspects of ensuring 100% unbreached encapsulation of the rod. This reinforcement technique is unidirectional, meaning that it is only effective in reinforcing the stone when the slab is being loaded in a manner that would cause the face to be concave and the back to be convex. Rodding is also ineffective if the groove is excessively oversized, as the adhesive cannot effectively transfer the strain to the rod and the resistance back to the stone. The third common error in rod installation is positioning the rod too deep, as the rod becomes less effective as its position advances toward the neutral axis of the stone.

4.3.2 Sticking, or dowelling, involves two pieces of stone being fastened together using a stainless steel pin epoxy-adhered into holes. This may be used to repair a cracked stone, or could be used as a higher strength method of adhesively bonding two stone units together. It may also be used as a secondary safety net in case the adhesive fails, such as a dowelled liner block on the back surface of a facing panel.

4.3.3 Fiberglass mesh backers are used to reinforce unstable slabs and tile to reduce the likelihood of fracture. This benefit is largely limited to the handling and transport of the slab. There is little permanent benefit after installation. Fabricators frequently use this technique in the interest of safety. If a slab is reinforced with a fiberglass mesh backer and is fractured during transport, the fractured portion will be retained by the mesh, rather than falling to the shop floor and compromising safety. Like rodding, this reinforcement technique is unidirectional, meaning that it is only effective in reinforcing the stone when the slab is being loaded in a manner that would cause the face to be concave and the back to be convex. Two complications arise from the use of adhered fiberglass mesh backers. First, the back surface of the stone is truly sealed, eliminating vapor transfer at this point. Second, the ability of portland-based thinset to adhere to the epoxy coated back is severely compromised, and in most cases, effective bond can only be achieved by using epoxy-based thinset.

NOTES:

RESTORATION AND MAINTENANCE –

STONE BEHAVIORAL GROUPS

1.0 INTRODUCTION

1.1 In this section, stone varieties are classified into behavioral groups to simplify the evaluation process and create predictable results across a broad spectrum of materials. Many stones can be applied to a particular behavioral group by sight. The technician begins by visually identifying the behavioral group based on common characteristics. It is important to have a general knowledge of stone and know the differences between marble, travertine, limestone, granite, and other stone. Physical characteristics and mineralogical makeup are the primary influences of how a stone behaves.

Stone Behavioral Groups		
Consistent	**Variegated**	**Quartzite/Granite**
Crema Marfil	Botticino	Serpentine
Limestone	Breccia	Quartzite
Travertine	Emperador	Granite
White Marble	Green Marble	

1.2 To refinish Crema Marfil and Noce Travertine to any level of gloss will require the same actions from the technician. Each of these stones can be classified into the same behavioral group. When considering how a stone will behave during the restoration process, the technician must look at the entire surface. Often there are two materials set into the same floor, either by design or mistake. Contrasting material such as Emperador Dark is frequently used in accent pieces between Crema Marfil or other class consistent tiles. If the accent pieces require refinishing, the technician must treat the entire floor as the more labor-intensive material. In this case, the entire surface must be considered to be Emperador Dark. Emperador Dark (a geological limestone) is a highly variegated brown commercial marble with multiple colored veins and textures ranging from white to tan to darker brown.

1.3 There are exceptions to any rule in creating qualitative results on natural stone surfaces. Most materials, however, will behave in predictable ways based on a sight classification.

2.0 TYPICAL GROUP CLASSIFICATIONS

2.1 Marble, Travertine and Limestone (referred to herein as MTL). There are two main behavioral groups for calcareous stones: Consistent and Variegated. MTL is a broad generalization of almost all calcareous stone, and covers probably 80% of what will be encountered when evaluating restoration and refinishing jobs. Most MTL floors can be treated with similar methods. Several specific trade names are used here as examples of stone products that fit into the described categories. These are examples only, and do not represent a complete list of materials. The specific stones were chosen because they are common and will be frequently encountered. The behavioral characteristics are the most important information to retain.

2.1.1 Consistent MTL group. This group has a consistent overall color, with light to moderate veining. While all stones are polymineralic, the stones in this classification will have one extremely dominant mineral in their fabric. Veining in consistent material is usually of one dominant color, as opposed to variegated stones, such as Emperador, and brecciated marble and limestone, which have multicolored veining trends. Crema Marfil is an example of the consistent MTL group. This stone is commonly commercialized as a marble, yet geologically is a dense limestone. The surface is creamy white, with light to moderate veining. Most procedures and approaches for marble refinishing are based from working with this stone. It can be refinished with a typical set of resin diamond marble abrasives and polished with most marble polishing compounds. Stones that are comparable to Crema Marfil should be repaired, maintained and refinished using similar methods.

2.1.1.1 Effective Techniques. Crema Marfil is fairly soft when compared to other marbles. Resin diamond marble abrasives should be used, usually starting with 220 grit (depending on the severity of wear), and ending with 1800 grit. This grit selection is based on normal wear and tear for this material. Lippage removal will require a more rigid and aggressive grit selection. A standard rotary buffer with a weighted drive plate is ideal for normal refinishing procedures. This stone can be polished with a traditional wet-style polishing powder (usually containing oxalic acid and tin oxide). It can also be polished with the newer wet-to-dry method.

2.1.2 Porous Limestone refers to any limestone that appears to have a visibly porous surface. Generally, these stones will have densities of less than 150 lbs/ft³ (2,400 kg/m³). When looking closely at the stone, tiny pinholes are visible in the surface, without magnification. Two common examples are Crema Europa from Spain and the French limestone, Beaumaniere. These are both very soft, very porous, and refinish using the same methods.

2.1.2.1 Effective Techniques. The micro-texture and inconsistent surface make this group difficult to repair. Most adhesives or patching material cure to a smooth, glossy texture and stand out easily against the grainy, matte surface of these stones. This group of limestone typically absorbs a lot of sealer in order to properly protect: approximately 100 to 200% more than typical marble or travertine surfaces. These stones will refinish nicely, but lack the depth and clarity of other materials due to the difference in surface texture. These stones also wear out resin diamonds very quickly due to the fluctuation of soft/hard mineral content. They should be taken as high as possible with diamonds before polishing and polished with a weighted machine and a traditional wet polishing powder.

2.1.3 Dense Limestone refers to any limestone that has a surface similar to marble. There are no visible holes or pits, and the surface will usually have a consistent finish. This class of limestone is very hard compared to other limestone, and densities can easily be in excess of 160 lbs/ft³. Examples of this class would be Jerusalem (also referred to as Ramon) and Jura Limestone.

2.1.3.1 Effective Techniques. Dense limestone is easier to repair, because the adhesives will blend better compared to softer limestone. Dense limestone acts more like marble than its porous counterparts, but will still lack depth and clarity. This group will also need to be sealed more thoroughly. This limestone is less abrasive than more porous limestone, but will still take its toll on abrasives. Dense limestone will sometimes not require the highest grit of diamonds when refinishing, but in most cases should be taken through the full range of resin abrasives before polishing. The full range of resin abrasives is important because dense limestone is so delicate, its surface tends to become uneven and bumpy (called "orange peel") when polishing due to its delicacy. Because of this, a chemically cold powder (one that has a relatively low acid content), or a two-step polishing procedure, should be used. By following these recommendations, the highest clarity can be achieved without the risk of "orange peel."

2.1.4 Travertine. Despite the common usage of the misnomer "travertine marble," travertine is a type of limestone. It is a sedimentary stone that is formed naturally by existing limestone deposits that were dissolved, usually by hot and/or acidic springs, then transported to the surface where the material was allowed to settle and form a new stone deposit. Most travertine varieties behave very similarly. They all naturally contain holes or cavities. In many regions, travertine is the most commonly used natural stone for floors. It is generally easy to refinish and repair. Its hardness is typically between that of limestone and marble. Travertine has a reputation for being hard to maintain in high traffic areas. Holes or pits can open or develop, which will then collect dirt, making the floor harder to clean. Despite this, travertine is very serviceable and restoration efforts are nearly always successful.

2.1.4.1 Effective Techniques. Travertine can be refinished wet or dry, and can be polished with most marble polishing compounds on the market. Some travertine varieties are vulnerable to stunning, yet susceptibility to stun marks is not a common characteristic of all travertine.[1] Travertine is a good material to use when learning how to polish because it forgiving and difficult to over-polish.

2.1.5 White Marble. White Carrara (*Bianco Carrara*) is what most people think of when they hear "Italian Marble." It is a true geological marble. White Carrara is a white marble with gray veining. The tone of the background and intensity of veining can vary. Because of the geological makeup, mostly calcium carbonate, this material is consistent in hardness throughout. Calacatta and Statuary (*Bianco Statuario*) marble are from the same area of Italy, but are currently considered more rare and exotic. Some Greek and Turkish marbles are also similar to these types of Italian marble, but they exhibit a larger, more defined crystal structure.

2.1.5.1 Effective Techniques. White Carrara and its relatives vary, even though they can look identical. They are somewhat softer than other varieties of marble and should not be refinished dry. This group will overheat and burn easily.[2] Polishing should be done with a traditional style wet compound, although sometimes this group responds well to the wet-to-dry process. These stones tend to be very difficult to repair due to their crystal-like transparency. Using solid color patching material will stand out, even when matching the correct color. A transparent epoxy or urethane should be used, taking precautions not to create a stain in the material. These marbles stun very easily, resulting in noticeable solid white marks. Refinishing using a high grit diamond abrasive is the best practice for this group. Carrara can "orange peel" easily and will typically have a very slight texture to it.

2.1.6 General Notes Regarding Consistent MTLs. When polishing consistent materials, ending with a lower grit abrasive, such as 400 or 800 grit, a large amount of "hot" or acidic powder will be needed to create a clear reflective finish. However, care must be taken to avoid the "orange peel" effect. Consistent materials are easier to clean, hone, and polish.

2.1.7 Repairing Limestone and Marble. Limestone and white marble will absorb the solvent from some epoxy resins when performing a repair. This can result in a stain around the perimeter of the repair. Sometimes this stain can be removed, but most of the time it is permanent. One way to avoid possible staining is to thoroughly seal the area to be repaired before applying any adhesive. Another way to avoid this issue is to use a patching material that will not create a stain. Be sure to test the patching material or consult the manufacturer prior to use.

2.1.8 Cleaning Limestone. Thorough cleaning is required for most limestone installations. While it may seem straight forward, there are some necessary precautions. Limestone is very porous, and oily cleaners

[1] Stun marks are the result of explosions inside individual crystals in the stone. These marks are caused by sudden, pinpoint pressure impacting the surface of the stone.

[2] Oxalic acid, which is used to speed the polishing process, can burn marble. Burned marble has a dimpled appearance and a molten, plastic shine. Rehoning is necessary to remove the burnt surface.

may cause some discoloration, particularly with extended dwell times. If this occurs, it can usually be removed with additional cleaning, but prevention is a better practice than remedy in this case. Limestone can take 24 hours or more to dry out, so account for this when the job involves sealing after cleaning.

2.2 Variegated MTL Group. With MTL, if there is any question, it may be better to treat the stone as variegated. Variegated stones typically have a multicolored field and multicolored veining. This look is caused by the variety of minerals included in the stone fabric, which in turn can lead to those differing minerals having a non-uniform response to the abrasives and chemicals used in the restoration process. This class is considered more difficult to polish and requires special proprietary methods. To polish these surfaces, the restoration professional must use the highest diamond abrasives in the sequence and finish with chemically-cold polishing powders. Another method is to finish with an ultra-high grit abrasive pad or powder. One example is Emperador Dark marble. Although most people refer to it as marble, it is a dolomitic limestone, yet it is actually harder than most marbles. It is variegated, with veining that is affected differently than the other minerals in the stone.

2.2.1 Effective Techniques. Variegated stones do not take a deep, glossy shine like Crema Marfil or other similar materials, and will typically have imperfections that can be seen with natural light. Refinishing requires a little more finesse than most marbles because of the variation in hardness. It is recommended to use a finer resin diamond abrasive, up to 3,500 grit, before polishing. The polishing step should also be more aggressive than normal—more pressure, friction and time is necessary. Good quality diamonds are highly recommended. Because of the hardness of these stones, granite diamonds can sometimes be effective.

2.2.2 Other Types of Variegated marble include Rosso (with the exception of Rojo Alicante), Tennessee Pink, and the various types of breccia. A short checklist can be helpful in determining the steps necessary for refinishing variegated stone. Technicians should look for the following: color, veining, and color of veins in contrasts with color of field.

2.3 Consistent Variegated. There exists a sub-classification of stones that could be termed "consistent variegated." A prime example of this classification would be Botticino. Botticino is very similar to Crema Marfil (which is Class Consistent) and is also a compact limestone but is a little different to refinish. To the untrained eye Botticino can sometimes be mistaken for Crema Marfil, but it is harder.

2.3.1 Effective Techniques. Botticino has one characteristic that makes it drastically different. It has white, cloudy minerals in it that do not polish easily. These areas tend to burn or become very hazy as soon as they are polished. They occur in different concentrations across the different types of Botticino marble, but are almost always present. Botticino should be handled the same way as Crema Marfil, with the exception that the final polishing step must be done in a way to balance the polish and clarity so the white areas do not burn. Sometimes, Botticino can be refinished exclusively with fixed abrasives, up to approximately 8500 grit resin diamond abrasives without a polishing compound being used. The quality of the abrasives plays a critical role when using only fixed abrasives. Other times, polishing powders or liquid crystallizer can be used to finish the polishing process.

2.4 Serpentine is a variegated stone with a marble-like appearance, but vastly different mineralogical makeup. True serpentine is a silicate, is acid resistant, and will be significantly harder (Mohs = 5) than marble. Due to the absence, or near absence, of calcium carbonate, serpentine does not typically react with the acids in most marble polishing powders that aid the polishing process. For this reason, technicians tend to treat serpentine surfaces more like granite. Many technicians prefer to use a crystallizer or low-acid, high-grit polishing powders and creams. Some stones, such as Rosso Levanto, are variegated marble, but include large swaths of serpentine mineral in them. Rosso Levanto is a distinctive reddish-maroon marble with white veins and hints of green and other colors, and should be treated as a serpentine for purposes of restoration and polishing. Most, but not all, green marble-like stones are serpentine.

2.4.1 Effective Techniques. Serpentine contains little to no calcium carbonate, and as such, will not react to traditional marble polishing powders. It can be etched and scratched, but not at easily as other MTL surfaces. When refinishing, it should be treated like granite. Using diamond abrasives and polishing compounds made for granite will be effective when working with serpentine. This group will not display a deep gloss or present a lot of clarity like marble.

2.5 Granite and Quartzite. Most dense crystalline materials behave similarly and can be classified into the same section. It is important to note that many of the "granite" materials evaluated may not actually be granite. Many of the "granites" with veining are actually gneiss. Solid black "granites" are usually gabbro. The main concern here is to simplify the selection process and avoid confusing the end-user. In other words, if it performs like granite in use, then it should be called granite. While this may not always be important to complete the project, a broader understanding of the mineral composition of the surface will help the technician diagnose and correct issues.

2.5.1 Identifying Granite and Quartzite. Quartzite and granite are very similar. In general, these are the hardest decorative stones. Granite or granite-like stone can be easier to identify because of the granular crystal structure. A true quartzite can look similar to marble, but is much harder. Since quartz is the hardest mineral found in abundance in granite, and since quartzite is nearly 100% quartz, it should be expected that a true quartzite is even harder than granite. This property can drastically increase the amount of time necessary flatten a floor to remove lippage. The best way to determine hardness is to perform a scratch test in an inconspicuous area.

2.5.2 Effective Techniques. Granite and quartzite are described as dense crystalline, but the crystal structures of some varieties are very porous. This is especially true on materials that are lighter in color, such as Giallo Ornamental, Santa Cecilia and Kashmir. It is very important to use a high quality impregnating repellent to minimize the darkening of the stone caused by absorption of water or other liquids. When polishing dense crystalline surfaces, the technician will often follow the same steps. These stones must be refinished using mechanical methods with abrasives to achieve the highest possible shine, because they do not react with conventional polishing powders and creams. This process takes a lot more time than polishing softer materials. The technician must take this into account when scheduling and bidding the project. Scratch removal on a granite countertop can take up to five times longer than the same scratch on MTL. Even though this group can be drastically different from one another, they are all refinished with the same processes and techniques. A granite-specific diamond abrasive is used for both. The major difference between the two is the final polishing step; quartzite requires several more applications of the final polish, and usually with much more pressure. There are several ways to approach the final polish that will allow the stone to be polished back to a factory finish or better. Because these stones are so hard and typically found on countertops, which are closer to eye level, there is little to no room for error when refinishing. Even the slightest pf waves, ripples, or gloss inconsistencies are visually noticeable. Selection of the right type of abrasives and good quality tools is paramount to a successful restoration of these materials.

2.6 Sandstone is an extremely porous silica-based stone. The term "sandstone" describes the clast size (1/16 to 2 mm), rather than mineralogical composition. Sandstone can therefore be of a variety of mineral types, although the most common found in dimension stone use is quartz-based sandstone. The material that cements the clasts together has more influence on its performance and behavior than the actual sedimentary clasts.

2.6.1 Effective Techniques. The surface of sandstone looks and responds like fine sandpaper. It will wear out abrasives very quickly. Sandstone is not frequently refinished as often as it is simply cleaned. If there are scratches that need to be addressed, honing can be done similar to a hard limestone. The material will not take a glossy finish. Sealing can be time consuming and costly, because the high absorption and porosity of the stone requires multiple applications of generous amounts.

RESTORATION AND MAINTENANCE – DIAGNOSTICS

1.0 INTRODUCTION

1.1 The word **diagnosis** comes from the Greek word *diagignōskein*, which means "to distinguish." It aptly describes the process that the restoration professional must accomplish during the earliest phases of the project, even prior to submitting a proposal to the client for performing the necessary work. Without a proper diagnosis, it is not possible to prepare an accurate estimate of costs, time, or reasonable expectations for the quality and performance capability of the stone after completed restoration. A thorough and accurate diagnosis requires distinguishing between symptoms and the problems creating those symptoms. For example, cracks or dull spots in a stone floor are merely symptoms, and while those symptoms can be cosmetically treated, they will reappear if the root problems that caused them are not addressed. A thorough onsite inspection is necessary to provide the most accurate proposal and treatment recommendation. In some situations, identification and remedy of the problems may exceed the level of expertise of the restoration professional, requiring the consultation of additional professionals. The items addressed below provide a general guide for the diagnostician to accomplish this task.

2.0 STONE TYPE

2.1 Identifying Stone Types. Identification of the stone by customary trade name may not always be possible, nor is the country of origin always identifiable. The geological type of stone must always be confirmed. This information provides insight into the material's behavior in various environments, as well as its porosity, density, hardness, and other inherent characteristics. For example, more porous limestone may require more regular maintenance, such as additional sealer applications when installed in a wet environment. Similarly, a polished marble floor in a commercial application can be better protected against scratching and traffic pattern wear by the use of walk off mats.

2.2 Location. A stone's behavior can differ depending on the environment in which it is installed. For example, the performance of the same stone may be markedly different in high traffic versus low traffic areas, or in wet areas versus

3.0 EXISTING INSTALLATION METHOD

3.1 The methods with which the stone was originally installed must be verified before restorative work may commence. Stone will naturally age and wear throughout service. Knowing the age of the installation helps determine if the condition of the stone represents normal aging and patina, or an abnormal, premature degradation of the product as a result of conditions that need to be corrected.

3.2 The method of attachment used in an application must be determined to ensure that the planned restorative techniques will not compromise the attachment. It also must be verified that the method of attachment is still stable and reliable. If this is not verified, an installation could be cosmetically restored, but then fail structurally. The simplest methods of attachment involve adhesive bonding only. Floor and wall tiles are typically held in place by adhesive methods only. When the stone becomes thicker, starting at 20 mm and greater, mechanical anchors may have been used in combination with or in lieu of the adhesive bonding.

3.3 Resources for Tile and Mechanical Anchors. Most adhesively-attached floor and wall applications have been installed using methods outlined in the Tile Council of North America's (TCNA) *Handbook for Ceramic, Glass, and Stone Tile Installation*. Readers are encouraged to obtain a copy of this publication (available for purchase through NSI's Online Bookstore) and familiarize themselves with it prior to evaluating existing tile installations. Readers are referred to NSI's Technical Bulletin, "Dimension Stone Anchorage; Theory, Practice, & Components," for a comprehensive discussion of mechanical anchorage techniques. A mechanical anchor is any device (usually a non-corroding metal such as stainless steel, aluminum, copper, brass, or bronze) used to secure the stone unit to an unyielding support, such as the building frame. Anchors are nearly always concealed in stonework, so the restoration professional must verify their location and ensure that the restorative procedures will neither expose them nor compromise their integrity.

4.0 MEASURING STONE THICKNESS

4.1 The thickness of the installed stone influences which restorative techniques may be attempted, and how aggressively those attempts may be implemented. Stone thickness should be evaluated in conjunction with stone strength. In flexure (bending), a stone's strength is proportional to the square of its thickness. Therefore, a 30 mm thick section of stone is over twice as strong as a 20 mm thick section of the same stone ($30^2 = 2.25 \times 20^2$)! But if the 30 mm stone is a relatively low strength stone with a flexural strength of 1,000 lbs/in² (6.9 MPa), and the 20 mm stone is a high strength stone with a flexural strength of 2,500 lbs/in² (17.2 MPa), the 20 mm section is actually stronger in service, despite its reduced thickness. When grinding operations are required, one must be careful to not only avoid grinding through the stone depth, but also grinding the stone to such a reduced thickness where it can no longer perform under load. It must also be ascertained that the stone is solid through its depth, as opposed to stone-faced units consisting of a very thin layer of stone laminated to ceramic, metal, or other backer units. While joint fillers can be abraded to facilitate viewing and measurement of the actual stone depth, a far easier and less invasive method is to take advantage of the existing mechanical and electrical penetrations. Simply removing a grate over a heating duct or removing the plate over an electrical switch or outlet will usually confirm the actual thickness of the stone units. Stone thickness can often be ascertained at the doorway to unfinished space; for instance, where the stone work truncates at the transition between a finished space and an unfinished utility room.

5.0 EVALUATION OF DESIGN AND EXECUTION

5.1 The existing design and installation must be evaluated for a series of potential deficiencies. If deficiencies are noted, the condition must be corrected as part of the restoration process, lest post-restoration failure is likely.

5.2 Five Categories of Movement Joints. A series of specialty joint designs is necessary in all finished stonework to facilitate dynamic building frame movements, differential thermal expansions and contractions, and permanent deformation (creep) of structural units. These necessary functional joints are frequently omitted from stone installation designs, and their absence is one of the most common contributors to stone installation failure. These joints can be placed into five general categories:

1: **Expansion joints** typically go through the stone installation assembly and building structure, and accommodate relatively large movements anticipated in the building frame at that location.
2: **Isolation joints** are also typically carried through the building structure, and are most often used to bridge between different structural elements; for instance the separation between a footing pad at a column and the surrounding concrete slab.
3: **Control joints** are merely shallow cuts in concrete slabs which create a slightly weaker zone and direct, or "control," where shrinkage cracks will occur as the concrete cures.
4: **Perimeter joints** separate the finished stone surface at regions of discontinuity, for instance where horizontal finish planes intersect with vertical elements, such as walls or columns.
5: **Generic Movement joints** are simple soft joints occurring in the finish stone surface only and are intended to provide an interruption in the accumulation of shear stresses resulting from differences in temperature or expansion rates between the stone and the rest of the assembly, or to accommodate differences in elongation or compression as a result of floor curvature. Refer to section EJ171 of the TCNA's *Handbook for Ceramic, Glass, and Stone Tile Installation* for additional information on these types of joints and requirements for their frequency in stone designs.

5.3 Substrate Rigidity. Stone is a quasi-brittle material and does not bend easily. A 12" x 12" x 3/8" (300 mm x 300 mm x 10 mm) stone tile could fracture with as little as 0.010" total deformation! As thin stone tiles (less than 20 mm thickness) are considered to be decorative, abrasion-resistance finishes only, they must rely on the rigidity of the substrate and bedding layers to develop their resistance to applied loads. There are two primary components to consider when evaluating whether or not the substrate has the required rigidity to adequately support the stone units.

5.3.1 Frame Deformation must be held to extremely low allowable deflections. Various documents (building code, ACI, and NSI) list a maximum allowable deflection anywhere from L/600 to L/1000. In addition to the basic deflection of the framing members, one must verify that the potential differential deflection between adjacent members is not excessive. Oftentimes, some type of load-sharing device is required to tie adjacent members together and reduce the inter-member differences in deflection under load. Since deflection and radius of curvature are not exactly the same thing, span length also becomes part of these analyses.

5.3.2 Substrate Panel Deformation. The substrate panel, be it a sheathing on a wall assembly or a subfloor/underlayment combination in a floor assembly must be sufficiently stiff to carry the loads experienced by the stone units back to the framing members without undue deformation.

5.4 The setting adhesive used, if possible, should be identified to verify its suitability and the quality control of its placement.

5.4.1 Appropriate Selection. Certain stone types require specific types of adhesives; for instance white colored thinsets are required for light colored marble and limestone, and epoxy-based thinsets are required for mesh-backed stones and many moisture sensitive stones.

5.4.2 Adequate Coverage. The adhesive must have adequate contact area with the stone unit. NSI's *Dimension Stone Design Manual* calls for 95% contact with no voids exceeding 2 in² and no voids within 2" of tile corners on 10 mm tile. In 20 mm thick stone, 80% contact with no voids exceeding 4 in^2 and no voids within 2" of tile corners is required. All corners and edges of stone tiles must be fully supported and contact shall always be 95% in water-susceptible conditions.

5.4.3 Bond Strength. Adequate bond strength may not be achieved between some thinsets and stone materials with compromised bonding surfaces, such as those that have had mesh backing applied, or those that have been sealed or resin-treated on their bonding surface.

5.5 Stone Jointery Alignment influences both performance of the system and aesthetics of the finished installation.

5.5.1 Joint Width Tolerances. The installing contractor is allowed a tolerance of the greater of either 1/16" (1.5 mm) or 25% of the specified joint width when installing stone units. Many existing installations do not comply with this tolerance. The issue can often be remedied by field cutting joints during the restoration process. A wider joint of a uniform dimension will look better than a narrower joint of varied dimensions.

5.5.2 Lippage Tolerances. Stone flooring units are typically supplied with little or no chamfer at their perimeter, and are typically installed with narrower joints than other hard surface flooring products. These factors accentuate the perceived lippage, both from a visual aspect as well as an occupant safety aspect. Lippage tolerance between adjacent units of smooth finished stone flooring units is limited to 1/32" (<1 mm). The easiest way to measure this is with a digital caliper, using 0.031" as the maximum allowable measurement. A common method of field checking for lippage issues is to use a standard plastic credit card as a gauge, since most credit cards measure ±0.030" in thickness.

5.6 Wet Areas. Water infiltration of a stone system is always a concern, particularly if the stone system was not designed for water exposure. Evaluation of a proposed restoration project should include careful study of water control and flow, as well as evidence of water damage. In many cases, water damage repair requires complete removal and replacement of the installation, since the damage may be concealed by several layers of the installation system and is not accessible without excavation.

5.6.1 Water Control Slopes. Water flow is governed by gravity, therefore, sloping of surfaces toward a drain or other path of effective evacuation is a necessity that cannot be compromised. In general, any slope of less than 2% (¼" per foot, or 20 mm per m) is ineffective in achieving positive water flow. Inadequate slope is a condition that cannot be corrected in normal restorative procedures. One must carefully guard against reducing or eliminating existing water control slopes during restorative processes.

5.6.2 Drain Function. If the goal of the sloped surfaces is to direct water to a drain, then achieving that goal is useless unless the drain is fully functional to evacuate the water once it arrives. Drains must be inspected for proper operation, and in particular, subsurface weep holes in the drain assembly must be checked for proper water flow functionality.

5.6.3 Efflorescence is a collection of water-soluble compounds (typically salts) that have been carried to the stone surface by water. Efflorescence deposits typically carry two or more of the following: potassium, sodium, calcium, sulfates, carbonates, bicarbonates, and hydroxides. In some cases, the water soluble compound can chemically combine with other compounds at the surface, creating a non-water-soluble compound. The key to preventing efflorescence is to control water migration. This may or may not be remediable in some restoration settings. Refer to ASTM C1400, *Standard Guide for Reduction of Efflorescence Potential in New Masonry Walls* for further guidance in this subject.

6.0 EVALUATION OF OCCUPANT AND IN-SERVICE INDUCED CONDITIONS

6.1 Current Maintenance Products and Procedures. A review of the products used and the procedures followed will provide insight into which professional maintenance treatments are to be prescribed for a situation. Some cleaners used by end-users can be harmful to the stone. These products may cause blemishes that require removing (e.g., acidic cleaners that cause etching, abrasive cleaners that create dullness, oil-based surfactants that cause residue, or wax-based cleaners that cause build up). Knowing which cleaners have been or are being used will help determine the best cleaning techniques available. One challenge in determining these things is that the owner may not be the original owner of the property, and therefore unfamiliar with the entire history of maintenance procedures. A second challenge exists in that most owners do not perform their own maintenance, and are unlikely to be familiar with which products and/or procedures were used by employees or vendors.

6.2 Previous Restoration Processes. A restoration professional is often contacted due to dissatisfaction with work performed by another company. Correction of previous, inappropriate restoration processes will further complicate the task of restoring the stone. In extreme cases, the stone may have been altered beyond a state from which it can effectively be restored. Candid communication with the client is imperative to establish reasonable and attainable expectations for the project's outcome.

6.3 Staining does occur in natural stone. However, the stain potential of natural stone has perhaps been overhyped by marketing claims made by producers of competing materials.

6.3.1 The most important step in stain removal is to identify the staining agent. If this is not achievable by interviewing the building occupants and maintenance staff, one must speculate as to what the staining agent likely could have been based on available information. Information used in this speculation includes the stain color, shape, size, location, frequency, and a list of potential staining agents commonly found near the site of the stain.

6.3.1.1 Food and Beverage Stains include natural pigments (e.g., fruit, juice, or wine stains), dissolved solids (e.g., coffee stains), and oil-based stains (e.g., cooking oils or meat fat stains). Food and beverage products may also be acidic and contribute to etching of calcareous stones.

6.3.1.2 Rust Stains are generated by contact or close proximity to corroding metals. Rust stains are some of the most difficult stains to eradicate. The source of the rust may be concealed by the stone assembly, such as a corroded fastener in substrate layers. In rare cases, the origin of the rust is a metallic-rich mineral within the stone fabric. Rust stains that originate from within or below the stone are generally not removable, since the source of the stain cannot be eliminated.

6.3.1.3 Soiling occurs when dirt mixed with oil or grease scratches, dulls, or discolors porous stone and grout. More porous stones, especially those pores visible to the naked eye (e.g., limestone & travertine) are most vulnerable to soiling. Aggressive grinding or chemical treatments may be required to restore the stone's color. In extreme cases, soiling may be cost prohibitive to remove.

6.3.1.4 Efflorescence (as discussed in section 5.6.3 above) is always the result of water-soluble compounds carried to the surface by water migration. In most cases, the stain is easily removed, but reoccurrence is a certainty unless the water migration can be arrested.

6.3.1.5 Hazing is most frequently the result of improper or incomplete cleaning after the initial installation. The source of the haze is frequently grout, although it can also be a result of inappropriate or incorrectly applied sealers. Some grouts are so prone to hazing that masking the stone during grouting is the only way to reliably prevent hazing.

6.3.1.6 Grout Stains. All agents that can cause stains in stone will also cause stains in grout. Due to the high porosity of grouts, the same type of stain may penetrate deeper into grout than it will in stone.

6.3.2 Eradication. Nearly all stains can be removed from nearly all stone types. Stain identification is key; after identification, the removal can generally be accomplished quickly and effectively using proven methods. If the origin of the stain is unidentifiable, varying levels of trial and error are usually required.

6.4 Cracks. A crack is a separation of the stone fabric, typically along a grain boundary. Cracks are easily visible. In most situations, they extend through the entire thickness of the material. The crack may be the result of a single occurrence trauma, in which case the crack may be repaired without addressing the cause, as long as there is reasonable confidence that the trauma will not be repeated. When multiple cracking occurs within a stone installation, it is generally the result of a repeated occurrence (i.e., excessive loading that occurs on a frequent basis), or a design/workmanship deficiency (e.g., inadequate substrate rigidity or insufficient bedding coverage). In these cases, the cause of the cracking must be identified and corrected prior to the repair of the cracks to avoid repetition of the cracking.

6.4.1 Impact Cracks and/or Chips are caused when a heavy object falls onto the surface or when a heavy object is moved across the floor. In soft stones, the crack may be accompanied by a depression in the stone surface. A white or light crack "stun mark" is often visible in addition to the crack. These types of cracks are typically due to a one-time experience.

6.4.2 Cracks caused by excessive loading. Excessive loads may occur from vehicles, freight delivery dollies, furniture, or other sources. These may be individual or repeat occurrences. If the latter, customer education is paramount to ensure that the practice of excessive loading is discontinued after cracks are repaired.

6.4.3 Cracks caused by building movement. Dynamic building movements can be caused by foundation settling, thermal expansions/contractions, frame deflections, creep, and seismic or wind loads. With the exception of foundation settling, all of these movements should be anticipated, and the failure of the stone installation suggests an improper design.

6.4.4 Cracks due to improper stone installation. Voids in the setting beds, inadequate accommodation for thermal expansion, or failure to use appropriate membranes where required are frequent factors in cracked stone flooring and paving.

6.5 Chips and Spalls are most often caused by impact from dropped objects or rolling loads with hard wheeled equipment. The client needs to understand the cause of the problem to prevent further damage after restoration.

6.6 Etching is a dull whitish mark that results from a chemical reaction between a caustic or acidic liquid and calcium carbonate in stones like limestone, marble, travertine or engineered marble (man-made marble). The depth of etching may vary, from a minor surface attack representing itself as a dull spot on an otherwise glossy surface, to a deep attack with a penetration of a millimeter or more where a textural difference can be felt with one's fingers. Simply cleaning, polishing or resealing will not remove an etch mark. To completely remove the mark, it must be ground to the depth of the damage and refinished.

6.7 Pits and Voids (holes, fissures, chips, cavities, veins, etc.) are common for various stone types. Materials are filled with either resins or cementitious fillers during factory processing, or less frequently, in the field during installation. Over time, the filling can dislodge, requiring replacement during maintenance or restoration. Some stones, notably fleuri cut travertine, will have voids just below the surface of the stone concealed by a thin shell of stone fabric. These voids do not get filled due to their concealment, and are likely to be exposed as the shell of stone covering them is broken during service. Rolling loads with small diameter, hard wheels, and concentrated loads such as spike heeled shoes are common causes of exposing these voids.

6.8 Scratches are commonly caused by grit beneath shoes or furniture, sliding objects, or maintenance equipment with improper, worn, or dirty cleaning heads. The severity of a scratch can be assessed by running one's fingernail across it. If the fingernail pauses or catches in the scratch, it will normally take more aggressive measures to eliminate it, but scratches that do not catch a fingernail are usually minor and can be eliminated with refinishing.

6.8.1 Scratch removal can be accomplished through abrasive grinding, refinishing, and honing. The depth of the scratch determines the coarseness of the initial grit needed to remove it. Trial and error iterations may be required before one knows what starting grit is required. More experienced technicians may intuitively know which grit is needed to start the process.

6.8.2 Pressure Scratches actually damage the body of the stone tile through compression and gouging. These types of scratches are usually permanent, but can be minimized.

6.9 Topical Sealers (also referred to as film-forming sealers and coatings) differ from impregnating (also known as penetrating) and enhancing sealers in that they create a sacrificial coating on the stone's surface as they cure. These products must be stripped before maintenance or restoration attempts. Topical sealers contain waxes, acrylics, urethanes, and other chemicals that are high in solids – therefore, they do not penetrate the pores as effectively as impregnating repellents. Since they do not allow for vapor transmission, moisture can be trapped within the stone. Additional undesirable traits of topical sealers include color change (yellowing), flaking, dirt attraction, vulnerability to scuffing, frequent reapplication intervals, and labor intensive removal processes.

6.10 Close grout examination is one of the more critical components of the site inspection. Grout is softer, more porous, and less resilient than stone. Grout will frequently show signs of distress before similar signs of distress are noted in the stone components of the installation. Sanded grout is most commonly used when stone tiles have been installed with relatively wide joints [≥3/16" (5 mm)]. Since the sand in these grouts is harder than some stone varieties, scratching may have resulted during the grouting process if the stone was not adequately masked. Additional scratching may occur during the restoration processes if the sanded grout is not removed prior to restoration.

7.0 ADDITIONAL CONSIDERATIONS FOR EXTERIOR APPLICATIONS

7.1 Weathering. Weather exposure causes a degradation of the stone surface over time. The degree of weathering is dependent on both the type of stone and the severity of the environment in which it was installed. Weathering includes both physical and chemical attacks. It should be noted that some stones are simply not exterior-worthy materials, and no level of restoration can effectively compensate for an improper selection of a stone material.

7.2 Freeze/thaw issues. In regions where freeze/thaw cycling occurs, weathering can extend beyond cosmetic issues and become structural issues. It is not uncommon for improperly chosen stone species in freeze/thaw environments to degrade beyond a level where restoration is achievable. Horizontal applications are more severely affected than vertical, and grout distress usually prefaces or accompanies stone degradation.

7.3 Water Damage. With or without freeze/thaw cycling, water ponding and water transmission through the stone can break down either the stone fabric, the bedding layers, or both. Excessive water exposure and ponding can result from inadequate drainage, improperly prepared substrates, insufficient or negative slope, ineffective moisture membranes, or ground water transmission. These can result in various issues, such as excessive mineral build up, mildew and moss accumulation, damage from the expansion and contraction of more porous materials, surface exfoliation, and distress in the setting beds and/or grout.

7.4 Saltwater Environments (regions near oceans). Stone applications near saltwater environments may experience additional degradation due to exposure to salts. Salts attack the more porous varieties of stone via a mechanical, rather than chemical mode. When salt is carried in solution by water, it penetrates the pores of the stone. As the water evaporates, the salts recrystallize within the confines of the pores, and this recrystallization pressure is great enough to exfoliate the stone surface. Some sealers have proven to be effective in minimizing the effects of saltwater environments, or at least in retarding the rate of attack.

7.5 Pool/ hot-tub/ resort/ commercial center environments. Exterior applications of natural stone in high traffic and wet environments should be inspected for various post installation treatments that may have been applied to help improve slip resistance. Some stones may have been exposed to treatments such as acid washing, brushing with abrasive-embedded brushes, or coated with topical finishes containing grit.

8.0 PREVENTING DAMAGE TO ADJACENT SURFACES AND BUILDING CONTENTS

8.1 SURFACES

8.1.1 Adjacent Floors. The maintenance or restoration processes used on natural stone may damage adjacent flooring materials. It is best to anticipate possible damage and take steps to protect these surfaces in the beginning.

8.1.2 Adjacent Rooms and Access Routes. Adjacent rooms are best protected by sealing the halls/doors that lead to them, particularly is any dry working will be performed. Access routes along which materials or equipment will be transported must be fully protected from damage to any of their surfaces.

8.1.3 Baseboards and Walls. If light honing and polishing is the only process needed, then it is only necessary to protect the base during the work. More aggressive restoration techniques, such as lippage removal, require the base to be removed. Depending on the material used for the base, removal and reinstallation may require a different trade be involved to assure quality workmanship results.

8.1.4 Thresholds and Transition Strips. If the threshold is stone, refinishing it should be part of the stone restoration process. If it is of a different material, it may be necessary to replace it after completing the project.

8.2 BUILDING CONTENTS

8.2.1 Furniture and other items. Moving furniture exposes the restoration contractor to additional liability in having his/her crews handle items for which they have not been trained. Moving a piano, for instance, is best handled by those who are professionals in that line of work, and in either case, is likely to result in the owner having to retune the instrument after it is returned to its original position.

8.2.2 Artwork and Antiques. Specialty items, such as artwork and antiques, can be valued at more than what the restoration professional's contract is. It is strongly encouraged that these items be handled by someone who is trained in this activity and specifically insured for the liability incurred.

9.0 UTILITIES AND ACCESS

9.1 Power Source. Prior to preparing an estimate for performing the work, it must be verified that adequate electrical power is available (both required voltage and amperage). If this is not the case, the cost of providing generators must be considered.

9.2 Water Supply. If adequate quality and quantity of water are not available onsite, considerable cost will be encountered in bringing water in from an outside source.

9.3 Water Discharge and Disposal. It must be verified if water discharge and disposal can be accomplished at the site, or if spent water supply and/or slurry needs to be removed from the site.

9.4 Building Occupants. Working in an occupied building may limit the hours available to the restoration contractor, and may also limit to number or size of areas that can be worked on at a time to avoid inconveniencing building occupants. Early communication with the client is essential in determining a sequence of work areas and establishing an estimated duration for the project.

9.5 Business Schedules. Few business can absorb the cost of suspending their business during restoration. This may mean that the site is available only after hours or weekends. It also may add costs in daily cleanups and removal of equipment to allow the business to continue with only minor interruptions.

9.6 Noise and Dust Restrictions. Clients and neighboring homes or businesses may have legitimate objections to the creation of noise or dust. Any possible restrictions must be researched in advance.

10.0 SERIOUS ISSUES THAT REQUIRE RESEARCH AND MORE EXPERIENCE

10.1 The restoration contractor must be aware of the limits of his/her experience and expertise. Following is a partial list of possible scenarios which may require the consultation of another professional.

10.2 Structural Problems. Any symptom that suggests a structural problem with the building may exist: Extensive cracking, chipping, grout distress, or misalignment may indicate a structural issue with the building foundation or frame. If structural issues are suspected, a consultant who is licensed to practice in that jurisdiction should be involved in the analyses.

10.3 Extensive hollow sounds or adhesion problems. While epoxy injection or grout replacement may be a feasible remedy for limited occurrences, extensive hollow sounds or adhesion failures may represent a systemic problem with the stone installation. In these cases, a consultant experienced in stone tile forensics should be contacted.

10.4 Inadequate structural support and/or building movement issues. If either of these is suspected, a consultant who is licensed to practice in that jurisdiction should be involved in the analyses.

10.5 Substrates with high moisture. Some issues involving substrates with higher moisture levels can be mitigated through the use of a moisture retardant membrane. These barriers have varying levels of effectiveness. The following are some of the issues caused.

10.5.1 Stained Stone. Subsurface water, with or without impurities, will result in surface discoloration or staining of the stone. Removal of this discoloration is an ineffective solution unless the source of the moisture can be eliminated.

10.5.2 Stained Grout. Just as the stone can be stained, the grout will be stained as well, often to a greater degree.

10.5.3 Efflorescence requires the presence of water soluble salts in subsurface levels that are carried to the surface by moisture transmission, where they then recrystallize after the moisture evaporates. Elimination of the moisture source or addition of a barrier to the moisture path are the only permanent solutions.

10.5.4 Moisture Hazing. Generally, a non-stone substance, such as a sealer or resin, is the affected component when hazing at the surface has been triggered by chronic moisture transmission.

10.5.5 Spalling and other factors. This may indicate water migration or higher moisture levels.

RESTORATION AND MAINTENANCE – EQUIPMENT

1.0 INTRODUCTION

1.1 A complete list of equipment used in the process of restoring or maintaining stone would be very extensive. Individual preferences can dictate the need for a wide variety of items. The primary focus of this section is to identify and describe the most common equipment used in restoring, refinishing and maintaining stone.

2.0 FLOOR MACHINES

2.1 Mono-rotary machines are an absolute "must have" for stone restoration companies. Because mono-rotary machines utilize a single, often rigid, drive plate; with the correct abrasive they can be good for edge work on floors. Mono-rotary machines are single disc, single speed machines. The most common type is a 17-inch (430 mm), 180-RPM machine. They weight approximately 85 to 95 lbs (39 to 43 kg). Speed and weight vary with the manufacturer, but "180 RPM mono-rotary" is the general description used for what has become the most commonly used piece of equipment for stone refinishing. These machines can grind, hone, diamond polish, powder polish, clean, texture, or buff, depending on the accessory used.

2.1.1 The speed and weight of the machine can have a significant impact on the efficiency and quality of the finished product. When only diamond honing and refinishing, the optimal accessory is a weighted drive plate. This adds approximately 35 pounds (16 kg) to the machine and speeds up the diamond honing process. When grinding (also referred to as lippage removal), weight should be added to the machine to increase pressure and help speed up the process. Weights vary in size and shape depending on the manufacturer, but they typically mount on top of or around the motor housing. The weight of the machine while grinding should be approximately 200 pounds (90 kg).

2.1.2 Diamond Honing and Polishing. When diamond honing and polishing (220 resin grit through a powder polish), generally the faster the speed of the machine, the more weight you will need. Most floors requiring refinishing are 12 to 18-inch (300 to 450 mm) square tiles. The diamond abrasives need a minimum time on each tile to cut. If the machine is moving too quickly, the abrasives will not make a thorough cut. Adding weight to the top of a faster machine (200 RPM or faster) will add pressure to help the abrasives dig in a little more and speed up the process. On European-style machines, the motors are usually much slower (150 RPM). This eliminates the need for the extra weight, because the diamonds spend more time on each tile. Either configuration can yield the same results.

2.1.3 Mono-rotary machines have many attachments (most commonly, brushes). A light duty nylon brush can be used for scrubbing and rinsing polished stone floors without scratching them. Brush attachments increase in abrasiveness to do heavy scrubbing, texturing and even scarifying. Soft nylon and natural hair pads of all different grits and densities can be fitted on a standard pad driver as well. These can be used to clean, scrub, strip, refinish, polish and hone stone floors.

2.2 Planetary machines can be belt or gear driven. They are much heavier than mono-rotary machines, making them ideal for grinding. They are usually reserved for large residential and commercial jobs. They have a pivoting head, which self-levels as it goes over the floor. This allows the technician to push it like a lawnmower and not have to use his or her body to swing the entire weight of the machine around. The most common configuration is 17 to 20-inch (430 to 510 mm) diameter with 3 satellite heads.

2.2.1 Active and passive planetary machines. Active planetary machines have “driven” heads. The main head, which is the large diameter, is driven by a belt or gear set. It is directly connected to the 3 planet heads and drives them continuously. Passive planetary machines have non-driven heads. The main head is driven by a belt or gear set, and the planet heads are essentially free to rotate in the direction they are pushed.

2.2.2 Floating and Rigid Heads. Floating heads are ideal for concrete. The heads are firmly attached to the machine, with rubber grommets or a cushion in between. This allows the heads to “float” over the highs and lows of the floor, or over bad lippage on stone tile floors. These types of heads are almost always present on belt-driven machines to help absorb the shock and keep the belt from slipping. Rigid heads are bolted to the machine. They are unforgiving and offer no flexibility. These are usually found on gear driven machines that are built heavy duty use. Rigid heads are used with the intention of planing down the stone floor to a perfectly flat surface. Some planetary machines have the flexibility to switch between the two head configurations by simply bolting the desired set of heads on the machine. These machines are preferred by many due to the flexibility that they offer.

2.3 Drive plates: 10”, 17”, 22”, (250, 430, 560 mm) and larger

2.3.1 Steel drive plates usually feature a hook and loop attachment configuration on the bottom that are used to attach various diamond and other abrasive pads. This style is designed to withstand adding weight to the machine to give the abrasive more pressure and contact with the floor. Steel drive plates also feature a low center of gravity to speed up production. The plate usually weighs approximately 35 pounds (16 kg) and normally requires 2 hands to remove or install.

2.3.2 Lightweight drive plates. Nylon or plastic drive plates are classified as lightweight. This style is used for light-duty scrubbing and buffing and sometimes light refinishing or polishing. Lightweight drive plates only weigh a few pounds and are easy to remove or install with one hand. The ease of changing out the drive plate results in significant time savings.

3.0 HANDHELD MACHINES

3.1 Variable speed angle handheld polishers come in multiple varieties. For restoration and refinishing, it is best to own a variable speed polisher. The most commonly recommended variable handheld polisher is typically referred to as a 7-inch (180 mm) polisher. This polisher is designed to accept 7-inch (180 mm) grinding, honing, and polishing abrasives. The 7-inch (180 mm) polisher is larger than the machine referred to as a grinder. The motor is larger and more powerful. A 7-inch (180 mm) polisher usually features variable speed control. The ideal speeds start as low as 600 RPM. Most stone refinishing jobs can be completed under 1,000 RPM. The use of a slower speed creates less mess. Some restoration technicians prefer the 7-inch (180 mm) polisher because of the larger motor so that they can apply additional pressure to the grinder by leaning on the machine without the motor stalling out.

3.2 Pad drivers: 3, 4, 5 and 7-inch (75, 100, 125, and 180 mm). Pad drivers, also referred to as backer pads, are the connection between the tool and the abrasive. They attach to the angle grinder or polisher and provide a surface or mechanism for attaching the abrasive. They are available in several configurations.

3.2.1 Rigid aluminum pad drivers are the most rigid type available and are ideal for refinishing slab counters. A rigid abrasive and pad driver will help the technician achieve a flatter finished surface, which is closer to the original factory polish.

3.2.2 Rigid composite pad drivers have the same features as aluminum pad drivers but have a tendency to lose their perfectly flat profile or warp after extended time in service.

3.2.3 Flexible pad drivers are made of hard rubber and will flex a moderate amount when under pressure. These are generally used for fabrication when there is a contour or shape that needs to be polished. For restoration, these are great for working in showers or on tile countertops where rigid pad drivers might cause the abrasive to bounce from tile to tile.

3.2.4 Super flexible pad drivers are made from soft rubber and can be bent with minimal force. They are designed for extreme contours. Many restoration technicians use these with dry abrasives for quick touch ups on the edge of a low tile where it meets an adjoining high tile. As with other flexible pad drivers, these can make quick work of shower and tile countertop restoration because of the ability to allow abrasives to make contact with stone in low areas. Super flexible pad drivers can also be used in repairing and refinishing complex edges on stone tops.

3.2.5 Free spinning pad drivers are relatively new to the industry. The main drive plate is aluminum and fits onto the arbor of the machine. It is surrounded by a second plate, which acts as a shell, and is isolated by a bearing in between the two. When the outside plate hits glass, metal, or any other delicate surface, it stops spinning, but allows the inner drive plate with the abrasive attached to keep spinning. These are convenient in showers and when working around metal and glass edges, since they minimize potential damage to adjacent materials.

4.0 ABRASIVES

4.1 Abrasives are used to grind, hone, and polish stone for the purpose of restoring or refinishing. As stone wears, it become necessary to remove light or deep scratches, fill in voids or cracks with a patching material, and sometimes taper a surface to improve a transition. Each of these processes requires the use of abrasives. For scratch removal, the abrasive is used to grind down the surrounding material to the same plane as the low point of the scratch and continue using consecutively finer grit abrasives until the original finish is matched. Voids or cracks are repaired with a patching material. Abrasives are commonly used to smooth out the patched area and blend it to the same plane and finish as the surrounding stone. Transitions are needed when a stone floor is on a higher plane than an adjacent floor or when tiles have been installed with excessive lippage.

4.2 Silicon carbide and diamond are the most commonly used abrasive types for stone refinishing and restoration. Both are hard enough to abrade the hardest stone, but diamond, being the hardest natural substance in the world, will cut noticeably faster when working with very hard stone materials. The cost of most diamond abrasives is usually higher than silicon carbide. It is important, however, to include the costs of labor and machine hours in addition to abrasive costs when estimating total actual cost. In some cases, a diamond abrasive may cut too fast for the task. Keeping both types of abrasive in inventory is the solution that works best for most companies. Either abrasive can be used for the full range of refinishing or restoration tasks. These abrasives are available in many varieties as outlined in the following sections.

4.3 Bricks. 14 cm (5½”) bricks are used in a sweeping rotary motion instead of a straight rotary motion. Because of the compound movement and features of most floor machines, 14 cm (5½”) abrasives are not used for refinishing and restoration. The most common abrasive bricks for stone refinishing and restoration are frankfurt segments. Frankfurt segments are a wedge-style brick designed to fit in to a wedge-shape shoe or opening connected to a drive plate. Frankfurt bricks, often referred to as frankfurt segments, are available in multiple abrasive types and bonds.

4.3.1 Frankfurt does not relate to a specific bond, but describes the shape and size of an abrasive type. The abrasives are attached to the drive plate by wedging them into a holder (sometimes referred to as a shoe). It is a widely recognized abrasive used on the more traditional style grinding machines and slab polishers from Europe. Frankfurt abrasives are typically used on flat floors or terrazzo only, and are generally not used on tile floors with lippage present. Some designs allow the abrasive to grind lippage flat. The brick-style frankfurt segments are inexpensive and wear out quickly but provide phenomenal results. Onsite results with these segments is very close to that of the factory process. Because of their rigid design, there is absolutely no flexibility with these abrasives. This design ensures a high quality finished product. The floor machines designed for these frankfurt segments usually are more complicated to operate than more commonly found floor machines.

4.3.2 Magnesite bond frankfurt segments are typically used after sintered metal abrasives. They are structurally unstable and can break easily. The instability of this abrasive bond is two-fold. First, they are a poured brick abrasive, so dropping them will usually result in chipping or breaking. Second, sometimes the mixture is not properly prepared, and the abrasives can shatter with the temperature change caused by getting them wet. Magnesite abrasive bricks, whether frankfurt or another type, wear down very quickly compared to other bonds. They are effective in removing heavy scratches from the lippage removal abrasives and leave a nice finish for the next step.

4.3.3 Synthetic bond frankfurt segments are similar to magnesite bond segments, but made from synthetic material. This makes them similar to resin bond abrasives. Synthetic bond abrasives can break fairly easily, but not as easily as magnesite bond. Using more forgiving raw materials creates the increased stability over magnesite. When finishing MTL floors and terrazzo, the synthetic tools will usually carry the finishing process to the end and complete the final preparation for the polishing step.

4.3.4 Hard synthetic bond frankfurt segments are very hard and can be used on concrete, granite, quartz, and quartzite surfaces. This abrasive bond is typically used after regular synthetic abrasives and continued to the end of surface preparation, or for hard materials only. Using a hard synthetic bond frankfurt segment will produce clarity that is ready for polishing.

4.3.5 Polishing and cleaning brick. The polishing (or cleaning) step is essentially an MTL (marble/limestone/travertine) polishing powder product compressed into a brick. There are usually two products and steps involved. The final frankfurt segment is usually made of pure oxalic acid. Many stone processing factories use oxalic acid during the final polishing step. When viewing MTL slabs in direct sunlight, faint swirl scratches can sometimes be detected. The swirl marks are a result of the final step being performed with a fixed abrasive and not a polishing powder.

4.4 Plugs are often referred to as terrazzo plugs because they are commonly used during the initial grinding process for terrazzo. The plugs are held in place using specially designed drive plates. Terrazzo plugs are usually made as a sintered metal bond diamond abrasive.

4.5 Abrasive pads are commonly referred to as discs or wheels because of their circular shape. Square or rectangular pads are also available for sanding blocks and orbital style sanders. The most common shape is round, and the most common sizes are 3, 4 and 5-inch (75, 100, and 125 mm). Pads are available in multiple bonds using diamond or silicon carbide as the abrasive type. Different manufacturers attempt to gain customer loyalty by using unique features like innovative bonds, grit size, segment design, tapered edges and others. A sintered metal bond abrasive used for more aggressive cutting is normally referred to as a lippage removal pad. These aggressive discs are typically mechanically attached directly to the tool or drive plate floor machines and handheld polishers. If using a handheld polisher to complete the outer edges of the floor near the walls, then a cup wheel would be used. A cup wheel is the handheld equivalent to lippage discs for floor machines. For lighter pads, the hook and loop system usually works well and helps to speed up the process of changing grits. Pads are the most common abrasive variety.

4.5.1 Fiber pads are not typically used for heavy grinding: only for honing and polishing. They are circular in shape, but the sizes used are typically much larger than the small 3, 4 or 5-inch (75, 100, and 125 mm) abrasive pads mentioned earlier. Fiber pads are woven, and some manufacturers use this weave to hold or suspend abrasive powders. Other manufacturers will lightly bond the woven pad with abrasives. A major advantage of fiber pads is that they will conform to low areas of the floor to abrade the entire floor. This is one of the most common varieties for refinishing.

4.5.2 Synthetic fiber pads are synthetic buffing pads that have abrasive grit incorporated into the pad. During the manufacturing process, these pads are sprayed with an abrasive impregnated liquid compound. This process allows the mixture to penetrate deep within the fibers of the pad. The result is abrasive content throughout the pad, which extends the service life of the pad. The abrasive life of these pads is similar to that of a thick resin diamond. When not in use, they should be stored properly to protect them from contamination from dirt or other foreign matter.

4.5.2.1 Pros of synthetic fiber pads.

- Cost effective
- Easy to use
- Very flexible; allows the abrasive to get in and out of low areas and lippage
- Work quickly
- Can achieve multiple levels of honed finishes, and in some cases, polishes, without leaving scratches or trailing marks

4.5.2.2 Cons of synthetic fiber pads.

- Cannot provide a flat for when used as a set (tend to texture the stone)
- Will not remove moderate to heavy scratches
- Can get damaged easily on stone tiles with heavy lippage

4.5.3 Dot pads. "Dot pad" is a generic name given to a certain type of fiber abrasive pad. These utilize a 17" (430 mm) synthetic fiber pad like described above but there are resin dots or diamond abrasive embedded resin sections permanently affixed to them. This variety has an advantage over the plain synthetic fiber pads because they contain hard resin dots, which allows them to work more quickly and provide a superior finish.

4.5.3.1 Pros of dot pads.

- Work quickly; provide a similar finish to traditional resin diamond pads
- Easy to work with
- Flexible and easy to navigate through lippage and other uneven areas
- Does not need to be protected as much as other synthetic fiber pads

4.5.3.2 Cons of dot pads.

- Expensive when compared to traditional diamond abrasive pads
- Fiber pad can get damaged before using the entire life of the pad

4.6 Abrasive bonds. The bond used for the abrasive can vary based on the abrasive type, grit, and task being performed. The bond holds the abrasive in place until it is used up. Depending on the task at hand and desired finish, different types of abrasives and bonds may be used. If the task is to remove heavy material stock, then a more durable bond and coarser abrasive is desired. If the task is to simply clean the surface, then a lighter bond and finer abrasive is desired. There are many different sizes, shapes, and prices for abrasives. With experience, each technician will develop a preference for different tasks.

4.6.1 Resin bond abrasives are by far the most commonly used and most widely recognized type. They are available in several shapes and sizes. Resin bond abrasives can start as low as 30-grit and go as high as 8,500-grit. This type is most commonly used for light refinishing to remove minor scratches, etch marks and to prepare for a honed or polished finish. Resin abrasives are produced in bonds specific for different stones and hardness. The general rule is that a soft resin is used for hard stones and a hard resin is used for soft stones. If a soft-bonded granite resin abrasive is used on marble, it will wear at an accelerated rate. The same scenario applies for using marble abrasives on granite. The resin needs to wear at the correct ratio in order to allow exposure to the diamond abrasive without causing the resin to form a coating over the abrasive. Soft stone attacks the soft bond in the abrasives, causing the bond to wear faster and lose diamond or abrasive particles. Resin bond abrasives come in rigid, semi-flexible, and flexible variations.

4.6.1.1 Rigid, puck style abrasives are usually used for flat floors. This type is also used after a floor has been ground flat, like in lippage removal. The rigid style will limit the amount of fluctuation in the flat appearance of the finished product by not allowing the tools to flex and dig into the stone.

4.6.1.2 Semi-flexible. For stone refinishing and restoration, semi-flexible abrasive pads are the most common flexible abrasives. Thick or thin, they all share a layer of foam or neoprene between the actual pad and the Velcro surface. This allows for some rigidity, but also some bend if the diamonds hit a sharp edge or uneven surface. If the flexibility is not there, the resin segments can break off. This type can be used on anything from a perfectly flat floor to a floor with moderate lippage. The flexibility of these pads will allow them to act as shock absorbers and ride up over the uneven tiles.

4.6.1.3 Flexible abrasive pads are the type most commonly used in stone fabrication shops, in 3" to 5" (75 to 125 mm) diameter. These are used on handheld machines to polish edges and tops of counters and other stone applications. Their flexibility allows the fabricator to avoid angling off a convex edge detail. A few companies make these in 3" (75 mm) diameter, which can be used on a floor machine. Foam risers almost always accompany this type of abrasive. The risers are very forgiving; almost spongy. They attach directly to the drive plate, and the abrasive pads attach to the riser, adding flexibility. This setup is used on floors with light to moderate lippage. The weight of the machine will compress the riser, allowing the edge of the pad to flex or curl slightly. This setup ensures that the abrasive reaches the low areas of the uneven tiles and help to eliminate picture framing.[1]

4.6.2 Marble bond resin diamond abrasive pads are designed specifically to be used on MTL surfaces. Marble abrasive pads can be used on these floor types, although some manufacturers produce pads specifically for each type. As mentioned previously in this chapter, a hard resin is more effective for soft stones like MTLs. Although not usually recommended, marble abrasives can also be used for concrete polishing. Many marble bond abrasives will work quite well and provide reasonable service life when used on residential-type concrete. Other abrasives suited for concrete will be discussed throughout this chapter.

4.6.3 Granite bond resin diamond abrasive pads are designed to achieve the highest possible clarity before the final polishing step. Granite is very hard compared to MTL stones, so time becomes a factor. The higher quality the granite resin pad, the faster

[1] "Picture framing" is a term used in the stone restoration industry meaning that the low section of a tile are not abraded when working on a floor that is not completely flat.

you will get to the polishing step. Also, the better quality finish the resin pads achieve, the less work is needed on the final polishing step. Due to the methods by which they are produced, higher quality abrasives will typically result in a premium price.

4.6.4 Phenolic bond resin diamond abrasive pads are used to withstand heat and friction. These abrasives are usually used for dry honing and polishing. Because of the heat generated from the friction during this process, the resin was designed to withstand the temperature without burning or glazing over. Most other abrasive bonds are damaged when exposed to the same conditions. Phenolic resins are made mostly for concrete and are classified as a resin or a resin-hybrid pad.

4.6.5 Hybrid bond diamond abrasive pads are relatively new. These utilize a traditional resin mixed with a soft metal like copper to create a pad that is extremely effective and forgiving. They are designed to remove material quickly and leave a smooth finish, so the next finer grit is easier transitioned. Hybrid pads can be used as transition pads when working your way out of the metal grinding stages into the resin honing stage. Hybrid bond abrasives will remove the heavy scratches of the metal lippage discs and leave a finish smooth enough to be picked up by the next resin step. They are a very helpful addition to the toolbox.

4.6.6 Metal bond diamond abrasives are heavy duty and used for coarse or initial grinding, also referred to as lippage or severe damage removal. They do the most work, take the most abuse, and produce the quickest results. Metal bond abrasives are mainly used for removing heavy scratches. They can also be used to remove chemical damage on terrazzo and concrete, remove lippage from uneven tiles, or remove a sizable amount of material. There are several different types of metal bonds that serve different purposes. Some of these are as thin as 1 mm (0.040") and are available up to 12 mm (½"). Metal bond abrasives can start as low as 6-grit and go all the way up to 1200-grit. The bond can greatly affect the finish. A metal bond 200-grit abrasive is much more aggressive than a resin bond 200-grit abrasive. To remove the scratch pattern of a metal bond abrasive quickly, it is necessary to use a much lower grit resin bond abrasive.

4.6.7 Sintered bond. Sintering is one of the most commonly used methods for assembling diamond abrasives in our industry. Bridge saw blades and most grinder blades use a sintered metal bond. When inspected closely, small diamond segments protruding from the metal surface can be seen, often with directional streaks trailing them. These appear almost like a comet and a tail. Sintering assembles abrasives in a manner that holds the diamonds within the body of the segment. As the abrasive or segment is used, the metal wears away, exposing new edges of the diamonds. This can be compared to a self-sharpening blade. However, if the metal used for the bond and the stone are not compatible, the metal will glaze over the diamond. It will essentially cover the diamond and slow down the process until it can be dressed to expose the diamond or cutting abrasive. This bond type is designed for rapid removal of stone. It will leave moderate to heavy scratches compared to other bonds. The most common application in the restoration industry for this bond is for lippage removal. Because of the materials used to make the sintered discs, they are the usually the most expensive, but also have the longest life span. Terrazzo plugs are made of sintered segments.

4.6.8 Copper bond. Copper diamond abrasive pads are also sintered, but significantly different. They are made with a softer lighter copper material as opposed to the heavier metal that is used for standard sintered tools. This bond is not recommended for the initial step in lippage removal because it will wear down very quickly and will not cut as fast. The copper bond was developed as a transitional bond to bridge the gap between metal and resin bonds. They offer the best of both worlds: heavy scratch removal while leaving a smooth finish to facilitate the transition into the resin steps. Copper bonds work well for cleaning up traffic worn or chemically damaged surfaces to prepare for refinishing. Copper bond discs are a “must-have” for the toolbox.

4.6.9 Vacuum brazed diamond abrasives are the most aggressive metals used for floor refinishing. This type of bond abrasive will cut very fast and leave heavy scratch marks. Unlike sintered diamond bonds, vacuum brazed abrasives are attached to the outermost surface, exposing all the diamonds on the face. This bond does not have the life span of sintered metals, but is less expensive. When the goal is to remove material as fast as possible, vacuum brazed is the normally the best choice. Because of their aggressive nature, they are not typically used on MTLs. Vacuum brazed diamonds are much thinner and lighter than sintered discs and will most likely have a convex shape to the face to allow for a smooth transition over uneven tiles.

4.6.10 Electroplated bonds are similar to vacuum brazed bond abrasives in appearance. These bonds are easily mistaken for each other. Electroplating is a coating, while vacuum brazing is a type of weld attachment. Electroplated diamonds are the thinnest in the metal group at 1 to 2mm thick (0.040 to 0.080”). The diamonds appear to be on the surface like brazed metals, but are attached through a different process. Electroplated bond abrasives are the least expensive of the metal group and also have the shortest lifespan. Similar to vacuum brazed abrasives, electroplated abrasives are extremely aggressive, but leave a much smoother finish when compared grit-to-grit. They can be used for quick repairs of heavily damaged material or as a transitional grit between sintered and resin abrasives. These abrasives can be used wet or dry, and excel on MTL stones. It is also possible to use them on concrete. However, electroplated bond abrasives do not hold up through use on harder stones, such as granite.

5.0 POLISHING COMPOUNDS

5.1 Marble polishing powders have revolutionized the refinishing and restoration industry by increasing production and improving quality. There are so many marble polishing powders on the market today it can be difficult to distinguish individual products. There are “hot” powders, “cold” powders, and many in between. For the purpose of this discussion, “hot” or “cold” refers not to temperature, but to acid content. Acids found in marble polishing powders vary, but a hot powder contains a higher percentage of acid. These tend to polish more quickly, but the technician risks over-use, which can result in a poor finish. Overuse of hot powders will result in an orange peel look on the stone. Cold powders have a lower acid content and take a little more time to work, but they provide better protection against overuse. Most polishing powders on the market work to some extent on most marbles. However, some marble will react differently and require the use of a different mix of acids. Each technician will develop the sense of what mixture is needed.

5.1.1 Types of marble polishing powders

5.1.1.1 Wet polishing powders are designed to be used with water. Water is added and worked into an area to generate a slurry. The polishing process is completed while the mixture is still wet, then the slurry is removed with a wet vacuum.

5.1.1.2 Wet-to-dry polishing powders are usually very “hot,” meaning that they contain a lot of acid and work very quickly. Using this type of polishing powder means that the process is started either in a wet slurry, or with just a mist of water and worked until completely dry. The technician will get a feel for how much water is needed through experience. It is better to achieve the polish in stages than to risk over-polishing the stone and resulting in an orange peel appearance. Using wet-to-dry powders eliminates the need to vacuum after polishing each section. This process requires the use of more heavy-duty machinery, because of the significant friction produced during their use.

5.1.2 Ingredients for marble polishing powders. MTLs are calcium-carbonate based stones that react to most acids. Every marble polishing powder includes an acid and an abrasive, along with other proprietary ingredients.

5.1.2.1 Oxalic acid breaks down the surface of the stone to allow the abrasives to do the work. It activates when water is added.

5.1.2.2 Shellac is a type of resin that naturally occurs on trees. It is pulverized into a powder and added to the compound. The heat created by the friction from the polishing process melts the resin and deposits it into the micro-pores of the stone. It hardens immediately after cooling and helps give the floor a more uniform look and increases gloss.

Shellac is not often used in more recent powders to enter the market.

5.1.2.3 Aluminum oxide is a manufactured, inert powder. It is a pure abrasive and is used to achieve final polish. It is considered a super fine grit, although it is unclear just how fine it is, and works to smooth out the surface of the stone while it is in a vulnerable state from the oxalic acid. Aluminum oxide is harder than granite.

5.1.3 Characteristics of polishing powders. Polishing powders vary significantly among products. The amount of water and pads used, speed and weight of the machine (including weights added), and how long each section is polished all have an impact on the final polish.

5.1.3.1 The amount of water used can make the biggest difference when polishing. Using less water creates a more concentrated, or potent, powder. Using more water will dilute the powder, making it less effective. "Hotter" (more acidic) powders can be diluted down more for sensitive stones. Using too much powder and not enough water will damage the stone's finish.

5.1.3.2 Type of pad. The two major types of pads are white nylon polishing pads and hog's hair polishing pads.

5.1.3.2.1 White nylon polishing pads are dense and soft to the touch, with multiple fibers intertwined into the same area. Due to their density, they tend to hold more of the polishing compound on the immediate surface. This allows the compound to do all the work. There are pros and cons of this, depending on what type of stone is being worked on and what type of equipment is being used.

5.1.3.2.2 Hog's hair polishing pads are much coarser and less dense than white nylon polishing pads. The fibers are a mix of natural boar and synthetic. The fibers are thicker and the pad is less dense. Due to the lack of density, more of the polish is absorbed by the pad, leaving less on the contact surface. This adds a new dimension to the polishing process.

5.1.3.3 The amount of weight needed depends on the material more than the powder. Some materials "burn" easier than others. It is very similar to polishing automotive paint. The harder you push, the more friction is generated. Friction translates to heat and can orange peel—leaving a textured look to the finish. The experienced technician will get a feeling for when adding weight is needed.

5.1.3.4 Speed has essentially the same effect as weight. More speed equals more friction, which in turn makes more heat. Increased speed also makes more mess, causing the slurry to travel further.

5.1.3.5 Time. How long each section is worked with a polishing powder can have a very big impact on the quality of the final polish. On marble, working a section too long with an acidic polishing powder can cause orange peel or etching. It is better to perform this task in stages until the technician is familiar with the reaction between the polishing powder and the marble. For granite, the overuse of polishing powders is not usually a problem, although it can leave the stone hazy or dull.

5.2 Polishing pastes are usually polishing powders in a paste form. They are already "active," containing their own liquid. Water can be added if the paste dries out or if a more diluted slurry is desired. Pastes are generally grittier than powders. The grit or chunks that can be seen and felt are oxalic acid chunks. These get absorbed into the polishing pad and act to further polish the material. Although it may feel like the paste will scratch the stone, it has no effect on the finished product. Oxalic acid is water-soluble and slowly dissolves while being used.

5.3 Liquid polishes, also known as crystallizers, are misted on the surface and buffed with a mono-rotary machine with heavy weight and a steel wool pad until dry. The liquid provides a chemical bond with the stone. The steel wool heats up the liquid and surface and allows it to harden as it fills in the scratches and pores of the stone. This process is used mostly in commercial maintenance settings, although it is not designed to be a maintenance product. Liquid polishes work differently than polishing powders and pastes. Polishing powders and pastes usually contain a fine abrasive and a mild acid which do not coat the material but act more like a super fine abrasive to enhance the reflective finish of the stone.

5.4 Honing powders can be used either for minor damage removal or finishing. Most honing powders are between 120 and 800 grit, depending on the manufacturer. Honing powders are made from aluminum oxide. These powders are used with water to create a slurry and are used to put a final honed finish on almost any material. Usually the stone will be refinished or the polish will be broken with diamond abrasives, then the honing powder will be used as a final step. Because the powder is loose, as opposed to a fixed abrasive, it leaves no detectable swirls or tool marks.

6.0 ADDITIONAL TOOLS AND SUPPLIES

6.1 Miscellaneous honing/polishing pads used with compounds and powders. Steel wool pads are used mostly when crystallizing. Champagne pads are used for honing and/or polishing. Black pads are used for stripping coatings. Tampico brushes are used for polishing.

6.2 Cleaners

6.2.1 Neutral cleaners have a pH of 7. They are neither acidic nor alkaline. Neutral cleaners are used for light washing, rinsing, cleaning and neutralizing after polishing or using an acid based cleaner. Homeowners are advised to use these.

6.2.2 Alkaline cleaners are at the top of the pH scale, with a pH typically between 12 and 14, depending on the manufacturer. Cleaners with a pH between 13 and 14 pH can damage polished MTL floors if not correctly diluted. This type of cleaner is usually used as a degreaser or to clean heavily soiled floors and grout. Alkaline cleaners are generally good at breaking down soap scum and weak waxes. They can also be used to neutralize acidic cleaners.

6.2.3 Acidic cleaners are only used on natural stone when absolutely necessary and should be avoided inside the home if possible. Most acidic cleaners usually have a pH between 4 and 2, depending on the acid used. The most common acids used are phosphoric, hydrochloric and sulfuric. These cleaners are usually used for removing mineral and hard water deposits, cleaning excessively dirty grout, and removing rust stains. Only use acidic cleaners when other options have been exhausted.

6.3 Wet/dry vacuums perform a very necessary function. It would be difficult to refinish or restore stone without the ability to remove the dirt and debris or slurry created that could interfere with honing and polishing.

6.4 Antiquing Brushes. Antique finishes have become popular in recent years. The brushes used to achieve this finish come in several configurations. Antique finishes are usually presented in a matte or non-reflective range. When a more reflective finish is desired, each progressive grit will not reach as far into the lower areas of the stone. This results in only the highest points of the stone having a shine, giving it an antiqued or worn look.

6.4.1 Diamond wire brushes are by far the most aggressive. These brushes are made of relatively thick, hard bristles impregnated with diamond abrasives. Diamond wire brushes usually start at 36-grit and go up to 600-grit. They are usually used to remove the polish from granite and give it the initial antiqued or textured finish.

6.4.2 Rubber bristle brushes are produced featuring several different thicknesses and layers of bristles. There are different bristles and features designed for different grits. Lower grits will typically have very thin, concentrated bristles, typically used to reach the softer, lower textured areas of the stone. Most grits feature thicker, stiffer rubber bristles designed to reach most areas, but not the lowest sections of the stone. Higher grits feature larger, wider rubber bristles designed to skim across only the top sections of the texture. The larger, wider bristles are designed to put a shine on the peaks of the texture.

6.4.3 Carbide bristle brushes are made using silicon carbide abrasives. Thin, wiry bristles are impregnated with the abrasive. Carbide bristle brushes can be used for antiquing, light texturing, or just for scrubbing rough surfaces.

NOTES:

RESTORATION AND MAINTENANCE – REPAIRS

1.0 INTRODUCTION

1.1 Repairing stone is a normal part of restoration. Many stones, especially very decorative varieties, have natural voids and weaknesses. Filling these voids and reinforcing these weaknesses is normally started early in the processing phase at the factory level. The material is quarried in a block form; it is then transported to a factory for processing into useable products such as slabs or tile. After cutting these blocks into slabs, many materials are filled, repaired, or reinforced using a variety of methods. Once the initial repair or reinforcement is done, the product is ground down to start the finishing process. After the initial grinding step, it is sometimes necessary to touch up the repair before proceeding to finalize the desired finish for the stone.

1.2 Many installers will cull pieces from the lot during installation. In some cases, the quantity ordered is insufficient if extensive culling is required. The bid process can be very competitive, so extra pieces are a luxury that cannot always be afforded in order to win the bid. After installation, the existing repairs may need to be retouched. Often, the processing factory performs a generic repair that may work in some areas of the stone but is very noticeable in other areas. The factory doesn't always know the intended application of the product when they are producing it, so sometimes an inappropriate patching material is used (for example a polyester resin when the material will be used for an exterior application). In that case, the patch needs to be removed and replaced with a more suitable patching material. Other times repairs need to be made due to everyday use, faulty installation products or methods, structure settlement or movement, and occasionally abuse or failure to maintain. Post-installation repairs will be the primary focus of this section.

2.0 PRODUCTS AND SUPPLIES

2.1 Adhesives and Patching Materials. Before beginning the discussion of techniques, patching material selection will be discussed. No matter how good a repair looks cosmetically, if the wrong material was used it will not perform and must be redone. The most reliable product must be used to ensure the longevity of the repair.

2.1.1 Adhesives and patching materials are used to adhere broken pieces back together (also known as "sticking"), fill pits or voids (either natural or created by movement) and reinforce weaker areas of the stone. The materials that are most common in the stone industry are polyester, acrylic, epoxy, urethane and cyanoacrylate (also known as "CA").

2.1.2 Most of these materials are available in different viscosities for different applications. When trying to penetrate micro-fissures, the least viscous or thinnest product would be selected for this task. Many manufacturers refer to this as a "penetrant" or "super penetrant." For sticking loose pieces of stone together, a slightly thicker product would typically be used. This product is often referred to as "flowing." Filling holes and voids would require thickest product. Most manufacturers call this a "knife grade." Many of the products are two-part. Part one is typically referred to as the adhesive or resin and part two is typically referred to as the catalyst, hardener or curing agent. One product category requires no curing agent because the curing process is activated by exposure to air. Each product category will be discussed in further detail throughout the section.

2.2 Colors and tints can be added to adhesives and patching materials to provide a better cosmetic blend between the repair and the surrounding stone. Follow the manufacturer's recommendation for use. Generally, if the missing sections of stone can be adhered back in to place, it will be a better repair than if patching material is substituted for the missing stone.

2.3 The basics of adhesives and patching materials are the same. One main difference is that most fast curing two-part products are mixed with colors or tints before the curing agent is added. Resin and curing agent for slower curing two-part products are often mixed together before the color is added. There can be differences even within adhesive categories because different manufacturers may use different ingredients to provide unique benefits. It is very important in any two-part product to mix the products according to the manufacturer's instructions.

2.3.1 CA glue. There is only one product listed below that is not categorized as a two-part adhesive or patching material. It is commonly known in the industry as CA glue or cyanoacrylate. This product can be used with an accelerating agent. The use of accelerators can expedite the already fast curing time. If using an accelerator, do not use an excessive amount on lightly colored stones. Overuse of accelerators is a common cause of staining in these stones. Accelerators are not necessary for the adhesive to cure. It is important to be familiar with the products before using something that may cause additional problems.

2.3.2 Volatile Organic Compounds (VOCs) can have a big impact on the selection of the material to be used for a repair. VOCs are typically measured in two main ways. VOCs as supplied is the measurement right out of the container. This value is typically higher because of the product concentration in the container. VOCs as applied is the measurement upon activation of the product. Once the product is activated the VOCs get consumed and there are fewer emitted in to the air. For projects requiring VOCs below a certain value it is important to know which VOC value is being referenced and how the measurement should be taken. Be sure to allow for proper ventilation and use the correct Personal Protective Equipment (PPE) while using adhesives or patching materials.

3.0 CHARACTERISTICS OF ADHESIVES AND PATCHING MATERIALS

3.1 Similar characteristics exist among the available adhesives and patching materials, although each variety has some distinct features which are described below.

3.2 Polyesters.

3.2.1 Polyesters resins are, at this time, the most popular patching material used in the stone industry. Some of the reasons for this popularity are assumed to be modest cost, rapid cure time, bond strength and familiarity in working with the material.

3.2.2 Polyester based adhesives are fast curing, two-part products, so colors or tints can be added to the resin before the hardener to achieve a visually better repair.

3.2.3 Using more catalyst can accelerate the cure rate, but there is a risk of a weaker and more brittle bond. The manufacturer's instructions for mixing should be followed closely for best performance.

3.2.4 Polyester adhesives are commonly used in countertop seams because movement usually results only in a failure in the adhesive without damage to the stone.

3.2.5 Polyester resin can be sanded and polished to a reasonably high shine, allowing it to better blend with polished stone.

3.3 Acrylics.

3.3.1 Acrylics became popular for use as penetrants and are considered among the least viscous among the categories. Penetrants are commonly used to penetrate micro-fissures or very minute openings. Fissures are natural separations in stone and are very common among the most decorative varieties of natural stone. The next feature that helped this category gain popularity was the availability as a “water-clear” product. Many repairs are made better when the repair is “water-clear.”

3.3.2 Curing agents are typically used on acrylics, and are usually liquid. This is done to keep the product clearer and less viscous.

3.3.3 Acrylics can be sanded and polished to a reasonably high shine, allowing it to better blend with polished stone.

3.4 Epoxy.

3.4.1 **Epoxies** became popular because of their superior bond strength when compared to other adhesives categories. Many people hesitate to use epoxies in some situations because of their lengthy cure time and increased cost. Epoxy is most associated for causing stains when used with white marble. Epoxies are most commonly mixed with other categories to make hybrid adhesives.

3.4.2 Staining can be a problem when using epoxy with white marble or other light colored porous stone. Be careful to test any adhesive for use with light colored marble, limestone and granite.

3.4.3 UV exposure can attack the look of epoxies, but the strength of bond is relatively unaffected. This makes it one of the few products that can be suitable for exterior applications.

3.4.4 The high strength and ductile properties of epoxy make it the preferred adhesive for use in structurally significant roles.

3.4.5 The curing of an epoxy is an exothermic chemical reaction, meaning it produces heat. Because of this, repairs requiring large amounts of adhesive may have to be done in steps to prevent excessive heat generation.

3.4.6 Epoxies are available in multiple viscosities: from penetrants to knife grade.

3.5 Urethane.

3.5.1 Urethane adhesives are the newest class of stone adhesives. The price of this category is relatively high. Urethane was developed to fill the gaps of the other product categories. Urethane has excellent clarity and its bond strength is close to the strength of epoxies.

3.5.2 Urethane is a slow cure, two-part adhesives. Using an accelerator can speed up the cure rate without the risk of a weaker or more brittle bond. Follow the manufacturer’s instructions for mixing for best performance.

3.5.3 Urethane is used for many projects, including patching or filling voids in stone and bonding pieces of stone together. Urethane is also used as a caulk-like material for expansion joints and exterior joints.

3.5.4 The stone must be dry before using urethane adhesives, but this product can withstand exposure to moisture after curing.

3.5.5 The mixing ratio and thorough mixing are both critical to ensure complete polymerization when using urethanes.

3.6 Cyanoacrylate (CA) glues.

3.6.1 CA glues are gaining popularity in the stone industry because of the different viscosities available and the rapid cure time. CA glues are typically sold in small units because of their relatively short shelf life. They are often used to fill voids and micro-fissures. Because it is a fast curing product that rapidly cures when exposed to air, most professionals tint the stone prior to applying CA glue.

3.6.2 CA glue should not be used to bond pieces of stone together. CA glues do not bond as well as other categories.

3.6.3 The use of an accelerator can cause staining if overused on lighter, more absorbent stones.

3.6.4 CA glues are ideal for quick and easy repairs. They are suitable for UV exposure and outdoor environments. They can also be used for seams in countertops because movement usually results only in a failure in the adhesive and less damage to the stone.

3.7 Hybrids.

3.7.1 Hybrids have been developed by many adhesive manufacturers in an attempt to reduce the price of some adhesives and expand the benefits of others. A polyester/epoxy hybrid, referred to as a poly/epoxy, is the most popular hybrid.

3.7.2 Poly/epoxy hybrids have a stronger bond than polyester adhesives. The cure time is shortened when compared to epoxy adhesives. As with polyesters, the cure time of poly/epoxy hybrids can be adjusted.

3.7.3 Poly/epoxy hybrids are more flexible than polyester adhesives. The mixing ratio is not as critical with poly/epoxy hybrids as it is with epoxy.

3.7.4 Structural movement usually causes failure in the adhesive, so poly/epoxy hybrids are considered suitable for countertop seams. They are also used for countertop laminations, mitered drop edges, and rodding or doweling.

3.8 General notes about adhesives and patching materials.

3.8.1 Polyester, acrylic, and poly/epoxy require less hardener (usually in a ratio of 1% to 4% hardener by volume) or curing agent than epoxy. The typical mixing ratio for epoxy is either 2 to1 or 1 to1 resin to curing agent.

3.8.2 Polyester, acrylic, and some hybrids can typically share coloring systems. Epoxies and urethanes usually require their own specific coloring systems depending on the manufacturer.

3.8.3 Urethanes are unique from the rest of the adhesive categories. Many do not cure into a hard, polishable surface. Typically urethanes remain like a hard rubber, to allow for expansion and contraction.

3.8.4 For adhesives that require very accurate mixing ratios, most manufacturers will list the required component ratio both by volume and by weight (mass). Accurate digital scales can be readily obtained at a modest cost, and it is recommended to measure these components by weight (mass) as this method is more accurate than measurement by volume.

3.8.5 In the table at the end of this section, each product category is compared by its typical features. These features are listed at the top of the chart and the product categories are listed in the far left.

4.0 COLORS AND TINTS

4.1 Coloring powders, pastes, and liquids can be product specific, meaning there can be different color products made for polyester, acrylic, and hybrids than for epoxy and urethanes. Some tints are more UV sensitive than others. Check with the manufacturer to be sure the right tint for the adhesive and application is used.

4.2 When the right color is chosen, a repair will be visually undetectable. It takes practice and patience to find the right color. For some materials, like white marbles, it is better to have a semi-translucent mixture with just a hint of the correct shade of white. For other materials, a water-clear mixture works best. Attention should be paid to the specific shade in the area of needed repair. The color should be tested on a small area of the stone to analyze the color match. If the patching material is a fast cure adhesive, the curing agent should not be added until the color is finalized. Sometimes the curing agent will change the color, so it is important to anticipate that and adjust for it. If the patching material is a slow cure adhesive, then there is usually time to make adjustments. For multi-colored materials, it may be necessary to use multiple shades and to repair in sections.

4.3 Translucent stones, such as onyx, will oftentimes be difficult or impossible to patch with perfect cosmetic results. This is due to the difference in light transmission within the stone fabric versus that of the patch.

5.0 TOOLS

5.1 Tools used for repairs may vary slightly, depending on the personal preferences of the technician. Despite this, the uses are universal.

5.2 Personal Protective Equipment (PPE). This includes gloves, vapor masks, dust masks, goggles, and other equipment as recommended by the adhesive, abrasive, or tool manufacturer.

5.3 Cleaning tools include vacuums, acetone, denatured alcohol, stone soap, intensive cleaners, razor blades, super fine steel wool, soft bristle brushes, rags, compressed air, and other items as recommended by the manufacturers.

5.4 Dispensing tools can be a pump, measuring cup, small capacity digital scale, putty knife, or anything similar.

5.5 Mixing tools can be a paint spatula, putty knife, mixing stick, or anything similar. Thorough mixing is necessary when adding color or curing agent to resin.

5.6 Spreading devices/tools. If the material is in liquid form, a spout is typically used for the initial application process. Afterwards, a putty knife or other spreading tool can be used. For thicker consistencies, a paint spatula, putty knife, or mixing stick will work. Afterwards, straight edge razor blades are mainly used to smooth out the mixture.

5.7 Finishing tools typically include razor blades, steel wool, and chemical solvents.

5.8 Grinding, honing, and polishing tools are die grinders, right angle grinders/polishers, diamond blades/grinding wheels, diamond bits, masonry bits, 3, 4, and 5-inch pad drivers (also known as backer pads), sandpaper (typically silicon carbide), and other abrasives (including antiquing brushes for textured finishes).

6.0 REPAIRS

6.1 Inspection. Performing a thorough inspection during the diagnostic phase of a project will allow the technician to discover which repairs are necessary to help prevent further deterioration of the stone. Many times the repairs will be natural voids or previous repairs that just need a touch up. Occasionally, repairs will be necessary because of structural movement or some other form of failure.

6.2 Types of Damage. It is helpful to determine what caused the damage so that changes can be made to help minimize the chances for reoccurrence.

6.2.1 Upward Crack. If one or two isolated tiles are involved, then the most probable cause is that the installer left a void under those tiles. Foot traffic, carts and other weight place on top of the damaged tiles exerted enough pressure on the unsupported section of the tile to cause it to crack. This is the classic example of an upward crack. In an upward crack, two sections of the tile are broken at an angle that has its high peak at the crack itself.

6.2.2 Inward or Downward Crack. Structural movement will typically cause damage to multiple tiles in a line that sometimes crack in an inward or downward angle. This line can be somewhat straight or it may move to one side slightly to seek out the weakest point of the stone. This is known in the industry as an inward or downward crack or indent fracture. These are mostly caused by the settlement of the floor and where the crack itself is at the lowest point of the tile.

6.2.3 Outward Crack. A crack in the sub floor, or the joint of two pieces of cementitious backerboard under the tiles, can be either upward, or simply a slight separation of the tiles called an outward crack. An outward crack is a slight gap caused by a separation of the stone. Both pieces of the stone are typically on the same plane.

6.2.4 Chips are typically missing sections of stone that is usually the result of an impact from a dropped object. Sometimes, as a result of a crack that splits, small sections of the stone will become dislodged and swept or vacuumed up and discarded. This creates a larger gap to be filled.

7.0 REPAIR SUGGESTIONS

7.1 Crack Repair.

7.1.2 For upward cracks, the first step is to determine is if any of the two (or more) parts of the cracked tile(s) are solid, or if they are slightly moving. In nearly all cases, the grout of a tile cracked upward has separated and become dislodged. It must be determined if there is enough room between the tiles (grout gap) to allow grout to be fully pushed in. If the section of grout is not deep enough to hold more grout, then more of the old grout may need to be removed. Before regrouting, check to see if either section of the broken tiles is loose. If there is no longer a bond between the tile and the subfloor, tapping the surface will produce hollow sounds. The unbonded area (or areas) can be fixed by injecting latex adhesive or a two-part epoxy to fill the void. After injecting the adhesive apply weight to the repaired areas and allow it to cure overnight or longer as recommended by the manufacturer. It is recommended to start these repairs a couple of days before you refinish the floor. After the tiles are secure, regrouting can be done to finish the repair.

7.1.3 Downward Cracks should not be repaired, because this can make them more noticeable. Most of the time such cracks are barely visible, because they only appear as an interruption of the light reflecting on the cracked tile. However, if the crack can be felt with the fingertips and is visible, it can sometimes be disguised by flattening it out. To flatten an indent fracture, use fine grit sandpaper (such as a 220 grit) and sand the hairline crack flat. Be careful not to create a dip by keeping the angle grinder flat. If the surface is being polished, it can be cleaned out and filled with penetrating adhesive to repair it and keep it clean during the process.

7.1.4 Outward Cracks involve several tiles in a row and can be repaired. It is important to inform the client that there is structural movement involved, so no guarantee can be given that it will not crack again. If the crack reoccurs, a better solution would be to install an expansion joint or a crack isolation membrane. Both of these remedies require that the stone tile be removed in order to make the corrections. It is very difficult to match existing stone unless the client kept extra pieces from the same lot.

7.2 Chips. For the best repair, some of the stone should be glued back in to place. If the chip was discarded and there are no extra pieces of stone available, then filling the void with an adhesive, as a patching material, is needed. It is necessary to clean the damaged area thoroughly before applying the adhesive. Once the patch has been made and cured the grinding and honing process can begin. To verify that the patch will blend, check the patch by wetting the area after grinding the section flat and before finishing the honing and polishing process.

8.0 REPAIR TECHNIQUES

8.1 Preparation. The crack must first be prepared, and the appropriate filler must be determined. Vacuums and die grinders with an assortment of bits and blades are the most commonly used tools for crack preparation. The die grinder is used to dress up or enlarge the opening as necessary to ensure proper filling. If repairing a broken corner of a tile that is loose but still in place, it is best to proceed by removing the broken piece and cleaning the edges of the tile and the removed piece with a die grinder and abrasive bit. Afterwards, the corner should be dry-fitted in place to ensure that it is finished at the same plane as the rest of the stone. If it is high, continue to clean the void until it is almost flush. If it is low, fill the hole where the broken piece was with color-matching knife grade adhesive or a mixture of knife grade and flowing adhesive. Set the broken piece back into place by pushing it against the broken tile and as flush as possible with it. It is better to leave the corner very slightly raised rather than depressed. Once the repair is cured, grinding it until it is flush with the rest of the stone can flatten the corner out.

8.1.1 The consistency of the repair adhesive necessary will depend on the type of crack being repaired. For general crack repairs, use knife grade adhesive and push the adhesive into the void with a spreading tool such as a razor blade. It is best on fast cure two-part adhesives to mix the adhesive with the intended colors without adding curing agent until the client approves the mix. For adhesives known to shrink, it is necessary to apply excess adhesive to allow for shrinkage. Consider the finished appearance of the adhesive before using it on honed or textured materials.

8.2 Fixing micro-cracks and separations using a penetrating adhesive.

8.2.1 Before beginning repairs, consult the product's SDS to determine if PPE is necessary for the task. Begin by cleaning and drying the stone thoroughly.

8.2.2 Use a torch to warm the stone until it is warm, but not hot, to the touch. Do not use a flame near acetone or other solvents.

8.2.3 To minimize the risk of a large stain, it is best to mask off the stone with tape. Leave only a narrow opening [approximately 1/8" or 1/16" (3 or 1.5 mm)] beyond the separation on each side) on the pieces needing repair.

8.2.4 Mix the penetrant according to the directions supplied by the manufacturer and add color if desired.

8.2.5 Pour and spread the adhesive into the crack. Allow the adhesive to penetrate the stone. The time span necessary will depend on the curing time of the adhesive. Allow the adhesive to cure for the time recommended by the manufacturer.

8.2.6 After the adhesive has cured, use a razor blade to remove the tape and any excess adhesive from the face of the stone. If this is done before the adhesive is fully cured, leave the excess adhesive to allow for shrinkage.

8.2.7 Grind, hone, and polish the stone as necessary to complete the repair.

8.3 Fixing macro-cracks and separations using flowing and knife grade adhesive.

8.3.1 Consult the material's SDS to determine if PPE is necessary before beginning repair. Begin by using a razor blade to remove loose pieces or existing fill from the crack. Clean all sections to be filled and allow the stone to dry thoroughly.

8.3.2 Mix adhesive according to directions supplied by the manufacturer. Add color if desired.

8.3.3 Apply adhesive. Use a razor blade or putty knife to smooth and remove any excess adhesive. Most adhesives shrink or settle as they cure; as such, it is recommended to leave any excess in the fill areas.

8.3.4 Allow the adhesive to cure for the time recommended by the manufacturer.

8.3.5 Grind, hone, and polish the stone as necessary to complete the repair.

8.4 Finishing the Repair.

8.4.1 In the case of a three-step restoration procedure (flattening, honing, and polishing), the de-lippage tools will take care of grinding the glue flush with the surface of the stone.

8.4.2 If performing a two-step restoration procedure (honing and polishing), excess filler should be grinded using a right-angle grinder/polisher with an 80, 120 or 220 grit sandpaper. The area should be sanded until the repair is flush with the rest of the stone.

8.5 Tips for a Better Color Match. For a better matching repair, it is sometimes necessary to mix an inert material with the adhesive to give it the necessary "body." The most common inert materials used are marble, limestone or granite dust. Another possible choice is to mix color-matching unsanded grout with the adhesive. The grout is usually mixed approximately two parts grout to one part adhesive. Once the compound is thoroughly mixed, check the color match, add the curing agent, and proceed to fill the voids as usual. When grout is mixed with adhesive, it will become darker – as if it were wet. It will not go back to a lighter color as it would if it were mixed with water. The color of the uncured mix is a good indicator of the cured color. Before adding the curing agent, make sure to lighten the mixture to the desired color. The resulting compound will cure into an extremely hard material that can be worked in the same way that stone would. It is also capable of taking a polish.

8.6 Countertop Seam Leveling or Scratch Repair.

8.6.1 The goal of a multi-piece countertop installation should be scratch-free material and seams that are not easily visible. Sometimes there can be unavoidable problems that require addressing from an experienced stone technician. Occasionally, for various reasons, stone pieces are not perfectly flat. When these pieces are joined together at a seam, especially a 90-degree seam, the irregularities are noticeable. There are techniques used by many installers to adjust the material to achieve a better, more finished look.

8.6.2 Seam Setter. The most common technique is to use a seam-setter. A seam setter is a device used to draw stone pieces together and fit them at the same plane.

8.6.3 Seam Setter + Biscuit. Another, less common, technique is to use a biscuit joiner in combination with a seam setter. A biscuit joiner is a device used to cut grooves in the concealed edge of joined pieces to give them a mechanical anchor to help pieces remain at the same position relative to each other. In the groove cut by the device an oval-shaped biscuit is inserted. For the stone industry, this biscuit is usually plastic or stainless steel.

8.6.4 Shims. Often after the weight of the countertops is added and the cabinets are loaded, there is structural movement and settling that changes the original placement of these tops. In these case it is best to adjust the tops to their original position by adding hard shims. Shims are spacers used to adjust the surface position of stone countertops.

8.6.5 Seam Polishing. When surface irregularities are present and countertops cannot be repositioned to an acceptable position, then seam polishing can be attempted. Before proceeding with any work, the area must be inspected to determine whether the seam is within grinding tolerance. 1/16" (1.5 mm) lippage is a significant amount of material to be taken down on a counter. Because of the height and frequent use of most countertops, it is viewed at and the close proximity to the eyes. Every dip and imperfection is magnified, especially in a well-lit area. The more material that must be taken down, the wider the work area must be to ensure a flat surface. A flat surface is free of any dips or wobbles in the reflection. While a seam of ⅛" (3 mm) lippage can be successfully removed, flattened, smoothed out and polished to show no distortion, it is extremely difficult and recommended to only be attempted by the most skilled technician. Lippage of 1/16" (1.5 mm) is the maximum recommended when grinding a seam in a granite countertop or vertical panel installation.

8.6.6 A seam that has been carefully prepared and installed with no obvious lippage should take approximately one to two hours to complete. Each additional 1/32" (0.8 mm) will add a significant amount of time to the process. Any additional treatment, such as adding glue to the seam, will add additional time. This process should not be considered a cure for unacceptable seam tolerances. It is more of an upgrade or premium service to provide the best possible finished product. As mentioned above, it can also performed to compensate for minor lippage instead of removal and replacing a top.

8.6.7 High sections of the seam must be identified. Because some granite slabs are prone to warpage, the high side may change positions several times from the front to rear of the counter. A warped slab or a high/low side that changes from front to back is not indicative of an inferior product, but it is a natural occurrence that sometimes cannot be avoided. Identifying the high side becomes more critical as the lippage increases. The idea is to grind the high side down to the low side: not to grind the high and low sides at the same time. Grinding only the high sections will minimize the physical work needed to flatten the seam, and it will significantly limit the chances of creating wobbles or dips in the reflection.

8.6.8 Conclusion. It is always best to practice the techniques described within this section in order to develop the skill necessary to achieve acceptable results. For practice, the ideal material would be a scrap piece of the same stone from the same lot, but that is not always possible. The next best piece to practice on would be a scrap piece of the same material from a different lot or a similar stone. Lighting on the job site, in all conditions, needs to be considered when analyzing the results. Only proceed after practicing and mastering the skills described.

9.0 RECOMMENDED TOOLS

9.1 Right-angle Polisher. The following features are recommended:

- 3-prong plug for safety
- Variable speed dial, up to 3,000 RPM
- Locking switch for continuous-on operation
- Lightweight (6 to 7 pounds, or ±3 kg)
- Variable trigger speed
- 5/8" – 11 TPI spindle thread
- 10 to 15 amps
- Constant speed under load

9.2 Turbo-style resin diamond abrasives (designed for use with granite) are the most preferred abrasive.

9.3 Rigid resin diamond abrasives are designed for use on granite floors.

10.0 RECOMMENDED PROCESS

10.1 All abrasives should be used with a generous amount of water, especially in the initial grinding and honing phases of the work. During the grinding and honing phase, abrasives below 1,000 grit are typically used. Granite, and stone sold as granite, is very hard and generates large quantities of heat when grinding, honing and polishing. The abrasives should stay lubricated and cool with the use of water.

10.2 Water supply can be reduced slightly during the polishing phase to improve contact between finer grit abrasives and the smoother stone surface. The polishing phase typically begins with 1,000 grit abrasives, then continues to the finest grit of the series. Water should not be reduced to the point that the area will dry completely.

10.3 Machine control is critical throughout the restoration process, but it is especially important during the grinding and honing stage. Any unnecessary or accidental pressure applied in the wrong area can create more work or even cause irreparable damage to the surface. The abrasives can be worked in a linear motion for part of the procedure, but the majority of the job should be done using tight, clockwise circles. Clockwise rotation is important because this will keep the slurry towards the center of the abrasive. This motion is opposite the motion of a floor machine.

10.4 When refinishing a seam or scratch in granite, the result is often slightly different than the factory finish of the surrounding areas. This is difficult to prevent, but it can be dealt with easily. During the final steps, the work area can be feathered out, or enlarged, while progressing to finer grits. When progressing to the final polishing step, fade the polish out into the surrounding area. This technique will make any difference in gloss or clarity almost impossible to detect. Client satisfaction is the ultimate goal, so leaving an obvious repair is unacceptable. Educating the client prior to repairing the stone will also help the client form reasonable expectations of what the finished job will look like.

10.5 Abrasives will often glaze over, meaning that the resin in the abrasive will cover the diamonds, rendering it ineffective. Abrasives should be dressed on a regular basis to ensure maximum efficiency.[1] Refer to the manufacturer's instructions before dressing abrasives.

[1] *Dressing* is the process of removing glazed resin, exposing the cutting abrasive.

PROPERTY	ADHESIVE TYPE						
	Polyester	Acrylic	Epoxy	Poly-Epoxy	Acrylic-Epoxy	Urethane (MPPH)	Cyanoacrylate
Usage	Most Common		Most Common				
Bond Strength	Strong	Stronger	Strongest	Stronger	Stronger	Stronger	
Cure Time	Fast (adjustable)	Fast (adjustable)	Slower	Fast (adjustable)	Fast (adjustable)	Fast (adjustable)	Fast (adjustable)
Clarity	Poor	Excellent	Good	Poor	Excellent	Excellent	Excellent
Staining Probability (dependent on stone)	Likely		Likely	Likely		Not Likely	Likely
Cost	Least Costly	Most Costly	Moderate	Middle	Most Costly	Most Costly	Most Costly
Fracture Mode	In Adhesive		Stone Fractures	In Adhesive			In Adhesive
Cosmetic Repair Difficulty	More Difficult	Easy	Most Difficult			Easy	Easy
Resistance to Dampness During Cure	Poor	Poor	Excellent	Poor	Poor	Poor	Poor
Resistance to Dampness After Cure	Poor	Poor	Excellent	Fair	Poor	Excellent	Poor
UV Resistance	Poor	Good	Fair	Poor	Good	Excellent	Good
Exterior/Interior Application	Interior Only	Ext/Int	Ext/Int	Interior Only	Ext/Int	Ext/Int	Ext/Int
Countertop Laminations/Mitered Edges	Not Recommended	OK	Best	Fair	OK	OK	Not Recommended
Doweling	OK	OK	OK	OK	OK	OK	Not Recommended
Rodding	Not Recommended	Not Recommended	OK	Not Recommended	Not Recommended	Not Recommended	Not Recommended
Flexibility	Poor	Poor	Somewhat	Somewhat	Somewhat	More Flexible	Poor
Shrinkage (after curing)	High	High	Slight	High	Moderate	Slight	Moderate
Penetration (low viscosity)	Slight	High	High	Slight	Slight	Slight	High
VOC Content	High	High	Low	High	High	Low	High
Flammability	High	High	Low	High	High	Low	High
Evaporative Rate (chemical components)	High	High	Low	High	High	Low	High
Resistance to "CHALKING"	Vulnerable	Good	Vulnerable	Vulnerable	Good	Good	Good
Resistance to "YELLOWING"	Vulnerable	Good	Vulnerable	Vulnerable	Good	Best	Good
Component Ratio Accuracy Requirement	Forgiving	Forgiving	Critical	Forgiving	Critical	Forgiving	N/A
Thorough Mixing Requirement	Forgiving	Forgiving	Critical	Forgiving	Forgiving	Critical	N/A
Shelf Life	1 to 2 yrs	6 mo to 1 yr	≥ 2 yrs	1 to 2 yrs	1 to 2 yrs	1 to 2 yrs	≤ 6 month

NOTES:

RESTORATION AND MAINTENANCE – RESTORATIVE PROCESSES

1.0 INTRODUCTION

1.1 The term *restoration* signifies "renovating, reconditioning, or returning" something to an "acceptable" or "near original" condition. Restoration starts with a comprehensive inspection of stone type, condition of the stone, and possible causes of the need for restoration.

1.2 Most often the need for restoration arises from the lack of proper maintenance. Other factors that make restoration necessary can include improper cleaning products, wear patterns, scratches, etch marks, stun marks, cracks, chips, breaks, contamination from pollutants such as smoke, leaks and floods, contact with wet environments, cold-weather treatments such as salt or ice melt, and degradation from years of normal exposure to the elements.

1.3 Processes unique to restoration include removing and replacing stained and degraded grout, removing deeper sub-surface blemishes, marks, soils, scratches, etch marks, cracks, chips, stun marks and wear patterns on stone, and filling larger holes and cracks with color-blended resins. Restoration involves the use of coarser diamond abrasives, such as 120, 100, 70, and lower grits. Refinishing involves the use of finer grit abrasives. Restoration also involves utilizing acidic or alkaline chemicals for more aggressive cleaning and stripping. During any process of restoration or refinishing, proper safety equipment must be used. For example, eye, skin and respiratory protection equipment must be used around chemicals, dust, and other hazards associated with the process.

2.0 SURFACE PREPARATION

2.1 Stripping and Removal of Coatings. When a stone surface has a coating, it must be removed before diagnosing what restoration work needs to be done to the stone. Coatings are applied to stone surfaces for several reasons. If a stone surface has been worn, scratched, or etched, a homeowner or contractor may apply a coating to inexpensively achieve a shine. Coatings are also used to seal stone surfaces. There are two distinct categories for coatings: water-based and solvent-based. Although solvent-based coatings have been the long-standing product of choice, there are many hazards associated with their use, including high VOCs and the need for respiratory and skin PPE. The technology for water-based coatings is improving rapidly, and the industry seems to be moving toward using more water-based products.

2.1.1 Coating removal is called "stripping." When stripping coatings, it is important to work in manageable areas. Failure to do so can cause the coating to cure in areas making it necessary to repeat the process. A chemical solution is used to emulsify and remove the coating from the stone surface. Most acrylic coatings that are installed on natural stone surfaces can be stripped using water-based stripping methods. Lacquers, urethanes, epoxies, and other clear paints are usually stripped using solvent-based methods.

2.1.2 Water-based Coatings. Acrylics and other waxes are stripped using a stripper properly diluted in water as directed by the manufacturer.

2.1.2.1 Dwell Time. The stripping solution is delivered with either a mop or airless pump sprayer. The solution must be allowed to sit in contact with the coating for a period of time in order to soften and loosen the coating and cause it to shrink away from the surface of the stone.

2.1.2.2 Agitation and Extraction. After the prescribed amount of dwell time, the surface is scrubbed with an abrasive pad or brush. This removes the remaining coating and converts it in to a liquid form. When the liquid becomes thick and colored, it should be removed from the immediate work area with a squeegee. The immediate work area should be examined to determine if the desired result has been achieved. If more work needs to be done, use the squeegee to move the liquid back in place to continue working the area. If the work is complete, use a wet vacuum to remove the liquid. This process is repeated until the entire area is complete.

2.1.3 Solvent-based Coatings. Lacquers and epoxies are stripped using a solvent-based stripper that is petroleum-based or from another solvent source, such as soy. Soy-based strippers tend to take longer to process, but the results are similar to petroleum strippers.

2.1.3.1 Dwell Time. Solvent-based strippers are gels and are usually applied using a brush or another type of spreading applicator. The gel is applied in such a way as to leave ¼" of the gel on the surface of the coating. Some technicians prefer to cover the treated surface with plastic to keep it wet and allow the stripper adequate time to react.

2.1.3.2 Agitation and Extraction. After the specified period of dwell time, the surface is scraped with a spatula and both the stripper and coating are discarded. Follow manufacturer's instructions for rinsing and removal of the gel.

2.1.4 Detailing is the process of completing stripping a coating. It can be done in several ways, based on the preference of the technician and the type of coating being removed. One method is to reapply the same stripper, allowing less contact time, then scrubbing and extracting it. This is done using the same methods as described above in the acrylic removal (water-based coatings). Some technicians use solvents such as mineral spirits, acetone, or alcohol to break and remove the remaining residues. Another method of detailing is done by immediate application and removal of water-based strippers.

2.1.5 Poulticing is a process of stain removal. A chemical is used to loosen the stain and an absorbent media is used to draw the stain out of the stone. While this can be used on any stone, it should first be determined if the chemical reaction might have an adverse effect of the stone. For example, when an acid is used to break down rust in any calcium carbonate based stone, the acid will etch the stone, making restoration or refinishing necessary. Poulticing requires the following steps.

2.1.5.1 Identify the stone type and the type and source of the stain. Often this can be determined by asking the building's owner, manager, or maintenance workers.

2.1.5.2 Once the source of the stain has been identified and removed, refer to Stains & Removal Procedures in the Maintenance section of this document to take the appropriate steps to remove the stain.

2.1.5.3 After the appropriate dwell time, remove the poultice from the stone. For large areas, a wet vacuum can be used to speed up the process.

2.1.5.4 Analyze the results and determine if another poultice application is needed. If not, follow up by cleaning the area with a pH neutral stone cleaner before restoring or refinishing the stone.

2.2 Masking and Protecting. Prior to stone restoration, adjacent areas should be masked. The term *mask* is commonly used to describe the process of applying protecting films or tapes to the surrounding area. The most common items that are masked include carpeting, hardwood floors, thresholds, trim or moldings, glass, and any and all dissimilar materials or stone types that could be negatively affected from contact with the cleaner, water, slurry, or polishing compound.

Delicate painter's tape can be applied directly onto painted surfaces, stained finished wood, metal, or other sensitive surfaces. Ensure no tape is covering the stone that needs to be refinished. Use caution when taping baseboard and finished hardwood because even the most delicate painter's tape may pull paint or stain off of these surfaces.

2.2.1 Adjacent areas should also be covered with other masking materials, such as static-cling painter's plastic film. Wax paper and pre-taped rolled plastic film is acceptable as well. Start at the baseboards and apply the masking material up and along the walls, cabinets, and adjacent flooring surfaces. Spot tape the masking material to these surfaces to ensure that plastic film does not fall into the working area during the restoration process.

2.2.2 Make sure to cut openings in the plastic film covering vents to allow proper airflow and to apply the film in a way that does not prevent the use of appliances and doors to a pantry, closet, or entry. Make certain that these accommodations do not allow the equipment, abrasives, or water and chemicals to cause damage. Use items like caution tape and wet floor signs if working in an area where pedestrian traffic is likely.

2.3 Cleaning. The stone should be swept, vacuumed, and wet mopped using a pH neutral stone cleaner prior to restoration. This will keep grit and dirt from doing further damage to the stone or causing damage to the abrasives.

3.0 MTL REFINISHING AND POLISHING

3.1 Preparation.

3.1.1 Equipment. There are many variations of machinery and abrasives. The list below is an example of what is typically used.

3.1.2 For lippage removal, use a heavy ridged planetary machine and/or a swing machine capable of being weighted. A variable speed machine can also be used. Access to extra weights is sometimes necessary.

3.1.3 An edging machine and/or variable speed angle grinder/polisher is the proper tool for edgework close to adjacent, dissimilar floor and wall materials. Use the same grit level of abrasives and steps that are being used on the main section of the floor.

3.1.4 A variable speed angle grinder/ polisher is recommended for wall restoration.

3.1.5 Other Recommended Equipment.

- A squeegee with a rubber head and extension pole
- A wet/dry vacuum
- Metal bonded diamond abrasives (multiple grits) for floor and handheld machines
- Marble-specific, resin-bonded diamond abrasives for floor and handheld machines (approximately 30 grit through 3000 grit or higher, depending on abrasive manufacturer)
- Transitioning abrasives to be used between metal and resin-bonded abrasives
- Marble polishing compounds
- Hog's hair pads
- Diamond dressing compound or product to dress diamond abrasives[1]
- pH neutral cleaner

3.1.6 Surface Preparation.

3.1.6.1 Mask and protect the work area as described earlier in this section.

3.1.6.2 Remove baseboards and other trim to make the edge work more accessible.

[1] To *dress* a diamond means to remove metal or resin coating over the abrasive, exposing a better cutting surface.

3.1.6.3 Use a vacuum to clean the entire floor, making sure there is no debris that could get under the machinery.

3.1.6.4 Remove any coatings or waxes from surface using the proper methods described earlier in this section. If no coatings are present, wet mop the entire area with a pH neutral stone cleaner to remove lingering debris.

3.1.6.5 Repair all cracks and chips. Allow patching material to thoroughly cure before starting the refinishing process.

3.1.6.6 Check for any missing grout at joints and caulk. Fill prior to starting the refinishing process. This will ensure that the color will be a better match when the process is complete.

3.1.6.7 If the floor was grouted with sanded grout, it will need to be removed and replaced with unsanded grout. Otherwise the sand in the grout can become dislodged and can scratch the marble during the restoration process.

3.1.6.8 If the lippage averages more than 3/32" (2.4 mm), it is better to float the floor with the same color unsanded grout to protect the tile edges from chipping and/or cracking.[2]

3.2 MTL lippage removal is the process of grinding the floor flat to help make it easier to polish and maintain.

3.2.1 Edging. Most floors installed in the United States are not laid completely flat, nor are they ground in place, meaning that the floor has lippage. Before beginning the grinding process it is necessary to consider the edges of the floor. In some cases it may be possible to stop the grinding process 3 to 6 inches from the edges. This is a method better suited for experienced technicians. For best results, it is better to grind the floor flat to the edges. Below are two edging options for lippage removal based on job conditions.

3.2.1.1 Option A. If the baseboard and other trim can be removed, the machinery can be run tight to the edge of the wall on the first abrasive step. The second and subsequent steps will also be run tight to the wall. Any scratches along the outer edges will be concealed under the moldings when they are replaced. Put a section of the new molding (baseboard and other trim pieces) in place without attaching it to verify that the edges are properly finished. If not, the edges will need to be finished by using handheld equipment.

3.2.1.2 Option B. If the baseboard and other trim cannot be removed, then this or a similar grinding process should be followed. A popular method is to use a 2 x 4-inch (50 x 100 mm) piece of wood laid flat along the outer edge of the floor. Use this as an edge to complete the first abrasive step. On the next abrasive step, flip the wood onto the 2-inch side to use as an edge. This method will help to avoid having heavy scratches against the molding. For the next steps, the edge work will need to be done using a handheld machine, such as an angle grinder/polisher, with the appropriate diamond abrasives. Several steps will need to be done by hand to get a 4 to 5-inch (100 to 125 mm) perimeter of the floor complete. The edging process should match the process that will be performed for the entire floor.

3.3 Steps 1 and 2: First grinding. Using either option A or B, above, start the first grinding step. Place the lowest grit metal bond diamonds on the machine. The technician will need to decide with which metal bonded diamond abrasive grit to start the process based on how much material needs to be removed. A good baseline choice would be a 70/100-grit metal abrasive followed by a 120/200-grit metal, copper, or electro-plated abrasive. 50-grit metal abrasives are very aggressive and are

[2] To *float the floor* means to fill any low areas with a recommended floating material.

mainly used to grind the surface of concrete, but are not recommended for use by a beginner. Abrasives should be secured to the bottom of the machine by bolts, magnets, or cup holders. A large quantity of water is necessary for this step, so take precautions not to flood lower floors or have any water escape the work area. Build dams or pour stops if needed to control water flow to adjacent or lower areas.

3.3.1 Initial Grinding should be done in an out-of-the-way corner. The metal bonded diamond abrasive will dig in to the stone upon starting the machine. Work 50 to 100 sq. ft. (4.5 to 9 m^2) sections for the first step and run the machine north to south and then east to west. The goal is to level the floor in sections and then blend it all together. This step is noisy and time consuming, signaling that the floor is not yet flat. Using a squeegee, check the area being worked. Rinse the floor and let it dry. Inspect the area closely for inconsistencies in the abraded finish. It is critical to finish this step with a uniformly abraded surface. There will typically be some low corners that will need more attention. If inconsistencies are found, continue to go over those areas until it is uniform. This step will set the precedent for the remainder of the processes.

3.3.2 An equal or greater time should be spent on the seconding grinding. Make sure that all of the previous grit's scratches have been removed. If this process is not performed correctly, it will be noticeable in the final polish of the floor. After the 120/200-grit is complete, the floor is ready for the refinishing phase of the process.

3.4 MTL Refinishing. When refinishing a floor without lippage removal, the technician must determine the abrasive coarse enough to quickly remove the deepest scratch without being too aggressive and causing additional work. In most cases it is best to begin with 200-grit diamond abrasives, then progress to 400-grit and 800-grit prior to final polishing on most marble. In some cases, to obtain the optimal outcome, it may be necessary to progress up to 1800-grit diamond abrasives before moving on to the final polishing process. For heavily soiled, worn, or damaged floors, it may be necessary to start with a 120-grit or lower abrasive. If the floor is less worn, it may be acceptable to begin with a 400-grit abrasive. Some companies manufacture a 400-grit abrasive capable of removing etching and normal wear. The type of stone being restored also determines the abrasive starting point. For travertine and other stones known to have many voids, overworking them with 200-grit abrasives or lower can open up the voids and make it necessary to fill them.

3.4.1 Picture Framing. If lippage is not removed, diamond abrasives will not abrade the low sections of the tile edge, leaving a diamond hone on the high sections but the original finish on the low tile edge. This is known as picture framing. The prominence of picture framing is affected by the thickness of the abrasives being used. Diamond abrasives are commonly produced in thicknesses of 11, 9, 4, or 3 mm. The thicker the abrasive, the more rigid it tends to be and the more pronounced the picture framing would be. If the technician is not being contracted to remove the lippage by grinding the floor flat, it is better to use 4mm or thinner diamonds with a foam spacer for additional flexibility to reduce the picture framing affect.

3.5 Step 3: Light grinding or transitioning (step 1 if lippage removal is not performed). For refinishing, it is most common to begin with 220-grit diamond abrasives. To begin, the technician attaches the abrasives to a flexible riser pad. The two most common diamond configurations are 3 or 4 abrasive pads. If using 3 abrasives, the technician should place the diamonds evenly on the drive plate (for example at 12, 4 and 8 o'clock positions), forming a triangle pattern. If using 4 abrasives, the technician should space them evenly on the drive plate (for example at 12, 3, 6 and 9 o'clock positions), forming a square pattern. Spacing of the abrasive from the outer edge of the drive plate is one method used by experienced technicians to ensure a more thorough overlap is achieved with finer grit abrasives.

3.5.1 If using a machine with a water tank, engage the water flow for 3 to 5 seconds at the beginning of the process to apply enough water to the working surface. Only enough water is needed to create a slurry with the consistency of skim milk. If water is running from the working area onto the low areas on the floor, too much water was used. Excess water will not affect the abrasive's ability to work in the initial stages, but it will cause potential work site problems such as water flowing into floor vents and through ceilings of the lower level floor. If necessary, add additional weights to the machine to increase the cut rate. Be careful when adding weight to the machine while working on filled stone like travertine. This will make it necessary to fill the voids created by overworking the stone.

3.5.2 Begin grinding in the far corner of the room, working backwards towards a natural stopping point, such as a front door or room transition. It is helpful to visualize the floor in 10 to 20 sq. ft. (1 to 2 m^2) sections and work each section moving from right to left or left to right in linear movements. When working in lower grits (200 and 400 grits), it is better to make two passes before moving down through the section. By making two passes, the technician will move the machine in a linear pattern from right to left or left to right, then reverse and move the machine over the same footprint returning to the starting point. Approximate coverage rate should be 10 sq. ft. (1 m^2) every 5 minutes when moving in a straight line. The technician should ensure 50% overlap of each pass throughout the floor. When using one pass (or 2 passes at lower grit levels), when the area is completed the technician should step back only about half of the width of the machine and reverse directions, moving at the same pace stated above. This will ensure there are no missed areas that will cause problems at the polishing stage of the project. Some technicians move the machine in circular motions. This is used across each section covering the same area, in the same amount of time, to ensure the stone is hit from different angles. Once a section is finished, all water and slurry should be moved from the working area using a squeegee, then extracted with a wet vacuum. Do not let the slurry dry on the surface of the stone. A clean, dry surface is necessary for the technician to inspect the work at each step to ensure that there are no inconsistencies in the abrasive pattern before moving to the next step. Using a squeegee to assess each area is the quickest technique. This step is accomplished more efficiently if a second technician is on hand to operate the squeegee and vacuum. This allows the first technician to move on to the next section of the floor while the second is vacuuming the previous section.

3.6 Step 4: Light grinding or initial honing step (step 2 if lippage removal is not performed). After the entire surface has been finished with 220-grit diamond abrasives, remove them from the drive plate and attach 400-grit abrasives, also using foam spacers. These abrasives should be attached in the same pattern as before, but placed slightly closer to the outer edge of the drive plate. This allows the technician to move the machine along walls and cabinets and easily overlap each grit level.

3.6.1 This step in the refinishing process can be thought of as the matte process of the honing phase. Each finer grit diamond abrasive will improve the color, shine, and clarity of the surface until a polish is produced.

3.7 Step 5: Honing step (step 3 if lippage removal is not performed). After finishing the entire floor with the 400-grit, the surface should be rinsed, vacuumed, and dried. The floor should be inspected to ensure that there is a consistent abrasive pattern and that it is ready for the next step. After 400-grit, each subsequent grit can be thought of as a polishing grit. The 800-grit abrasives should be attached to the drive plate as before but moved even closer to the edge of the plate.

3.7.1 When refinishing MTL floors, it is common to stop after finishing with 800-grit. Some technicians choose to progress to 1800-grit or even 3000-grit. With 800, 1800 and above grit steps, it is acceptable to deviate from the process above. The technician can perform just one pass in each direction. This means that if the technician is moving from right to left, when they reach the opposite edge of the working area it is acceptable to take a step back half of the width of the machine and reverse direction. This makes work with the higher grits progress much quicker. The hardness and color of the stone being refinished usually has an impact on how fine the last grit needs to be. With experience, the technician will know how far to take this part of the process.

3.8 Step 6: Polishing step (step 4 if lippage removal is not performed). Prior to polishing, make sure masking is still intact. Polishing compounds contain acidic components that could damage metal or other adjacent surfaces. This step is typically the messiest, so proper masking will reduce clean up time upon project completion. Polishing compounds are covered in much more detail in chapter 5 of this document (Equipment).

3.8.1 After the floor has been refinished using traditional abrasives, it is ready for polishing. If at this point there are still picture frames, low points on the tile that are untouched by abrasive and appear polished, they should be minimal and will be completely removed by an experienced technician during the polishing step. There are a number of compounds that will achieve the desired result. The amount of compound used and time spent in each section varies slightly based on the hardness, mineral makeup, and color of the stone and compound being used. The processes as described below are general guidelines that may need adjustment in the field depending on job site and product variables.

3.8.2 Begin in a far corner of the room, working backwards towards a natural stopping point such as a front door or room transition. Slurry should not be tracked onto other sections of the floor, because it can create etch marks. Think of the floor in sections. On most MTL floors it is acceptable to polish 20 to 30 square foot sections at time. Place the polishing compound of choice on the floor by pouring it in a circle approximately 14 inches (350 mm) in diameter. When the machine head is put in contact with the floor, it should cover the applied compound. This will reduce the spray or spread of the compound across the floor. It is common to use ¼ to 1/3 of a cup (60 to 80 ml) of compound in each section of the floor. Place a white or natural hog's hair pad to the drive plate, ensuring that the plate is centered on the pad. Drop the machine head over the powder and apply water. If using a machine with a water tank, engage the water flow for 3 to 5 seconds at the beginning of this process.

3.8.3 Once the machine has started, work in circular motions covering approximately a 20-inch diameter section, while moving in a linear pattern. As with the diamond refinishing steps, it is important to overlap the work areas to ensure an even and uniform finish over the entire floor. Most technicians will check the polishing progress with a squeegee. When the desired polish has been achieved, rinse the working area and extract the slurry from the floor. Total working time per section should be between 90 seconds and 3 minutes, depending on floor type and compound used. This step should be repeated until the entire floor has been covered and the desired results have been achieved.

3.8.4 After the floor is polished, there will be residue in grout lines and on the surface of the tile. To remove the residue, add a pH neutral stone cleaner to the water tank of the machine or apply the cleaner to the floor using a pump sprayer. Then place a clean white pad or soft brush on the machine. Starting at the far end of the floor, working backwards toward a door or room threshold, scrub the floor to remove residue from the tile and grout lines. While the cleaner is still on the floor, use a sponge to clean edges and corners to remove residue and debris. When the floor is dry, remove all tape and plastic film, then thoroughly dust mop the floor. The floor is now ready for sealing.

3.9 Sealing (using an impregnating repellant). For sealing, refer to chapter 8 of this document (Sealers). In general, a simple water test on the surface of the stone will determine its porosity. If the stone darkens when wet, sealing the stone can be beneficial. The general rule that applies to sealing stone is to start with a thoroughly clean and dry floor. Follow the manufacturer's recommendations for applying their product. A majority of sealer-related problems are caused by not following directions properly.

3.10 Other Finishes. Polished is still the most popular finish for stone. Other finishes typically seen on MTL are honed, bush-hammered, tumbled, and brushed (also known as antiqued, leathered or caressed). A floor will sometimes have a mixture of finishes in a pattern, making refinishing difficult. Understanding the factory process of creating these different finishes can be beneficial during refinishing.

3.10.1 Honing. A honed finish is achieved by stopping the process at least one step before achieving a polish. The typical honed finish is defined as being a matte or non-gloss finish without visual abrasive patterns. With MTL, this usually begins at the light grinding and honing steps.

3.10.2 Bush-hammering is a mechanical finish produced from impact by hand or a pneumatic hammer that creates a textured surface. It is typically used on cubic material; stone with a thickness greater than 2 inches (50 mm).

3.10.3 A Tumbled Finish is usually achieved by placing smaller pieces of stone tiles in a tumbler, causing a chipped and worn look on unused pieces of stone. Bush-hammering, sandblasting and other methods can be used to give larger stones a tumbled look.

3.10.4 A Brushed Finish is achieved by using abrasive brushes in place of rigid abrasives to hone the surface of the stone. Materials that have a wide range in hardness usually produce the most diverse texture using this technique. Materials that do not contain a wide range of minerals with varying degrees of hardness are often textured mechanically before being honed with the abrasive brushes. These brushes usually start at 36 grit and continue to 1200 grit for an even finer finish. It is always best to research and experiment with different finishes to avoid damaging the installed floor.

4.0 GRANITE REFINISHING AND POLISHING

4.1 Process. The scope of this section includes all stones traded as granite by the stone industry. Refinishing and polishing a granite floor is considered a pinnacle achievement for any stone refinisher. A sound plan and the right tools and equipment are required. The technician must research available machinery and abrasives. Chapter 5 (Equipment) is a good place to begin this research. The machine and abrasive needs will vary.

4.1.1 Technicians must be patient when working on granite. To achieve a factory-like finish, some technicians may state that granite floors can be refinished without grinding by using only resin diamond abrasives and granite polishes. This is possible under the right conditions and on the right floor, but there are many variables that affect the results.

4.1.2 Granite refinishing becomes necessary for several reasons. Technicians may be called to restore a badly worn or abraded surface or a new floor installation with excessive lippage. Another reason would be to change the existing finish (changing from a polished to honed or honed to polished floor) for any number of reasons. It is also possible to be called in to brush or texture a granite floor. Textured finishes are becoming more popular each year, so it is important to understand the process.

4.2 Equipment. There are many variations of machinery and abrasives. The list below is an example of what is typically used.

- A heavy ridged planetary machine and/or swing machine capable of being weighted. A variable speed machine is preferred. Access to extra weights can be necessary.
- An edging machine and/or variable speed angle grinder/polisher
- A squeegee with a rubber head and extension pole
- A wet/dry vacuum
- Metal bonded diamond abrasives (multiple grits) for flor and handheld machines
- Granite-specific, resin bonded diamond abrasives for floor and handheld machines - approximately 30 grit through 3000 grit or higher (depending on manufacturer)
- Copper-bonded diamond abrasives or hybrids used for transitioning between metal and resin-bonded abrasives
- Other transition abrasives for use after grinding to remove any excess scratches and prepare surface for honing
- Granite final polishing compounds
- Hog's hair pads for polishing
- Diamond dressing compounds or product to dress diamond abrasives
- pH neutral cleaner

4.3 Surface Preparation.

4.3.1 Mask and protect the work area as described in section 2.2.

4.3.2 If possible, remove baseboards and other trim to make edge work easier and more accessible.

4.3.3 Use a vacuum to clean the entire floor, making sure there is no debris that could get under the machinery.

4.3.4 Remove any coatings or waxes from the surface using the methods described in section 2.1.

4.3.5 If the floor was grouted with sanded grout, it must be replaced with unsanded grout.

4.3.6 If lippage averages more than 3/32" (2.4 mm), it is better to float the floor with the same color unsanded grout to protect the tiles from chipping and/or cracking.

4.4 Granite Lippage Removal. Before refinishing, all lippage must be eliminated so that the floor is flat. This is a once in a lifetime process for a granite floor that increases its value exponentially.

4.4.1 Edging. Edges must be considered before beginning the grinding process. In some cases it may be possible to stop the grinding process 3 to 6 inches from the edges. This is a method better suited for experienced technicians. For best results, grind the floor flat to the edges. Below are two edging options for lippage removal.

4.4.1.1 Option A. If baseboards and other trim can be removed, machinery can be run tight to the edge of the wall on the first abrasive step. The second and subsequent steps will also be run tight to the wall. Any scratches along the outer edges will be concealed under the replaced moldings (baseboards and other trim pieces). Put a section of the new molding in place without attaching it to verify that the edges are properly finished. If not, the edges will need to be finished by using handheld equipment.

4.4.1.2 Option B. If baseboards and other trim cannot be removed, then this or a similar grinding process should be followed. Use a 2 x 4-inch piece of wood laid flat along the outer edge of the floor. Use this as an edge to complete the first abrasive step. On the next abrasive step, flip the wood onto the 2-inch side to use as an edge. This method will help avoid having heavy scratches against the molding. For the next steps, the edge work will need to be done using a handheld machine, such as an angle grinder, with the appropriate diamond abrasives. Several steps will need to be done by hand to get a 4 to 5-inch (100 to 125 mm) perimeter of the floor complete. The edging process should match the process that will be performed for the entire floor.

4.5 Step1: First grinding step. Using option A or B (above), start the first grinding step. Place the lowest grit metal bond diamonds on the machine. The metal bonded diamond abrasive grit used to start the process should be determined based on how much material needs to be removed. Although many variations can be used, a good baseline choice would be a 46/50 grit followed by a 100 grit abrasive (depending on the abrasive manufacturer).

4.5.1 Abrasives must be secured to the bottom of the machine by bolts, magnets or cup holders to ensure the first step goes smoothly. This step requires a great deal of water; build dams or pour stops if needed to control water flow to adjacent or lower areas. Start the machine at approximately 300 to 500 rpm, then find a speed that works best with the abrasives and the granite. Work 50 to 100 sq. ft. (4.5 to 9 m^2) sections for the first step and run the machine north to south, then east to west. Level the floor in sections and then blend together. It will take approximately 30 to 60 minutes for 50 to 100 square feet. This step is noisy, indicating that the floor is not yet flat. When the machine quiets down and becomes smooth, the floor is getting flat. This step sets the precedent for the remainder of the process.

4.5.2 Using a squeegee, check the area being worked. Rinse the floor and let it dry. Inspect the area closely for inconsistencies in the abraded finish. This step must finish with a uniformly abraded surface. If inconsistencies are found, continue to go over those areas until they are uniform. Areas with negative lippage should be worked using handheld machinery to avoid the risk of overgrinding, but be careful when using handheld machinery not to create a dip in those areas. It may be a better to add weight to the machine and make the corrections on the second step.

4.6 Step 2: Second grinding step. When the first step is complete and consistent, begin the second grinding step. Attach the next set of grinding abrasives to the machine. The machine can be run in any direction that ensures adequate surface coverage. Work the entire floor and remove all scratches from the previous grit. Run the machine as close to the edge as possible. After completing this step, rinse, dry, and examine the floor. This step must be finished with a uniformly abraded surface. Once the abraded surface is consistent, move to step 3. If using option B (described in section 4.4.1.2), complete the edging work using a handheld machine before moving to step 3.

4.7 Step 3: Transition step. This step transitions from metal-bond to resin-bond diamond abrasives. Use copper, ceramic, phenolic, or granite-specific resin-bond diamond abrasives to remove scratches from the last grinding process. It is usually best to drop to a lower grit than the last metal-bond grit used. For example, if the last metal bond grinding grit was a 100, step 3 should start with a 50 grit transition abrasive. Remove all scratches from previous grits and finish with a uniform abrasive pattern. If using option A, continue working each grit to the edge of the floor. If using option B, work the grit over the last metal cut to start blending each cut into the edge previously created. Clean, dry, and inspect the entire floor for uniformity before moving to the next step.

4.8 Steps 4 through 10: Honing and polishing steps. When floor is thoroughly clean and dry, inspect before proceeding.

4.8.1 Step 4. Attach 50 grit (or comparable grit) resin-bond diamond abrasives to the machine. The machine can be run in any direction that ensures adequate coverage of the surface. Work the entire floor and remove all scratches from the previous step's grit. After completing this step, rinse, allow the floor to dry, and inspect. If the abrasive pattern is uniform, move to step 5.

4.8.2 Step 5. Attach 100 grit (or comparable grit) resin-bond diamond abrasives to the machine. Continue with the same process as Step 4.

4.8.3 Step 6. Repeat step 4 using 200 grit resin-bond diamond abrasives.

4.8.4 Step 7. Repeat step 4 using 400 grit resin-bond diamond abrasives.

4.8.5 Step 8. Repeat step 4 using 800 grit resin-bond diamond abrasives.

4.8.9 Step 9. Repeat step 4 using 1500 grit resin-bond diamond abrasives.

4.8.10 Step 10. Repeat step 4 using 3000 grit resin-bond diamond abrasives.

4.8.11 Considerations. Inspection after Step 7 is typically more critical as you move into the honing and polishing phases. This can give you a glimpse of the consistency of the final polish. If the surface is uneven, it is imperative to go back over the floor until it is consistent. The speed of the machine can be increased when using the finer grit abrasives. For example, on Step 9 (1500 grit) the speed can be set to 1,100 RPMs. During the use of finer grit abrasives there is less material being removed and the water required to keep the stone and the abrasives cool is reduced. A heavy water flow during this phase increases the changes of hydroplaning or reduced stone to abrasive contact. However, too little water will cause the abrasive to heat up and glaze over.

4.9 Step 11: Final polishing step. The final polishing will only be as good as the honing of the surface. Simply put, if the floor is honed well, the polishing results will reflect that work.

4.9.1 There are many polishing compounds on the market, and each has its own strengths and weaknesses. For highly competitive jobs, an inexpensive but effective compound is often used. Stone that is polished with a chemical compound should receive a final cleaning with a pH neutral cleaner. The easiest compounds to use will be compounds that can be worked wet. Some companies prefer granite crystallizers that are applied using #1 grade steel wool.

4.10 Sealing (using an impregnating repellant). For sealing, refer to chapter 8 of this document (Sealers). In general, a simple water test on the surface of the stone will determine its porosity. If the stone darkens when wet, sealing the stone can be beneficial. The general rule that applies to sealing stone is to start with a thoroughly clean and dry floor. Follow the manufacturer's recommendations for applying their product. A majority of sealer-related problems are caused by not following directions properly.

4.11 Other Finishes. Different finishes are increasingly becoming more popular for natural stone. Finishes typically seen are honed, flamed, bush-hammered, and brushed (also known as antiqued, leathered or caressed). Most granite can be flamed and this is a popular choice for improving slip resistance. On occasion, a floor will have a mixture of finishes in some form of pattern, making refinishing difficult. Understanding the factory process of creating these different finishes can be beneficial when refinishing it.

4.11.1 A Honed Finish is achieved by stopping the process at least one step before achieving a polish. The typical honed finish is defined as being a matte or non-gloss finish without visual abrasive patterns. With granite, this usually begins at Step 7 and continues to Step 9.

4.11.2 A Flamed Finish is achieved by using and oxygenated torch to heat the surface of the granite to approximately 1,600 degrees Fahrenheit. This process is not recommended for installed stone without thorough research and trials.

4.11.3 A bush-hammered finish is typically used on cubic material. It is a mechanical finish produced from impact by hand or a pneumatic hammer that creates a textured surface.

4.11.4 A Brushed Finish is achieved by using abrasive brushes in place of rigid abrasives to hone the surface of the stone. Materials that have a wide range in hardness usually produce the most diverse texture using this technique. Materials that do not contain a wide range of minerals with varying degrees of hardness are often textured mechanically before being honed with the abrasive brushes. These brushes usually start at 36 grit and continue to 1200 grit for an even finer finish. It is always best to research and experiment with different finishes to avoid damaging the installed floor.

5.0 GRANITE COUNTERTOP POLISHING

5.1 Granite is naturally resistant to scratches, chemicals (it is not acid sensitive), and moisture. Because of this, most granites maintain a high quality finish. It is not unusual for granite countertops to be serviced in 5-7 year windows or longer. In most cases only spot refinishing is required to remove a scratch or other imperfections from a portion of the countertop. These smaller areas can be polished to blend in with the entire countertop. Because they are naturally scratch resistant, granite countertops rarely, if ever, require refinishing using diamond abrasives. When they do, abrasives up to 3,500-grit followed by a buff abrasive pad should be used. Buff pads typically come in black or white varieties and contain extremely high grit abrasives (8,000 or 11,000-grit). The use of the buff abrasive pad will result in a high quality mechanical finish. When polishing granite, the better quality mechanical finish the technician can achieve, the easier it is to achieve an acceptable polish using chemical and abrasive granite polishing compounds.

5.2 Equipment. The following equipment is recommended for granite countertop polishing:

- Variable speed right-angle grinder/polisher
- 3, 4, 5, or 7-inch backer pad
- 3, 4, 5, or 7-inch diamond abrasives
- Water supply (spray bottle or water supply for a center water feed polisher)
- Squeegee
- Granite polishing compound
- Hog's hair burnishing pad
- pH neutral cleaner

5.3 Surface Preparation. Before beginning the refinishing process, adjacent areas (including floors, cabinets, walls, mirrors, ranges/cooktops, and refrigerators) should be masked. Delicate painters tape can be applied directly onto painted surfaces, finished wood, metal, and other sensitive surfaces. 2" painter's tape can also be applied to the edge of the counter, leaving approximately 1 to 1½-inches of tape above the surface of the countertop. This will reduce splatter and necessary cleanup. Use caution when taping painted cabinets and finished hardwood because even the most delicate painter's tape may pull paint or stain off of these surfaces.

5.3.1 Other masking materials should also be used. The most common masking material is static-cling painter's plastic film. Wax paper and pre-taped rolled plastic film are also acceptable. Starting at the top of the cabinets just below the countertop, unravel masking material down and along cabinet faces. Then use a small piece of plastic to cover the range or cooktop. Plastic film or canvas tarps should be laid on the floor in the working area. Review the surroundings and cover furniture or other items that are close enough to be hit by splatter with plastic film or canvas tarps. Masking for countertop refinishing is designed to catch splatter. The splatter caused by countertop refinishing and polishing compounds will generally not stain or damage floors, cabinets, or nearby furniture, but protecting these surfaces with plastic film provides a professional look and greatly reduces clean up upon completion of the project.

5.4 Refinishing. Begin by identifying the area that requires refinishing. If it is a small scratch or small area, use a china marker or lumber crayon to circle the scratch.

5.4.1 Use a variable speed right-angle grinder with a 3, 4, 5, or 7-inch backer pad. It is common to refinish small areas using 3 or 4-inch diamond abrasives. Spray the working area with water. Allow for consistent and even water distribution; do not flood the surface. Choose a coarse grit abrasive (typically 50, 100, or 200-grit) and attach it to the backer pad. Use the highest or finest grit abrasive capable of effectively removing the imperfection. This will decrease the steps necessary to achieve the desired result.

5.4.2 After selecting the abrasive, place the machine flat on the surface and run the machine in an even, consistent pattern across the working area. The first step is not completed until the imperfection is removed. It may be necessary to pause and spray more water onto the surface if a constant water supply is not being used. Ensure that the edge of your working pattern (also known as the scratch profile) is even and does not show arrant scratches. Stop to clean slurry off the working area, using a rag or small squeegee to check progress. When finished with each step, clean the working area and dry it for inspection. Inspect the area closely to ensure that there is a consistent abrasive pattern. Once the imperfection has been successfully removed and the abrasive pattern is consistent, move to the next step.

5.4.3 Repeat the process above with the next finer-grit abrasive. Overlap the previous scratch profile by about 25% of the abrasive footprint to prevent a halo. Continue by moving the machine in a consistent pattern across the designated work area with each abrasive. The abrasive part of the work is completed when technician has progressed to the use of the buff pad and achieved a near factory shine mechanically. By overlapping and thoroughly inspecting the work, the reflective finish will be the same from the center to the outside of the scratch profile.

5.4.4 When using higher grits (1000-grit and finer) some technicians prefer to use the tool wet-to-dry. To do this, use a sprayer to apply a mist of water on to the work area. Start the machine on the lowest speed, applying more pressure than usual to the machine. Work the area back and forth until the area begins to dry out. As the area dries out, the abrasive will start to grip the surface and jerk the machine. Apply more pressure to the tooling head, creating more friction and heat. The work area will completely dry out. As this happens, continue applying pressure while increasing machine speed no higher than the middle speed setting of approximately 3,500 RPMs.

5.4.5 At this point, the work area should start to show a polish but the color will appear muted or greyed in comparison to the rest of the countertop. The depth and clarity of the reflection in the working area will be slightly diminished when compared to unworked areas. The surface is now ready for the use of polishing compound.

5.4.6 There are several different types of granite polishing compounds. Some are strictly abrasive products that contain aluminum or tin oxide. Others are creams that combine chemical and abrasive technology. Regardless of the type of compound used, most technicians use a hog's hair burnishing pad that is cut to fit the backer pad (pad driver) to finish polishing the work area.

5.4.7 If a traditional powder is used, add enough powder to cover the area. Spray with enough water to wet the powder slightly, then place the machine on the wet powder. With the dial set to the lowest speed, start the machine. The process should produce a thick slurry of polishing compound. As the slurry dries onto the surface, spray a small amount of water to keep the surface and polishing compound wet. As the compound dries, add a little more, apply pressure, and increase the speed of the machine. The added pressure will cause friction and heat that creates a better polish.

5.4.8 If using a granite polishing cream or paste, place a quarter-sized amount on the surface of the work area for a section approximately 8-inches in diameter. Attach a 5 or 7-inch (125 or 175 mm)foam backer pad to the machine and use a hog's hair burnishing pad cut to fit the backer pad. Start the machine at the lowest speed to spread the product around on the surface in small sections. Use moderate pressure to work the product into the surface in a linear or figure-8 pattern. As the heat generated by the machine dries the cream, increase the speed of the machine and maintain a light pressure. After a few passes it may be necessary to increase the speed to the middle setting of approximately 3,500 RPMs and burnish the surface to achieve the high-gloss deep color of a factory finish. It may take multiple applications to achieve the desired finish and depth of color. The surface is ready for sealing when the desired level of polish and depth of color are achieved.

5.5 Cleaning and Polishing. Because granite holds up so well and rarely requires refinishing, technicians are often asked to clean and polish granite countertops. In these cases, it is common to polish the entire countertop surface with a granite polishing cream using a hog's hair burnishing pad or a spray polish/crystallizer with a steel wool pad. The hog's hair pad or steel wool pad is cut to fit the machine's backer pad. Both processes remove grimy buildup that dulls a countertop. This process enhances the color and shine of the stone and restores the surface to the level of finish the customer desires.

5.6 Sealing (using an impregnating repellant). For sealing, refer to chapter 8 of this document (Sealers). In general, a simple water test on the surface of the stone will determine its porosity. If the stone darkens when wet, sealing the stone can be beneficial. The general rule that applies to sealing stone is to start with a thoroughly clean and dry floor. Follow the manufacturer's recommendations for applying their product. A majority of sealer-related problems are caused by not following directions properly.

6.0 CRYSTALLIZATION

6.1 The term *crystallization* (also known as *vitrification* and *re-crystallization*) describes the act of polishing MTL and other surfaces containing calcium carbonate. Crystallizers usually contain magnesium hexafluorosilicate or a like compound. The compound is designed to react with the surface of MTL and chemically etch a shine into the surface. Although the majority of crystallizers are liquids, magnesium hexafluorosilicate is naturally a solid white salt and is present in many commercial marble polishing powders and pastes.

6.2 The polishing medium used during crystallization is a hog's hair pad, a white pad, or a steel wool pad. Steel wool is the most popular polishing medium used to crystallize a MTL surface. However, many newer products have been introduced that can be successfully used with hog's hair or white pads. When using steel wool, the fragments left behind can rust causing staining to the stone and grout. Vacuuming or using a magnetic broom should always follow the use of steel wool to ensure that all fragments are removed.

6.3 Popularity. Crystallization is popular is because the average well-trained maintenance professional can crystallize 300 (or more) square feet per hour. A steel wool pad typically lasts 300 to 500 sq. ft. (~30 to 50 m^2) when both sides are used. Crystallization is performed with a janitorial swing machine (also known as a janitorial buffer or floor buffer). A drive plate with sufficient "grab" to turn the steel wool is all that is needed. The operator usually pours the crystallizer, undiluted, into a chemical squirt bottle and sets the nozzle to a medium mist.

6.4 Process. Start from the upper left of a room or area (based on the revolutionary turn of the machine) and work toward the door or exit. Add a small amount of liquid to the surface and move the machine with the polishing media across it. Buff the surface until the streaks and liquid disappear. The movements should be overlapping to make sure all spatter marks are removed. Most technicians will work a 5 sq. ft. (0.5 m^2) area and work backwards, but some technicians work larger areas. After a short period of time, the steel wool pad will become loaded with residue from the buffing process and removal of excess crystallizer. When this happens, turn the pad over and buff the area just completed to remove final residue. The entire service area will be treated in the same way.

6.5 Dust will settle on the floor after polishing is complete. This is usually from the steel wool used in the process. Clean the area with a vacuum, magnetic broom, or microfiber dust mop to remove all steel wool residue. If the cleanup is not performed in a diligent manner, adding water from mopping and maintenance will react with the steel wool fragments and cause the floor to yellow and rust. This is usually seen on the edges of the tiles, in the grout, and sometimes on the surface of the stone.

NOTES:

RESTORATION AND MAINTENANCE – SEALERS

1.0 INTRODUCTION

1.1 Sealing is the process of applying chemical solutions—known as sealers—to stone that, when cured, alter the inherent absorption qualities, increase the resistance to staining, and/or alter the stone's appearance for aesthetic enhancement.

1.2 Sealing natural stone is a science involving knowledge from disciplines such as geology, construction, chemistry, and maintenance. The larger question is, "Does stone have to be sealed?" The short answer is, "No." Before dimension stone was cut and polished and set in a home or office, it was just a rock in the ground. There are millions of unsealed stone installations with which humans have interacted for hundreds, if not thousands, of years. Why is stone sealing now common? Modern consumers want to protect stone's appearance, reduce maintenance costs, and preserve the investment that stone surfaces represent.

1.3 Because of different performance goals, desires, and perceived acceptability for stone use, there are different product offerings in the market. The sealer product selection needs to be made based on sealer type and other criteria as described within this document. There are three basic categories of sealers commonly used in the stone industry.

2.0 TYPES AND CHARACTERISTICS OF SEALERS

2.1 Impregnating Repellents (also known as impregnators and penetrating sealers) are chemical compounds known as "Solids" or "Actives" (a contraction for "active ingredients") that are carried by water or a solvent ("Carriers") into the interior of the stone. When cured, these compounds provide resistance to stain sources or contaminants that are water or oil-borne. Impregnating repellents minimally affect the stone's color, texture, or finish, and require a minimum level of maintenance. They are composed mostly of silicone-based chemicals and fluoropolymers, and are ineffective against highly acidic or alkaline chemical etching. They require the use of pH-neutral cleaners. Most importantly, they allow moisture vapor transmission (MVT), which is the natural process of moisture transfer through the stone.

2.2 Color-enhancing Impregnators are a sub-category of impregnators that contain a higher concentration of actives or solids that darken and enrich certain natural stone colors. They are more viscous in consistency, moisture sensitive, require greater care during application, and should be applied when the stone is as dry as possible. Be sure to consult the manufacturer's directions for specifics. Color-enhancing impregnators also allow vapor transmission (MVT). They accentuate color and contrast, texture, and finish variations in the stone and grout and may create a light sheen.

2.3 Film-forming sealers (also known as "coatings" or "topical coatings") contain higher concentrations of actives compared to impregnating repellents or color-enhancing impregnators. The actives are deposited by a carrier onto the stone's surface, where they cure and ultimately create a hardened film. The film-forming sealer creates a sacrificial physical barrier between the stone's surface, potential contaminants, and the environment. They can consist of acrylic, urethane, and epoxy chemical compounds.

2.3.1 Important Characteristics of Film-forming Sealers. Film-forming sealers protect the stone's factory finish and diminish the effects of pedestrian and vehicle traffic. They can effect slip-resistance when wet, unless combined with grit additives, and can create various types of finishes, from matte to high-gloss. Film-forming sealers can enhance color, texture, and finish variations in the stone and grout. They are subject to abrasion, which can breach the integrity of the protection the film-forming sealer affords and reflect the wear patterns of foot traffic. In the presence of Moisture Vapor Transmission (MVT) they could turn milky white. Film-forming sealers require additional cleaning steps and require the surface of the stone be maintained by high-speed burnishing and/or recoating at regular intervals.

2.4 Sealer Components. Sealers are comprised of two main components: carriers and actives (also known as "solids"). The primary carriers are water and solvent, and new carriers are being tested regularly.

2.4.1 Carriers. The carrier component of a sealer facilitates the delivery of the active ingredients to the interior of the stone.

2.4.1.1 Solvent-based Carriers usually contains higher amounts of Volatile Organic Compounds (VOCs). Most solvent-based sealers have strong, distinctive odors and require the use of Personal Protective Equipment (PPEs) and adequate ventilation during application and curing. Solvent-based sealers are sensitive to ambient air and surface temperatures. The stone should be dry. Excessive moisture inhibits a sealers' curing and may also prevent adequate protection. What constitutes "a dry stone" needs to be defined by reading the instructions or contacting the sealer's manufacturer. Generally, solvent-based sealers are better for higher density stones with lower porosity.[1]

2.4.1.2 Water-based Carriers usually have less VOC components, less odor, and less environmental regulations concerning their use. They rarely require PPE, though the method of application may require breathing protection. Consult the manufacturer's documentation for information. Water-based sealers are sensitive to lower temperatures, but less sensitive to higher moisture content in the stone. Consult sealer manufacturer for specific recommendations. Generally, water-based sealers are better for lower density stones with higher porosity.

2.4.2 Actives. Also known as "solids," actives are the chemicals that penetrate the stone and cure a few millimeters below the surface. They reside in the intercrystalline boundary areas and pores of the stone.

2.4.2.1 Silicone-based chemicals are used primarily for repelling water or water-borne contaminants. This quality is commonly referred to as hydrophobic. The actives for this category include silane, siloxane and silicone.

2.4.2.2 Fluoropolymers are used primarily for repelling oil or oil-borne contaminants. This is trait is commonly referred to as oleophobic.

2.5 General Characteristics of Sealers.

2.5.1 Sealing can alter the inherent absorption qualities of stone, increase resistance to staining, and/or alter the stone's appearance for aesthetic enhancement. In certain situations, sealers can be employed to improve slip resistance.

2.5.2 There are some conditions in which sealing stone could be ineffective or dangerous. Moisture, vapor, UV light, landscape, and chemical exposure are all variants that may render sealing inappropriate. For instance, freeze-thaw conditions and standing water can create slip hazards, and have the potential to damage material over time. Careful consideration of the activities and the manufacturer's recommendations will aid in the selection and application of a sealer for a particular installation.

[1] *Density* is the weight of material expressed as its mass divided by volume; *porosity* is the ratio of a stone's pores to its total volume.

2.5.3 Sealers are maintenance products and require periodic reapplication. Even though some manufacturers warrant their sealers for certain time periods, because these sealers dissipate and lose their protective quality as time goes on, resealing is required.

2.5.4 Sealers do not alter a stone's molecular structure. In stone restoration work, a class of products known as consolidators and densifiers do reintroduce mineralogical components lost from the weathering process in order to slow the natural deterioration of the stone. These products are not considered sealers.

2.5.5 Depending on the type, sealers do make stone surfaces more resistant to water, oil, contaminant and weather. Some sealers repel both types of contaminants. However, they are not weatherproofing and waterproofing agents. They act as a barrier, but will break down through prolonged exposure to contaminants.

2.5.6 Sealer performance is not dependent on whether a product is solvent-based or water-based. There are varying degrees of quality amongst the water-based and solvent-based sealer categories. The sealer's quality is based on purity of the carrier, quality of the actives used, and concentration of actives in the product.

2.5.7 Sealer performance is dependent on the type of stone, the demands on it, and the location of the installation. Interior or exterior location, traffic levels, and climate extremes of the installation are contributing factors to product performance and will help determine the sealer selected. Tests should be conducted to ensure the right sealer is matched appropriately to a particular stone and application.

2.5.8 Sealer performance is only as good as the technician applying it. Following the manufacturer's directions is the best way to ensure a successful result. Thorough cleaning and preparation of a stone with approved chemicals and procedures, adequate drying time, and proper application techniques are critical to ensure a successful application.

3.0 DETERMINING THE APPROPRIATE SEALER

3.1 After the decision has been made to use a sealer, it is important to narrow the offerings. When determining which sealer is best suited for a material, stone care professionals must take several factors into account. It is best to begin with the identification of the stone's geological classification and identify the protection needed.

3.2 Geological Classification. Proper stone identification is important when applying sealers. Each stone classification has performance parameters. These parameters help establish the suitability of a particular stone for the considered or existing installation.

3.2.1 Hardness is a measure of the mineral's resistance to scratching.

3.2.2 Permeability is the capability of a porous rock or sediment to permit the flow of fluids through its pore spaces.

3.2.3 Chemical Sensitivity is a reaction to acid or alkaline. Natural stone is categorized into three basic geological classifications by their respective formation processes: sedimentary, metamorphic and igneous. Additionally, stones in each category can be either calcareous or siliceous, based on their mineral components. These mineral components determine the reactiveness of the stone to acid or alkaline solutions.

3.2.3.1 Calcareous Stone is composed mainly of calcium carbonate, a chemical compound commonly found in natural stone, shells, and pearls. Calcium carbonate is sensitive to acidic solutions, so mild, non-acidic cleaners are recommended.

3.2.3.2 Siliceous Stone is composed primarily of silicates such as quartz, feldspar, and mica. As such, siliceous stone is generally resistant to most acids found in kitchen settings. Acidic cleaners are still not recommended, because these stones may contain trace levels of minerals that are vulnerable to acid attack, or the cleaners may contain levels of one of the few acid types that attack silicates such as hydrofluoric acid (e.g., toilet bowl cleaners, rust removers, chrome wheel cleaners, plant food and wood treatments containing ammonium bifluoride).

Geological Classification Chart

	Sedimentary	Metamorphic	Igneous
Calcareous	Limestone Travertine Onyx	Marble Serpentine	
Siliceous	Sandstone	Slate Quartzite Soapstone	Granite

3.3 Appropriate Material for the Intended Use. An analysis of whether the stone is suitable for the proposed use or existing installation is important. First, the environment needs to be identified. This is often done by consulting plan specifications and post-construction manuals and talking to sources such as the homeowner or tenant, building or maintenance manager. Once the nature of the use or environment is determined, stone professionals can help specify materials best suited for that use or environment. Possible sources to determine suitability can be the stone supplier, a stone maintenance and restoration contractor, an installation contractor, a stone geology resource, or NSI.

3.4 Determining the Potential Source of Staining or Problems. Residential homes require some different care and considerations than commercial or industrial buildings. Because of the different elements of exposure, interior stone behaves differently from exterior stone. Understanding the various types of contaminants and the environmental impact on stone applications will provide the information to decide the appropriate sealer. The product performance expectations must be realistic. It is important to note that neither impregnating repellents nor film-forming sealers can prevent normal weathering and deterioration from normal traffic and use.

3.4.1 Residential and Commercial Interiors. Always identify the possible sources for stains, evaluate the materials, stones, and sealers relative to the activities and stain sources present, and determine suitability of masking adjacent surfaces prior to sealing.

3.4.1.1 Considerations for Residential Interiors. The type of stone and susceptibility to reaction, abrasions, and other breakdown should always be considered, especially when working with polished marble and granite or honed travertine and limestone. The use area should also be considered, especially in high-traffic areas such as kitchens, family rooms, and bathrooms/showers. Other factors to consider in residential applications include: family size, pets, and associated use; foods and liquids (lemon, vinegar, wine, juices, and oils); cleaning chemicals (toilet bowl cleaners and citrus cleaners); and personal toiletries (lotion, shampoo, conditioner, hand soap).

3.4.1.2 Considerations for Commercial and Industrial Interiors. Factors to consider in commercial and industrial interiors include: issues caused by luggage, bell carts, dollies, and other equipment; water features and fountains; interior landscaping; proximity to food courts, restaurants, and common areas; maintenance practices and needs; slip resistance and safety; increased volume and traffic patterns; and sealer odors multiplying through HVAC systems.

3.4.2 Exteriors

3.4.2.1 Considerations for Exterior Applications. Vapor transmission must be achieved in exterior applications. A lack of vapor transmission can lead to spalling and other issues. Several other things must be taken into consideration for exterior applications, including: biological growth (moss, algae, lichen, and mold), environmental conditions (freeze-thaw, salt water, high water tables, acid rain, pollution, UV exposure, and cold weather treatments such as grit or salt), vehicle stain sources (oils, antifreeze, and rubber marks), pitch of surface (should be 2%), landscape, fertilizer run-off, irrigation, and water run-off systems.

3.4.2.2 Further Considerations for Exterior Applications. Exterior installations are unique, because they will interact with climate and environmental forces as well as human activities. It is important to consult with manufacturers to determine their sealer's suitability with the stone and installation. A sealer's resistance to ultraviolet light degradation impacts its effective lifespan. In order to prevent freeze/thaw issues, a sealer used in an exterior installation should have an acceptable percentage of Moisture Vapor transmission (MVT).

3.5 Determining the Desired Finished Appearance. The choice of the final appearance of the stone is driven by aesthetic considerations, which will be determined by an architect, interior designer, and/or the owner of the property. Aesthetics is a major determinant in sealer selection. As mentioned above, different sealer types provide unique options for appearance. Impregnating repellents provide resistance to staining while retaining the natural appearance and beauty of stone. Color-enhancing impregnators can darken or bring back the color of polished stone to stone that has been textured or honed. Film-forming sealers provide a mechanical or physical barrier between the stone and potential stain sources. Film-forming sealers will also alter the natural appearance of a stone, changing sheen of the surface from a matte finish to a reflective finish or from a reflective finish to a matte finish.

3.5.1 Performance Expectations. There can be a trade-off between appearance and functionality. For instance, a film-forming sealer provides protection against chemical exposure to the stone, but usually gives the surface a plastic-like look. Each installation is unique and the sealer selection will require consideration of a number of variables, as listed in the next section.

3.5.2 Factors to Consider. Impregnating repellents are best for maintaining a stone's natural appearance. Color-enhancing impregnators best enrich a stone's color and character. Film-forming sealers are best for creating low-gloss, semi-glass, and high-gloss finishes.

3.6 Determining the Desired Level of Maintenance. Maintenance costs are often overlooked in the process of selecting a stone and sealers. Maintenance is the most important factor in preserving the appearance and protection of a sealed stone. The client's expectations need to be clarified in order to best assess the material and sealer for the desire outcome. Use and traffic, compounded with sealer choice and material used, can all affect maintenance needs.

3.6.1 Residential Clients typically expect a high level of presentation, but may fail to consider preservation requirements. It is important to set achievable expectations. Many residential clients want a material that usually requires a high level of maintenance to be maintenance free. Residential environments are typically maintained on a sporadic basis, depending on the commitment of the owner to the cleaning process.

3.6.2 Commercial Clients, Such as Hotel Facilities Managers, are often concerned about cost, durability, and safety. There are times when these clients have similar desires to the residential client, but there is usually very little emotion tied to their objectives. Commercial environments are typically maintained on a daily basis by either in-house personnel or contracted cleaning firms.

3.6.3 Guidance in Sealer Selection. Type of sealer used and installation location will dictate the level of maintenance needed. Maintenance refers to regular periodic cleaning with the appropriate products and procedures. The installation type determines the cycle of cleaning.

3.6.4 Maintenance Needs. Maintenance charts, lists of acceptable products and equipment, training material, and training sessions with cleaning personnel are important in developing a realistic plan to sustain the service life of the sealed surface. Sometimes the cleaners recommended for use on stone with an impregnating repellent will contain small amounts of the sealer. This will help increase or eliminate the interval for reapplication. Check the specific product manufacturer's guidelines as to the maintenance of their products. A thorough understanding of an end user's expectations involves balancing form and function when applying sealers and because each installation is unique, sealer selection involves the consideration of multiple variables. Impregnating repellents provide longer-term protection and are less costly, due to their less-frequent maintenance needs. Also, there needs to be periodic reevaluation of methods based on product and technique advancements.

3.6.5 Determining the Tolerance for Volatile Organic Compounds (VOCs). Most solvent-based sealers have strong, distinctive odors and require the use of Personal Protective Equipment (PPE) and adequate ventilation during application and curing. If adequate ventilation is impossible during the application and curing process, then VOCs must be considered when deciding the appropriate sealer. Even when there is adequate ventilation, the use of personal protective equipment is still recommended.

4.0 BUDGETARY CONCERNS

4.1 Points to Consider. End users need to be informed about the projected maintenance costs. Facility managers need information regarding regular scheduled visits and the associated costs. Commercial and industrial applications need regular professional maintenance; and require daily or nightly cleaning as an ongoing service. Maintenance charts, lists of acceptable products and equipment, training material and training sessions with cleaning companies. Follow up visits by a stone care professional to ensure that the proper maintenance program has by followed.

5.0 FIELD TESTS FOR DETERMINING SEALING NEEDS

5.1 Performing field tests is a common industry practice for stone professionals. Most consider water absorption as being an important test, especially if the surface is exposed to water and water-borne contaminants. Water beading on the surface is not indicative of a sealed stone. The beading of water demonstrates the properties of surface tension. For example, water will react similarly when applied to factory resin-coated or enhanced stones and denser stones with tighter mineralogical matrices. It is important to note that some natural stones may not require sealing, and can even be negatively impacted if sealed. This negative impact is the result of the product not being absorbed in to the stone and drying on the surface. This is a correctable error, but it requires reactivating the product with a solvent and removing the residue while the product is in the reactivated state.

5.2 Selecting the Test Specimen. It is better to test a sample of the exact material (same stone and lot) than to risk damage to the installed material. The main negative issue with sample testing is the lack of the exact same history of the installed material after use. Sometimes inconspicuous areas, such as closets, also lack chemical treatments that may have been applied to the conspicuous areas. If the issue can be duplicated on a sample or an inconspicuous area, then proceed by testing the sample or the inconspicuous area. To be sure that each sealer is given a fair chance it is recommended to determine that each sample or area has similar mineral and porosity characteristics. To keep chemical wicking from affecting your tests, be sure to physically separate or allow enough distance between test areas.

5.3 Recommended contaminates for basic field testing include: oils (corn, olive, coconut, or others that may come in contact with the stone), water (or water-based contaminants such as tea or coffee), acids (vinegar, citrus, fruit juice, etc.), red wine, or any other contaminant that may come in contact with the stone.

5.4 Preparation of the Stone. Clean the stone with a neutral pH stone cleaner and allow to dry for 24 hours or until thoroughly dry. Be sure to follow the preparation procedures recommended by the manufacturer of the sealer.

5.5 Application of Sealers. Sealers should be applied according to manufacturer's instructions. To get proper protection more than one application may be necessary.

5.6 Cure Time. Allow appropriate cure time per the manufacturer's recommendations.

5.7 Test Procedures. Stone care professionals must understand how to properly perform informal field tests. Testing is the best way to learn how the specific product or products will perform in a real life setting.

5.7.1 Record Keeping. Prepare a written and photographic log to document the test methods and results. Note date, time intervals, test area, and quadrant. Identify each contaminant tested, the quantity, and the amount of time left on the surface. Add any other important information such as moisture levels and temperature.

5.7.2 Label Test Area. Use a permanent marker on the label. Make sure that the marker or any label adhesive does not stain the stone. Include things that identify the whole area and quadrants (measurement marks can also be used with axis labels).

5.7.3 Exposure. Determine the length of exposure to each contaminant. If it is likely that the area may not be cleaned for a week, then the exposure time needs to be a week or more. On countertops, where they are likely cleaned multiple times throughout their use, an exposure of 8 to 24 hours should be sufficient.

5.7.4 Execute the Field Test in the Following Manner. Ensure surface is clean and dry. Apply an adequate, measured amount of the contaminant to the surface (for example: 1/2 teaspoon of water, oil, or vinegar). Allow the contaminant to dwell on the horizontal surface for five minutes or longer (as mentioned above). Ideally the contaminant (with the exception of acid) will be repelled for no less than ten minutes when placed on a properly cured sealer. Remove the contaminant by blotting the area. Do not wipe to dry. Carefully exam the test area directly afterwards and again later.

5.7.5 Results. After the predetermined exposure time has been reached, clean specimens with a neutral pH stone cleaner. Allow the area to dry once contaminant is removed (approximately 20 minutes for initial review and sometimes after a day or more depending on the results). Visually evaluate and log results. A successful stone/ sealer test would show no absorption, no staining, and no etching. If the stone turns darker, it will stain if not sealed. If the stone turns dull and whitish in color, then the stone is likely to etch. Another possibility is that an acidic solution can disturb the impregnating repellent that has been applied to a very dense stone so it appears whitish. In this last scenario, the difference is that it still has polished reflection.

5.7.6 Etch Test. When working with an unidentifiable stone, the etch test will confirm if the stone is calcium carbonate based. To perform the etch test the stone care professional should use an acid that is commonly used around the stone on different areas of the stone. Serpentines will typically only react to mild acids in the calcium carbonate-based veins. It is recommended to test a sample of the same material and lot if possible. If the stone reacts to the acid, it will need to be restored to the original finish.

5.7.7 Other Things to Consider. Only perform these tests in an inconspicuous area or on an uninstalled sample tile. It is important to note that impregnating repellents will not repel acidic liquids like vinegar, lemon juice, red wines, tile cleaners, and so on. In fact, acids will damage the surface. Be prepared to repolish the surface after testing with acidic liquids. Topical sealers are much more effective at repelling acidic liquids.

6.0 FINAL THOUGHTS ABOUT SEALERS

6.1 The stone care professional plays a critical role in determining the selection of sealers. The desired appearance, functionality and maintenance required are all important considerations in the selection process. Whether involved with new construction or maintaining an existing structure, it is important to consult with others involved in the natural stone industry, understand the role of the specifying authority, and the various aspects of stone behavior in relation to environmental suitability to ensure the information provided is thorough, accurate and beneficial. The consummate professional is educated and experienced and has a thorough working knowledge of natural stone, sealers products, and the effects of various environments. The stone care professional provides counsel and evidence regarding which sealers would best preserve a stone's condition and presentation, and meets the end user's needs.

6.2 Important Points to Remember. Sealers are water, oil, dirt, contaminant, stain, and weather resistant agents only. Sealers minimize the effects of harmful contaminants, making end-user care and professional maintenance easier and less costly. Sealers are most effective when paired with the appropriate stone and substrate. Sealers applied to stone used in exterior and wet environments can alter the dynamic coefficient of friction. Appropriate tests should be performed to determine suitability prior to application. Sealers can minimize and slow the effects of biological, chemical, and physical interior and exterior weathering and their byproducts, such as exfoliation, fracturing, frost or salt-wedging, movement, oxidation, slaking, sugaring, etc., but cannot prevent them from occurring. No natural stone installation is maintenance-free.

RESTORATION AND MAINTENANCE – MAINTENANCE

1.0 INTRODUCTION

1.1 This section will provide end users with basic information pertaining to natural stone maintenance. Since general specifications and finishes of natural stone affect cleaning procedures, this section will include an overall description of the most common stone specifications and finishes. It is important to also acquire background data on the individual stone(s), such as type and source of stone, type of sealer used (if any), and recommendations of sealer manufacturers as to care of sealed stone, etc.

2.0 SLIP RESISTANCE OF STONE FLOOR SURFACES

2.1 In commercial environments it is important to maintain a log detailing daily and periodic maintenance. This log should document the procedures followed on days of inclement weather, such as rain or snow.

2.2 The Americans with Disabilities Act (ADA). This federal legislation, passed in 1990, is the most comprehensive civil rights legislation adopted to prohibit discrimination against people with disabilities. Public and private businesses, state and local government agencies, and private entities offering public accommodations and services, transportation, and utilities are required to comply with the law. At one time, ADA documents prescribed a recommended minimum coefficient of friction for walkway surfaces in accessible routes of commercial and public buildings, but the section of the ADA documents that contained this recommendation have since been withdrawn.

3.0 DEFINITIONS, PURPOSE, AND BENEFITS OF STONE MAINTENANCE

3.1 Polished-finish Stone has a glossy surface that provides clear reflections and accentuates the color, contrast, and character of the material. Due to abrasion from foot traffic, soft stones with a polished finish will generally wear to a dull surface. Due to varying hardness of the minerals that comprise the stone's fabric, uniform gloss and/or reflectivity may not always be achieved in all stones.

3.2 Honed-finish Stone has a smooth, matte surface with limited reflection. This finish is generally preferred for softer stone varieties used for floors, treads, thresholds, and other pedestrian locations where heavy traffic would dull a polished finish. Its lack of gloss makes it a more forgiving surface in that unevenness or waviness will not be as easily detected. Due to varying hardness of the minerals that comprise the stone's fabric, uniform gloss and/or reflectivity may not always be achieved in all stones.

3.3 Maintenance. Regular cleaning should be scheduled, using specific procedures, products, and equipment. Inspections should be performed at prescribed intervals.

3.4 Restoration involves the refinishing of existing stonework to return its appearance to that of a newly supplied, unworn product. This process may include minor repairs such as filling of chips or pits in the stone surface, replacement of cracked or missing grout, removal of stains and/or etching, and honing or polishing.

3.5 Purpose and Benefits of Maintenance.

3.5.1 Appearance. Efficient regular cleaning removes fine particulates, which can abrade and dull the surface of the stone over time.

3.5.2 Sustainability. Proper maintenance will lengthen the stone's service life, effectively delaying the need for more aggressive restoration methods or replacement.

3.5.3 Safety. A properly maintained stone surface that is free of contaminants will provide a safer walking surface with better, and more uniform traction available for occupant ambulation.

4.0 CONDITIONS INFLUENCING MAINTENANCE

4.1 Stone type will determine necessary methods and frequency of maintenance. Knowledge of the stone's properties will aid in designing a maintenance program. For example, granite is a very hard stone with little absorption capacity, while limestone has a softer composition and a greater absorption capacity. The stone properties will also influence the selection of appropriate sealing products. For maintenance purposes, specific groups of stones should be considered in order to properly maintain them.

4.1.1 Group 1. Stones that typically do not contain calcium carbonate and typically do not react to most common acids:

- Igneous rocks: granite, basalt
- Metamorphic: slate, gneiss, schist
- Volcanic: Adoquin, Canterra

4.1.2 Group 2. Stones that contain calcium carbonate and typically react to common, mild acids:

- Calcite: marble, travertine, limestone, onyx, terrazzo

4.2 Installation Methods and Related Components.

4.2.1 Substrate. The rigidity and quality of the substrate may affect not only the performance of the stone, but also the necessary maintenance. Some substrates are very vulnerable to water infiltration, so maintenance methods must limit the amount of water used and the dwell time water is allowed on the stone surface.

4.2.2 Adhesives. Some adhesives may be adversely affected by some cleaning agents.

4.2.3 Grout. Various products are used for grouting joints (e.g.: cement, cement with additives, and epoxy), all of which have unique maintenance and sealing requirements.

4.2.4 Joint Sealant. Different elastomeric materials are used to caulk joints in finished stonework (e.g.: silicone, urethane, acrylic), each of which have unique performance traits and maintenance requirements.

4.3 Characteristics of Certain Stones. Many stones have unique features, such as fillers, voids, or repairs, which influence maintenance practices.

4.4 Condition of Stone Installation. Residual issues from the initial installation or previous restoration attempts, such as lippage, scratches, etch marks, acid burn marks, and cracks will influence maintenance needs or create a requirement for subsequent restoration activity.

4.5 Location of Installation.

4.5.1 Interior. Whether residential or commercial, interior surfaces require careful consideration of the surrounding materials. Maintenance can impact adjacent surfaces such as floor molding, furniture, other stone surfaces, wall coverings, and painted walls. Care must be taken to protect these surfaces or use materials that will not impact their appearance or function.

4.5.2 Exterior installations require the same attention to adjacent surfaces as interior settings. Additional attention must be paid to landscape, vegetation (plants, bushes and trees), and water runoff. Check federal, state, and local codes for building, safety, and environmental requirements.

4.5.3 High Rise Claddings. Cladding restoration is a specialty area due to the difficulty of access and potential influence to building seals and curtainwall performance. Adjacent materials, such as joint sealers and aluminum and glass curtainwall wall components must be protected from damage by chemical or abrasive cleaning methods used on the stone panels.

5.0 MAINTENACE METHODS FOR RESIDENTIAL CLEANING

5.1 Products and Equipment.

5.1.1 Products. Use only stone cleaners or pH neutral cleaners. Some stone cleaners also contain small amounts of sealer. These products help to maintain the level of protection.

5.1.2 Equipment. New equipment is being developed continually to clean stone surfaces. Common equipment used includes:

- A small canister vacuum with non-metallic wheels and a flat floor head with soft bristles made of nylon or horsehair, or a smooth felt liner along the bottom edges. Metal attachments should never be used.
- Clean cotton string or sponge mop. Dirty mop heads are a major source of residual soil on the floor.
- Plastic buckets. Never slide the bucket on the floor. If the bucket has wheels, they should be non-metallic and non-marring.
- In-home steamers. Steamer head rags should be changed frequently.
- Small scrub brush and/or a deck brush. Bristles should be soft nylon to reduce scratching.

5.2 Daily Maintenance. The removal of dirt, debris, and dust is essential to maintaining the appearance of the floor. All stone flooring should be dust mopped or vacuumed daily or as necessary to remove debris, dirt and fine particulate matter. Vacuuming is the preferred method because it lifts abrasive materials up and away from the floor. Dust mops should be dry and untreated.

5.3 Weekly maintenance involves washing with clean, potable water and pH neutral cleaners. Soapless cleaners are preferred because they minimize streaks and film. Mild, phosphate-free, biodegradable liquid dishwashing soaps or powders or stone soaps are acceptable if rinsing is thorough.

5.3.1 Process. Wet the stone surfaces with clean water. Using the cleaner (following manufacturer's directions), wash in small, overlapping sweeps. When using the brush apply light pressure so that only the ends of the bristles are doing the scrubbing. Work from the bottom up if it is a vertical surface. Rinse thoroughly with clean, potable water to remove all traces of soap or cleaner solution. Change the water in the rinse pail frequently. Dry with a soft cloth and allow to thoroughly air dry. Alternatively, employ the use of a wet vacuum to extract contaminants. In commercial applications with high traffic levels, the use of an automatic scrubber fitted with a disc-type brush system and continuous extraction is generally the most effective method. Brush aggressiveness must be matched to the stone type and hardness to prevent damage.

5.4 Safety Precautions. Any flooring surface, regardless of its finish, can be slippery when wet. Promptly remove liquids or foreign materials that might result in safety hazards before permitting pedestrian traffic. Use warning cones or other means of alerting occupants to a temporary reduction in traction.

5.5 Precautions. For counter or table tops, use coasters under all glasses, particularly those containing alcohol or citrus juices. Many common foods, drinks, and cosmetics contain acids that will etch or dull stone surfaces. Use trivets or mats under hot dishes and placemats under china, ceramics, silver, or other objects that can scratch the surface. Blot spills with a paper towel or cloth as they occur or as soon as possible thereafter. Clean regularly with a neutral cleaner that does not contain solvents.

5.5.1 In food preparation areas, stone surfaces may require an impregnator or topical sealer. If an impregnator or topical sealer is applied, it must be nontoxic and safe for use on food preparation surfaces.

5.5.2 Never use acidic or ammoniated cleaner or chemicals on calcium carbonate-based stone surfaces. Use a cleaner specifically formulated for stone cleaning.

5.6 Heavy Duty Cleaning. High traffic areas such as kitchens may require a yearly deep cleaning and resealing. This requires the use of floor machines, brushes, and specialized pads.

6.0 MAINTENANCE METHODS FOR COMMERCIAL CLEANING AND SEALING

6.1 Group 1 includes stones that typically do not contain calcium carbonate and typically do not react to most common acids.

6.1.1 Igneous Rocks (granite and basalt).

- Clean daily, using methods outlined in section 5.0.
- Yearly (for floors and stairs): Scrub floors with a standard 175 RPM buffer, using a soft nylon brush and a neutral cleaner. An automatic scrubber machine can be used for larger floors. For stairs, use a slow speed hand polisher.
- Stone and/or grout may need to be resealed at intervals of 3 to 5 years. See section 9.0 for more information on sealing.
- Extremely worn or damaged surfaces will require restoration rather than standard cleaning.

6.1.2 Metamorphic Rocks (slate, gneiss, and schist).

- Clean daily, using methods outlined in section 5.0.
- Yearly (for floors and stairs): Scrub floors with a standard 175 RPM buffer, using a soft nylon brush and a neutral cleaner. An automatic scrubber machine can be used for larger floors. For stairs, use a slow speed hand polisher.
- The stone and/or grout may need resealed at intervals of 2 to 5 years. See section 9.0 for more information on sealing.

6.1.3 Volcanic Rocks (adoquin and canterra).

- Clean daily, using methods outlined in section 5.0.
- Yearly (for floors and stairs): Scrub floors with a standard 175 RPM buffer, using a soft nylon brush and a neutral cleaner. An automatic scrubber machine can be used for larger floors. For stairs, use a slow speed hand polisher.
- The stone and/or grout may need resealed at intervals of 2 to 5 years. See section 9.0 for more information on sealing.

6.2 Group 2 includes stones that typically contain calcium carbonate and react to acids. These calcite stones include marble, travertine, limestone, onyx, and terrazzo.

- Clean daily, using methods outlined in section 5.0.
- Twice yearly: Scrub floors with a standard 175 RPM buffer, using a soft nylon brush and a neutral cleaner. An automatic scrubber machine can be used for larger floors. For stairs, use a slow speed hand polisher.
- Stone and/or grout may need to be resealed at intervals of 2 to 3 years See

section 9.0 for more information on sealing.

- Extremely worn or damaged surfaces will require restoration rather than standard cleaning.

6.2.1 Maintaining Finishes on Calcite Stones.

6.2.1.1 Polished Surfaces. Buff the stone with a slurry of water and a non-acid polishing compound. Specialized diamond impregnated pads can also be used, using a standard 175 RPM buffer or a high-speed burnisher. Combining the compound with a diamond impregnated pad may produce a higher-gloss finish. A slow speed hand polisher can be used for stairs, walls, and tops. This should be done four times a year, or as needed.

6.2.1.2 Honed Surfaces. Buff the stone with a slurry of water and a non-acid honing compound. Specialized diamond impregnated pads can also be used, using a standard 175 RPM buffer or a high-speed burnisher. Combining the compound with the diamond impregnated pad may produce a better honed finish. A slow speed hand polisher can be used for stairs, walls, and tops. This should be done four times a year, or as needed.

7.0 MAINTENANCE METHODS FOR EXTERIOR STONE

7.1 Exterior stone is a general term denoting stone installed where temperature, moisture, and airborne contaminants are caused primarily or solely by forces of nature. It can be used in a honed, textured, or polished finish in any mode in an exterior environment. Uses include building cladding, walkways, steps or stairs, retaining walls, paving, fountains, benches, planters, and decorative items such as sculptures.

7.2 Normal Maintenance. In accessible areas, routinely follow maintenance procedures as specified in Sections 5.0 and 6.0 of this chapter, as applicable. Normal maintenance should include periodic inspection of stone surfaces for structural defects, movement, deterioration, or staining. Distress in joint fillers is a common sign of stone unit or substrate movements.

7.2.1 The large expanses of stone generally found on exterior applications may make it impractical to perform frequent normal maintenance. Large installations, however, should be given periodic overall cleaning to remove accumulated pollutants. If the exterior stone surface has calcium deposits, an acid cleaner can be used on igneous rocks only. Easily accessible stone surfaces such as steps, walkways, and fountains should be kept free of debris and soiling by periodically sweeping and washing with water.

7.3 Local Regulations. Many local municipalities have regulations related to water use and chemical disposal. Always check these regulations and authorizations before bidding on such cleaning projects; in some cases, there are additional costs associated with these regulations.

8.0 EXTERIOR BUILDING STONE CLEANING

8.1 Exterior building stone is considered in this section to be all stone used on the exterior of a structure, either as a structural component or as a facing material, with the exception of polished, finished marble. Although a polished finish is not recommended for exterior use with most marble varieties, it is occasionally used on storefronts, column facings, and similar treatments.

8.2 Regular Cleaning. The ideal in maintaining exterior building stone is to clean it at periodic intervals (at least annually, depending on atmospheric conditions) by simply hosing down with clean water. This will prevent accumulation of dirt and impurities. In accessible areas, routinely follow maintenance procedures as specified in Sections 5.0 and 6.0

of this chapter, as applicable. Brushes may be necessary for the removal of certain surface impurities. Soft fiber brushes are recommended.

8.3 Sporadic Cleaning. If the stone is not cleaned regularly, a water system (hydraulic, hydro-air, or plain water) will be the most effective method at the lowest cost.

8.4 Dirt on Older Buildings. When dirt has accumulated on older structures over a long period of time, a combination of methods may be necessary to properly clean the stone. A plain water jet will remove most accumulation. No chemicals should be used that could be harmful to the stone.

8.5 Test Panels. By cleaning and inspecting test panels, the Specifying Authority can determine if the method is satisfactory. This procedure eliminates the possibility of improper cleaning; since the Owner and Specifying Authority can see what results will be obtained prior to commencement of the total contract. It also gives the Cleaning Contractor a standard to work toward, making definition of the cleaning more specific for all parties.

8.6 Local Regulations. Many local municipalities have regulations related to water use and chemical disposal. Always check these regulations and authorizations before bidding on such cleaning projects; in some cases, there are additional costs associated with these regulations.

9.0 TOPICAL SEALERS AND IMPREGNATORS

9.1 Topical sealers are coatings designed to protect the surface of stone against water, oil, and other contaminants. They are formulated from natural wax, acrylic, and other plastic compounds.

9.2 Impregnators (penetrating sealers). Impregnators are generally hydrophobic (water-repelling), but some are also oleophobic (oil-repelling). They penetrate below the surface and become repellents. They keep contaminants out, but do not stop interior moisture from escaping. Impregnators are considered breathable, meaning they have vapor transmissibility.

9.3 Treatment Type. The type of stone and environment of the application determine the type of sealer treatment (impregnator or topical) to be used. All treatments must be applied in accordance with the manufacturer's specifications.

9.4 When to Seal. A treatment may be used when a defined benefit can be determined. For example:

- When the risk of staining is present
- As an aid in daily maintenance procedures
- Where a coating may help to preserve the stone finish in excessively high wear conditions
- Where weathering has affected or may affect the integrity of the stone surface
- To prolong the aesthetic beauty of the original installation
- Where the risk of graffiti or other vandalism is high.

10.0 STAINS AND REMOVAL PROCEDURES

10.1 Oil-based Stains (grease, tar, cooking oil, cosmetics). An oil-based stain will darken the stone and normally must be chemically dissolved so the source of the stain can be flushed or rinsed away. First, remove excess staining agent by wiping or chipping (if tar). Clean gently with a liquid cleanser, household detergent, ammonia, mineral spirits, or acetone. Do not pour cleaner directly on the staining agent, as this can thin the contaminant and further its penetration and spread. Partially saturate a paper or cloth towel with the cleaner and attempt to draw the stain into the towel. Commercially available specialty cleaners, such as alkaline degreasers and/or poultices may also be used.

10.2 Organic Stains (coffee, tea, fruit, tobacco, paper, food, urine, leaves, bark, animal droppings). Organic stains may cause a pinkish-brown stain and may disappear after the source of the stain has been removed. Outdoors, with the sources removed, normal sun and rain action will generally bleach out the stains. Indoors, clean with 12% hydrogen peroxide and a few drops of ammonia. Commercially marketed cleaners and poultices are also available.

10.3 Inorganic Metal Stains (iron, rust, copper, bronze). Iron or rust stains are orange or brown and leave the shape of the staining object, such as nails, bolts, screws, cans, flowerpots, or metal furniture. Copper and bronze stains are green or muddy brown and result from the action of moisture on nearby or embedded bronze, copper, or brass items. Metal stains must be removed with a poultice (see Section 11.0 of this chapter). Deep-seated rust stains are extremely difficult to remove, and the stone may be permanently stained.

10.4 Biological Stains (algae, mildew, lichens, moss, and fungi): Clean with diluted [1⁄2 cup per gallon of water (32 ml/liter)] ammonia, bleach, or hydrogen peroxide. Do not mix bleach and ammonia; this combination creates a toxic gas. There are a number of commercial products available that are as effective as ammonia, bleach, or hydrogen peroxide without the potentially hazardous downside.

10.5 Ink Stains. Clean light-colored stones with bleach or hydrogen peroxide. Use lacquer thinner or acetone for dark-colored stones. Do not pour cleaner directly on the staining agent. This can thin the contaminant and further its penetration and spread. Partially saturate a paper or cloth towel with the cleaner and attempt to draw the stain into the towel.

10.6 Paint Stains. Small amounts of paint can be removed with lacquer thinner or scraped off carefully, using a razor blade. Heavy paint coverage should be removed with a commercial liquid paint stripper. Other methods to remove paint would include baking soda blasting or glass bead blasting. These methods should be undertaken by experienced professionals. Begin by testing a small area to determine the efficacy of the method. Do not use acids or flame tools to strip paint from stone. Use of solvents can potentially drive the stain further into the stone.

10.7 Water Spots and Rings (surface accumulation of hard water). Buff with dry steel wool.

10.8 Fire and Smoke Damage. Older stone surfaces and fireplaces stained by smoke or fire may require a thorough cleaning to restore their original appearance. Commercially available smoke removal products may save time and effort. Calcareous stones may also require refinishing due to etching from carbonic acid.

10.9 Etch Marks are caused by acids left on the surface of the stone. Some will etch the finish but not leave a stain; others will both etch and stain. Once the stain has been removed, wet the surface with clean water and sprinkle with polishing powder. Rub the powder into the stone with a damp cloth or by using a buffing pad with a low-speed power drill or polisher. Continue buffing until the etch mark disappears and the surface shines. Honing may be required for deep etching. This process may require the services of a professional refinisher.

10.10 Efflorescence is caused by water carrying soluble salts from below the surface of the stone. The salts are deposited and recrystallize upon evaporation of the water, leaving a powdery salt residue. If the installation is new, dust mop or vacuum the powder. Repeat as necessary as the stone dries out. Do not use water to remove the powder. If the problem persists, contact the contractor to identify and remove the cause of the moisture.

11.0 POULTICE MIXTURES FOR VARIOUS STAINS

11.1 Overview. A poultice is a chemical or mixture of chemicals combined with an absorbent material to form a thick paste, which is applied to stone to remove stains.

11.2 Poultice materials include kaolin, fuller's earth, whiting, diatomaceous earth, powdered chalk, white molding plaster, and talc. Approximately one pound (0..45 kg) of prepared poultice material will cover one square foot. Do not use whiting or iron-type clays such as fuller's earth with acid chemicals as the chemical reaction will cancel the effect of the poultice. A poultice can also be prepared using white cotton balls, white paper towels or terry cloth rags, or gauze pads, which may be more effective when using highly volatile solvents such as acetone or mineral spirits. Premixed poultices are available in ready to use form or require adding only water. These are available from stone maintenance supply companies.

11.3 Prepare the Poultice. If using a powdered poultice material, mix with the cleaning agent or chemical to a paste with a thick, creamy consistency (approximately the consistency of peanut butter). If using paper, soak it in the chemical and let drain. Do not let the liquid drip. Prepare stain area. Wet the stained area with distilled water.

11.4 Apply the poultice to the stained area about 1⁄4" to 1⁄2" thick (6 to 12 mm), and extend the poultice beyond the stained area by about 1". Use a wood or plastic scraper to spread the poultice evenly.

11.5 Cover the poultice with plastic and tape the edges to seal it. Punch several small holes in the plastic to allow vapor to escape.

11.6 Allow the poultice to dry thoroughly; this usually takes 24 to 48 hours. The drying process draws the stain out of the stone and into the poultice material. After approximately 24 hours, remove the plastic and allow the poultice to dry.

11.7 Remove the poultice from the stain. Rinse with distilled water and buff dry with a soft cloth. Repeat the poultice application if the stain is not removed. It may take five or more applications for difficult stains.

11.8 If the chemical etches the surface, apply polishing powder and buff with a polishing pad recommended by the polishing powder's manufacturer.

11.9 Poultice Mixtures for Various Stains.

11.9.1 Oil-based Stains. Poultice with baking soda and water or one of the powdered poultice materials and mineral spirits or a commercial degreaser.

11.9.2 Organic Stains. Poultice with one of the powdered poultice materials and acetone or 12% hydrogen peroxide solution.

11.9.3 Iron Stains. Poultice with diatomaceous earth and a commercially available rust remover. Rust stains are particularly difficult to remove; professional assistance may be required. Many rust removers contain acids that will etch marble, limestone, and certain granites.

11.9.4 Copper Stains. Poultice with a powdered poultice material and ammonia. These stains are difficult to remove; professional assistance may be required.

11.9.5 Paint Stains (water-based). Poultice with a powdered poultice material and a commercial paint remover.

11.9.6 Paint Stains (oil-based). Poultice with a powdered poultice material and mineral spirits. Deep stains may require methylene chloride. When using highly volatile solvents in poulticing, use a paper towel, pouring the solvent on the paper towel and then placing the towel on the stained area.

11.9.7 Ink Stains. Poultice with a powdered poultice material and mineral spirits or methylene chloride. When using highly volatile solvents in poulticing, use a paper towel, pouring the solvent on the paper towel and then placing the towel on the stained area.

11.9.8 Biological Stains. Poultice with a poultice material and diluted ammonia, bleach, or hydrogen peroxide. Do not mix ammonia and bleach; this combination creates a toxic gas.

11.10 Flammable Materials. The preceding text does not address possible safety concerns associated with the use of flammable solvents. Refer to the manufacturer's labeling and MSDS for further direction in the safe handling and use of these products. Commercially available cleaners exist for remedy of many common stains. These cleaners may have fewer health and safety concerns. Always use appropriate Personal Protective Equipment (PPE) when handling solvents or other chemicals.

12.0 SPECIFICATIONS FOR BUILDING CLEANING

12.1 Introduction. This section pertains to the furnishing of all labor, materials, equipment, and services necessary for the complete cleaning of exterior building stone as indicated on the plans and described in the specifications.

12.2 Information to be shown on drawings:

- Location, size, and area or items to be cleaned
- Location, size, and number of test panels
- Areas not included in cleaning
- Location, size, and description of materials requiring protection
- Building and property boundaries

12.3 Repointing, Sealing, and Replacement. Specify if repointing or re-sealing of joints and replacement of stone are included in the cleaning scope of work.

12.4 Related sections are to be determined by design requirements.

12.5 Requirements.

12.5.1 General requirements include the plans, general conditions, supplementary general conditions, and the executed agreement.

12.5.2 Certified statements must be furnished as required, attesting that all materials to be used meet the requirements specified and approved.

12.5.3 Scheduling. Provide Specifying Authority with schedule of cleaning operations indicating time of day work will be performed. Wet cleaning methods should not be performed when temperatures reach 35°F (2°C) or lower.

12.5.4 Test Areas. For approval by Specifying Authority, clean at least a 4'x4' (1.5 m^2) test area for each type of soiling, stone variety, and finish requiring cleaning. Test panels should include intersection of horizontal and vertical joints. The approved panel(s) should be the standard for cleaning methods and finish of all areas to be cleaned.

12.5.5 Protection. For approval by Specifying Authority, provide material types and methods to protect adjacent materials and surfaces from damage, moisture, and staining. If other refurbishing operations are being conducted, protect cleaned stone areas with an approved non-staining covering.

12.5.6 Cleaning. After the surface has been cleaned, rinse with potable water applied to the temperature and pressure of the municipal water supply.

12.6 Materials. Water should be potable, non-staining, and free of materials detrimental to the surface being cleaned.

12.7 Methods to be determined by approved test areas.

12.7.1 Hydraulic. Water at varying pressures between 300 and 600 psi (2 - 4 MPa) and at municipal supply temperatures shall be jetted against the surface to be cleaned. Care must be exercised in selecting nozzle tip degree; zero nozzle tips should never be used.

12.7.2 Water Misting. Clean the surface with water. Misting heads are set up on scaffolding and water is misted onto the surface of the building. The misting heads may be set on a timer so that they go on and off intermittently. The intermittent cycle allows the building to dry and prevents oversaturation of the stone. This method is the safest for cleaning and is widely used on historical buildings.

12.7.3 Pressure washing employs the use of high-pressure water jets of up to 2,500 psi (17 MPa) or more. Pressure washing works by blasting the dirt off the surface of the stone, and can cause irreversible damage to the stone surface. Pressure washing can be an effective and efficient means of removing dirt and other contaminants. Modern pressure washers can produce pressure in excess of 2,500 lbs/in^2, which can permanently damage many stone types. Maximum allowable pressure should be determined by slowly increasing pressure while testing in an inconspicuous area. In no case is pressure in excess of 1,000 lbs/in^2 (7 MPa) recommended, and usually much less pressure is appropriate. Always use a fan-tip spray nozzle. Only highly trained technicians should employ this method.

12.7.4 Chemical cleaning is used in combination with one or several of the water washing methods to dislodge soiled particles. Chemicals can be dangerous to the stone, the technician, and the surrounding landscape. Therefore, all chemicals used must be tested and monitored.

12.7.5 Acids. Chemicals with a pH below 7 should not be used on calcareous or dolomitic stones.

12.7.6 Alkalis. Chemicals with a pH above 7 are safe for use on most stones. These are usually followed with a mild acid wash to neutralize the alkaline salts.

12.7.7 Neutral Cleaners. Chemicals containing surfactants with a pH equal to 7 are safe for most stones.

12.7.8 Solvents. Waterless chemicals, such as mineral spirits and acetone, are rarely used for building cleaning due to their high flammability.

12.7.9 Bacteria. Special bacteria can be applied to “eat” dirt and salts.

12.7.10 The J.O.S. (or TORC or DOFF) system for removal of dirt and graffiti uses a low-pressure washer and milled glass or dolomite powder. Pre-rinsing is required.

12.7.11 Dry cleaning uses organic powder or mineral powder (aluminum silicate) crystals sized between 10 and 90 micros.

12.7.12 Sandblasting is an extremely aggressive method of cleaning and should only be considered when believed to be the only effective solution. Soda blasting (using baking soda in lieu of sand) is generally not as destructive and has some limited usage in the cleaning of natural stones.

12.8 Safety Requirements. All the methods listed above require specialized equipment. Adherence to OSHA safety requirements by highly skilled technicians is mandatory.

12.9 Testing. All methods must be tested for potential damage to the stone.

COMMERCIAL AND HISTORIC RESTORATION

1.0 INTRODUCTION

1.1 When compared to residential restoration, commercial and historic stone restoration poses several unique requirements and challenges. While many underlying techniques in residential restoration are applicable to commercial projects, changes must be made to adapt to a more complex nature. Commercial and historic stone restoration both require a strong understanding of laws and regulations to protect the integrity of the structure as well as to avoid fines and/or citations. Further challenges arise due to the scale, intensity, location, traffic patterns and management of these projects. This section will cover most of the common requirements and challenges associated with commercial and historic restoration. For the purposes of this document, the term "restoration" will include cleaning, refinishing, repair, sealing, and maintaining.

2.0 DIFFERENCES

2.1 Rules and Regulations. On any commercial or historic project, it is absolutely necessary to familiarize oneself with and follow all federal, state, and local regulations and requirements. Regulations are in place for worker protection and public safety. Noncompliance with these mandates is not only dangerous and unprofessional, but can result in substantial fines. The most common sources for these regulations in the U.S. are the Occupational Safety and Health Administration (OSHA) and the U.S. Department of the Interior, through the National Park Service (NPS).

2.2 Size of Project. The size of lobbies or commercial spaces are typically larger than residential spaces, with significantly more "foot traffic," making "efficiencies of scale" more important for these projects.

2.3 Levels of Pedestrian Traffic. Pedestrian traffic rates in most commercial settings will generally be much greater than those encountered in residential settings. The amount of abrasive particles (dirt and grit) introduced to the stone surface via footwear is also substantially greater. These abrasive particles can do significant damage to most stone finishes, particularly in the softer stone varieties.

2.4 Challenges Encountered With Site Access and/or Restrictions

2.4.1 Work Platforms. Vertical surfaces in commercial applications can extend to great heights, often necessitating the use of work platforms beyond ladders. Scaffolding, scissors lifts, and even mast climbers or suspended scaffolding may be required to gain access to commercial facades. The use of these and other equipment requires knowledge of OSHA regulations, local ordinances (right-of-way permits), and common sense safety knowledge. All workers using elevated work platforms must be trained in the safe use of the equipment and the health and safety regulations that govern its use.

2.4.2 Existing lighting in commercial spaces may be insufficient for restoration work, or may be on automated switches that cannot be overridden by onsite restoration mechanics. The restoration contractor is usually best served by providing his/her own lighting equipment to adequately illuminate the work area.

2.4.3 Electrical Power. It must be verified that adequate electrical power is available (both required voltage and amperage). If this is not the case, the cost of providing generators must be taken into consideration.

2.4.4 Water Supply. If an adequate quality and quantity of water is not available onsite, considerable cost will be encountered in bringing water from on outside source.

2.4.5 Water Discharge and Disposal. It must be verified if water discharge and disposal can be accomplished onsite, or if spent water supply and/or slurry must be removed from the site. This is just as important as verifying water supply.

2.4.6 Hours of Site Access. Many commercial restoration projects require that the work is performed when the building is unoccupied or at a reduced level of occupancy. This may require working at night or on the weekend. Ensure that onsite workers have access to the restoration company's management personnel, safety managers, and building managers while working during these non-traditional hours.

2.4.7 Maintaining Occupants' Access during Working Hours. Work areas may be limited in certain projects so that access can be maintained. For example, if the restoration includes the elevator cab floors in a hotel, it may be necessary to do one elevator at a time so that the other elevators remain functional, even in off-peak hours.

2.5 Unique Features Found in Commercial Buildings

2.5.1 Revolving Doors. In most cases a revolving door is not the only entrance to a building, so the revolving door area can be worked on while occupants are given an alternate, temporary entrance to the building. The doors can be collapsed or removed to increase access to the workspace during restoration. Pending weather and location of the project, varying levels of temporary building enclosure may be required over the area until the revolving doors can be replaced.

2.5.2 Staircases are common in commercial and historic restoration projects. Smaller equipment is normally utilized, and the production rate is greatly reduced. Due to mandated accessibility guidelines, staircases are rarely the only access point to a floor, so alternate means of access can usually be arranged while the staircase is being restored.

2.5.3 Vertical Surfaces (interior and exterior). It is far more common to encounter expansive vertical surfaces in commercial projects than in residential projects. In addition to general soiling, these surfaces can be abused by other construction trades, delivery equipment, improper cleaning methods, snow removal equipment, or signage and decoration mounting. It is important to eliminate the source of abuse to the surface prior to restoration, otherwise the damage will simply reoccur after the stone is restored.

2.5.4 Special Features (stone trim such as base, plinth blocks, jambs, casings, etc.) are not subject to normal foot traffic, but can still take abuse from getting hit with carts, vacuums, floor scrubbers and other items. Restoring specialty features can be very time consuming and the required hours can be difficult to estimate in the bidding phase. Additionally, these features are by design a "focal feature," so the customer's demands of the quality of the restoration efforts may be elevated.

2.5.5 Multi-component Surfaces. Surfaces that include different materials such as metal dividers, carpet, wood, or even stones of differing hardness present an additional challenge to the restoration professional. Protection of the various components becomes the responsibility of the restoration professional. Refer to the Restorative Processes section (page 21-51) for more information on how to handle multiple surfaces.

3.0 MAINTENANCE HISTORY AND PRODUCTS USED

3.1 Janitorial staffs of commercial buildings may be employees of the building owner, a building tenant, or a subcontractor.

Varying levels of stone care knowledge and experience exist amongst janitorial staffs and supervisors. Those with higher knowledge and experience levels, particularly when willing to research the unique maintenance needs of the stone product, are undoubtedly more successful in keeping building owners and occupants satisfied with the appearance and performance of the stone products. Refer to page 21-75 (Maintenance) for more information on this topic.

3.1.1 The restoration professional is often responsible for instructing the janitorial staff on required techniques and products to use after the stone has been restored. In these cases, it is often easier to instruct a staff with little or no stone care experience, which eliminates the need to change the bad habits previously used by the staff.

3.1.2 The restoration professional is usually best serving the client by encouraging them to contract with experienced, competent stone maintenance providers for their daily or weekly maintenance needs. This usually proves to be a wise investment for facility managers and owners that want to protect their stone investment.

3.2 Maintenance Products

3.2.1 Topical sealers and/or coatings. Long-term waxes, sealers, epoxy coatings, and other topcoats are more common in older lobbies, when topcoats were the preferred option. These coatings must be removed prior to restoration of the stone surface. Identification of the product is usually necessary to ensure that the removal and disposal of it is done in a safe, environmentally friendly, and legal manner. Refer to page 21-75 (Maintenance) for more information on this topic.

3.2.2 Short-term Coatings or Waxes. Stone maintenance and restoration professionals do not advocate the use of these products, except in extremely rare cases. Less competent restoration contractors may use these products to cover up processes that were not performed properly. Due to the topical coverage and prohibition of both fluid and vapor transmission, these products can actually damage the stone. However, since these products form a sacrificial layer above the stone's surface, there are unique exposure conditions where they may be recommended.

4.0 LABOR RESTRICTIONS

4.1 Unions. Commercial restoration projects frequently mandate that the work be performed by union personnel. Check all union regulations, including pay scales, benefits, and staffing requirements prior to bidding to ensure that adequate funding exists to comply with the unions' requirements. It is possible, depending on the nature of the work, that more than one union will have jurisdiction over parts of your scope of work.

4.2 Federal Projects. Most federal jobs require certified payroll reports. This report show which days were worked, labor classifications of the workforce, and rates of pay.

4.2.1 Labor Classifications and Education. All labor classifications and corresponding pay scales must be met. Maintain records to verify compliance in case the project is audited.

4.2.2 Confusion Regarding Classifications and Pay Scales. In some cases, it may be difficult to find an exact match of job descriptions in federal documents to accurately determine the correct pay rates. If doubt exists, contact the agency involved for their input. Maintain records and document all conversations in case a dispute develops at a later date.

4.2.3 Report Filing. Frequency of filing may vary from weekly to monthly. Determine the frequency required and comply with the reporting requirements.

4.2.4 Other Restrictions. Federal Department of Interior Standards must be followed. This requires a thorough knowledge of various restoration disciplines and an aptitude for report writing. Information on this can be found beginning on page 21-121 of this chapter (Additional Learning Resources).

5.0 GETTING APPROVAL FOR WORK PERFORMED

5.1 Customer satisfaction is the ultimate goal. In order to achieve this goal, it is necessary to communicate the proposed improvements accurately. Test patches, mockups, and samples will help with this communication. Ideally, test areas or mockups should remain in place until the balance of the work is completed to serve as a benchmark of acceptance.

5.2 Single Person Responsibility. It is typically easier to communicate with and satisfy one person, such as a maintenance supervisor or facilities manager, who may have the sole authority to accept or reject the work of your crews. Additionally, if a problem or question arises, this person can usually be included in the problem solving and decision making processes.

5.3 Boards and Committees. When the contracting and acceptance of the work is decided by a board or committee, it may be difficult to achieve consensus within the group, since the individuals comprising the group may have differing standards, perceptions, and experiences. It is a good practice to meet with the group prior to submitting your proposal. This will allow you to learn of their exact expectations and provide an opportunity to discuss of how these how these expectations may impact the cost of the project.

5.3.1 Commercial Committees. One of the most common committees encountered in commercial work is the "condominium board," when doing work in a condominium complex. The emotional investment of its members may be high, since they are usually all property owners in the complex.

5.3.2 Historical Review Committees will be encountered any time work is done to a project that is deemed to have some level of historical significance.

6.0 MANAGING PERFORMANCE

6.1 Large commercial restoration projects may have extremely long durations. Progress and expenses must be tracked throughout the project to ensure that the anticipated profitability can be achieved. Discuss the labor and material requirements with the job foreman or superintendent at the beginning of the project and revisit these requirements frequently.

7.0 FUNDING, BILLING, AND COLLECTING

7.1 The process of payment on a commercial or historic project can be different than on a residential project. Sometimes payment will only be considered if the request is submitted on the responsibly party's form. Payment can also depend on the tax and restoration parameters allowed by the Historical Review Board, various funding procedures and taxes. Every state usually has a historical society, committee, or department in charge of maintaining and preserving historical landmarks. Depending on the historical structure or place, there may be available tax credits to help offset the costs of restoration or repair. The National Register of Historical Places, which is administered by the National Park Service, gives status and possible tax credits and funding for significantly historical structures.

8.0 ADDITIONAL RESOURCES

8.1 See the last section of this chapter for Additional Learning Resources (page 121).

TROUBLESHOOTING

Application	Symptom	Stone Type	Possible Causes	Potential Solutions	Prevention or Cross Reference	Photo Reference
All	Cracking, alignment, and grout distress	All Natural stones	Structural settling or instability	Consult with structural engineer for remedial suggestions. Replace tile or clean, prep and repair tile and refinish as necessary to smooth out repair.		Photo 53, Photo 75, Photo 127
All	Cracks in Slabs	All Natural stones	Fractures caused by material handling, substrate deformation, or vibration from field cutting.	Clean, prep and use a penetrating or flowing epoxy to bond though the stone. Next use a knife grade epoxy with the correct color tint if needed. For outdoor repairs, use a UV stable, two part epoxy with the correct color tint. For white marble and porous limestone, preseal to keep the resin from bleeding into the stones.		Photo 121
All	Exfoliation of Minerals at face of stone	All Natural stones	Exfoliation occurring either to poorly cemented minerals or minerals that have been loosened by expansions, mechanical stress, or freeze/thaw cycling.	Clean, prep, and fill with a clear or a custom colored epoxy. The stone may need to be resurfaced. If stone is resurfaced, apply appropriate impregnating sealer.		Photo 37, Photo 38, Photo 47, Photo 72
All	Spall (chips or splinters separated from the main mass of a stone)	All Natural stones	Lack of vapor transmission at stone's surface.	Remove coatings that block stone’s ability to breathe.		Photo 68, Photo 80, Photo 84, Photo 128
All	Fissures	All Natural stones	Natural seams in the stone that have fully opened to be considered a crack or fracture.	Clean, prep and use a penetrating or flowing epoxy to bond though the stone, then a knife grade epoxy with the correct color tint if needed. For outdoor repairs, use a UV stable, two part epoxy with the correct color tint. For white marble and porous limestone, preseal to keep the resin from bleeding into the stones.		Photo 43
All	Gray colored stain bleeding through light stone	Light colored calcareous stones	Stone was installed using gray colored portland based thinset	Remove and replace - only white thinsets may be used with light colored calcareous stones.		

TROUBLESHOOTING

Application	Symptom	Stone Type	Possible Causes	Potential Solutions	Prevention or Cross Reference	Photo Reference
All	Pin Holes	Marble	Occasional small holes (*taroli* , in Italian) and voids are to be expected, and are characteristics of Soundness Classification B marbles.	Clean, prep and fill holes with color matched epoxy.		Photo 15
All	Ink Stains	All Natural stones	Ink pen or marker stains.	On light colored stones, clean with bleach or hydrogen peroxide. On dark colored stones, clean with lacquer thinner or acetone. Do a test in an inconspicuous area to make sure this is the correct method.		
All	Pits	Limestone	Numerous, possibly hundreds of small pits in the stone visible with certain lighting.	Clean and prep as best as possible and fill with CA glue, or color matched polyester acrylic.		Photo 59
All	Random Stains	All Natural stones	Random stains caused by known or unknown staining agents.	If possible, identify the stain origin, then poultice with appropriate poultice recipe. If stain origin cannot be identified, several trial and error attempts may be necessary. Multiple applications of poultice may be required to fully eradicate the stain.	MIA's book on Poultice	Photo 7, Photo 101
All	Dark spots remain after water wiped from stone.	All Natural stones	Sealer did not fully penetrate stone due to improper application.	Review manufacturer's application instructions to ensure proper application methods are being used. Allow full cure time between applications. Use multiple applications until desired performance is achieved.		Photo 64
All	Sticky or Clouded Surface	All Natural stones	This is usually the result of too much detergent or cleanser being used during normal cleaning maintenance.	Clean with a heavier cleaner for stone and hot water. For hair spray on marble, use a safe HD cleaner with a white pad.		Photo 44

TROUBLESHOOTING

Application	Symptom	Stone Type	Possible Causes	Potential Solutions	Prevention or Cross Reference	Photo Reference
All	Streaking or Haziness from Sealer	All Natural stones	Streaks or haze in cured sealer cannot be cleaned with regular cleaners.	Identify the sealer that was used, then try to re-emulsify with the same sealer with a white or hog's hair pad by breaking the surface tension and then wipe it up and buff it out. Or use Mineral Spirits and again break the surface tension. Or use a safe alkaline stripper and break the surface tension, wipe off and buff out. If unsuccessful, then stone must be refinished.		Photo 74, Photo 78
All	Swirl Marks	All Natural stones	Swirl marks in the stone surface are generally caused by equipment malfunctions or operator errors in the original fabrication of the stone or in a previous restoration attempt.	Start refinishing from the least abrasive diamond grit until you can successfully remove the swirl marks, then proceed to finer grit sizes until the desired gloss level is achieved.		Photo 40
All	Tape marks	All Natural stones	Dark banding visible in the stone surface is frequently residual adhesive from tape that had been applied and removed. Some tapes have mildly acidic adhesives, which are more prone to surface damage of calcareous stones. Extended dwell time on the stone surface, and exposure to sun or other heat source also increase the likelihood of tape marks.	Use acetone with a white nylon pad and rub vigorously. Multiple applications may be required. If unsuccessful, diamond grind the areas and then refinish to desired level of gloss. Some "feathering" and blending will be required.		Photo 42, Photo 51

TROUBLESHOOTING

Application	Symptom	Stone Type	Possible Causes	Potential Solutions	Prevention or Cross Reference	Photo Reference
All	Tape Residue	Countertop settling - edge not polished to factory polish - correct: break the seam, relevel the tops with proper support and polish the edges	Dark lines, usually dull, and often showing dirt collection.	Clean with acetone and a white pad vigorously. It the stain does not go away, diamond grind until the residue is gone, then bring back to the factory shine. (Note: tape adhesive may have penetrated significant depth of the stone, which can make the lines reappear if color enhancer is used).		Photo 71, Photo 51
All	Topical, colorful stains	All Natural stones	Usually this can be identified as paint.	Small amounts can be removed with lacquer thinner or scraped off carefully with a razor blade. Paint strippers can be effective but may etch some stones. Follow the manufacturers' directions for use of these products, and flush the area thoroughly with clean water. Use appropriate PPE when using these chemicals. Use only wood or plastic scrapers for removing the sludge and curdled paint. Normally, latex and acrylic paints will not cause staining. Oil-based paints, linseed oil, putty, caulks and sealants may cause oily stains. Refer to the section on oil-based stains. (In short, a good quality colloidal cleaner is probably the best and safest solution.)		
All	Yellowing	Light colored Natural Stones	Yellow-to-orange staining can either be from ferrous content indigenous to the stone fabric, or from an outside source, like a metal container or object in contact with the stone, or a fastener corroding beneath the stone.	Rust poultice will be required Most rust poultices are acid based and will etch calcium-carbonate based stones, so refinishing will be necessary after the rust treatment. Quick rust treatments can be less damaging to the stone but the purple stain left from improper use of some products can be fixed with 20-30% hydrogen peroxide. Testing in an inconspicuous area should be done before the final application.		Photo 95, Photo 96

TROUBLESHOOTING

Application	Symptom	Stone Type	Possible Causes	Potential Solutions	Prevention or Cross Reference	Photo Reference
Countertop	Chipping due to impact	All Natural stones	Chips occurring from impact by pots, pans, and other hard objects.	Clean, prep, and fill chips with a polyester epoxy with a custom tint or CA Glue. For outside chips you will need a UV stable two part epoxy with a custom color tint. For white marble and porous limestone, preseal to prevent any bleeding from the resin in the two part epoxy. In some cases you may need to drill small holes into the chip to get better tooth or bite.		Photo 79
Countertop	Colored Stains	All Natural stones	Food, and specifically fruit and fruit juices, like grape juice, wine, coffee, vegetables, tea, and even grass and mud create different colored stains.	Use a poultice (a blend of clays) with hydrogen peroxide (20%). Use nitrile gloves and safety goggles when using this product. Sometimes a mild bleach solution will take stains out. Neutralize the beach after use with water mixed with a neutral cleaner. Calcareous stones may etch and the surface may need to be refinished.		
Countertop	Dark areas around fixtures and/or soap dispensers	All Natural stones	This is obviously a soap stain.	Wiping with a towel saturated in mineral spirits will usually be effective, although many applications are usually required. Denatured alcohol is also sometimes effective.		Photo 101
Countertop	Change or faded color	All Natural stones	Resin, color enhancer, or sealer not 100% UV resistant.	Refinish; use UV resistant resin/ color enhancer.		Photo 4
Countertop	Dark Stains (Oil)	All Natural stones	Dark colored stains are frequently oil based.	Use a poultice with the correct additive in the blend of powder or a good, ready-to-use poultice liquid. Follow manufactures' directions. This may have to be done over weeks or months until the stain is gone.		Photo 8, Photo 41, Photo 100, Photo 101, Photo 102
Countertop	Dull Edges	Granite, Marble, Limestone	Substandard edge polishing on original material.	Regrind with coarse grits and then bring the surface back to a factory shine using progressively finer grits.		Photo 12, Photo 13, Photo 14
Countertop	Dull or Clouded edges	All Stone Types	The edges are fuzzy and not even.	Diamond grind surface and repolish back to the desired gloss level.		Photo 63
Countertop	Dull Spots or Rings	Marble	Areas are dull and have reduced gloss due to mild etching.	Diamond grind surface and repolish back to the desired gloss level.		Photo 45, Photo 110

TROUBLESHOOTING

Application	Symptom	Stone Type	Possible Causes	Potential Solutions	Prevention or Cross Reference	Photo Reference
Countertop	Etched areas	All Calcareous Stone Types	Dull areas around grout due to inappropriate (acidic) grout cleaner.	Diamond grind surface and repolish back to the desired gloss level.		Photo 104
Countertop	Green-to-blue Colored Stains	All Natural stones	Green-to-blue colored stains are usually cuprous in origin.	Clean the copper stain with a **very mild** acid. Neutralize and you have to resurface the stone back to its original state. If the stain remains, a poultice may be need with the correct additive for the stain.		Photo 18, Photo 28
Countertop	Hard water deposits near faucet fixtures	All Natural stones	Hard water deposits are usually caused by a combination of high mineral content water supply and occupants allowing the water to puddle, unwiped, on the countertop surface.	Carefully use single edge razor with mild soap to remove buildup from counter top, or remove the fixtures and refinish.		Photo 22
Countertop	Linear Crack at front of sink location	All Natural stones	This is typically indicative of a slab that has been "rodded," meaning that a reinforcement rod had been embedded into the underside of the slab at this location. If a mild steel rod has been used, and if the fabricator did not successfully fully encapsulate the rod in epoxy, corrosion can occur. The swelling of the rod due to corrosion can create enough pressure to crack the stone slab.	If you can open the stone carefully, pull out the metal rusted rod, using a two part UV stable epoxy with the correct color tint and glue it back together and top polish the next day. If the crack is too small to get any penetrating glue in, you might want to wait till it opens further. If unrepairable, the only remedy is replacement of the countertop.		Photo 29, Photo 30, Photo 76, Photo 99

TROUBLESHOOTING

Application	Symptom	Stone Type	Possible Causes	Potential Solutions	Prevention or Cross Reference	Photo Reference
Countertop	Lippage on Countertops	All Natural stones	One stone slab is higher than adjacent slab.	Break the seam if possible. Use a seam setter to level the two slabs and apply a flowing epoxy followed by a knife grade epoxy with the correct color. Or diamond grind the high slab to match the other slab, and then refinish to original gloss.	DSDM, COUNTERTOPS: TOLERANCES -Lippage Section	Photo 17
Countertop	Mineral Pitting	Granite	All true granites contain a micaceous mineral called "biotite," which is a black colored mineral of "flakey" or layered construction. During the polishing process, biotite can be "plucked" from the stone fabric by the abrasive heads of the polishing machine, leaving a shallow pit in the surface.	Fill pits with CA adhesive and when cured, scrape with a razor in multiple directions until the filler matches the plane of the stone surface.		Photo 35
Countertop	Rings or Spots	Granite	Whitish rings or spots occurring on black granite (which technically are not granite) have often been blamed on dyes used in the stone. While this is possible, it is not as common as believed. These materials may have complex mineralogy including minerals that are not traditionally included in true granites. Calcium-carbonate based minerals and clays can be present in these materials, both of which can change color due to wet/dry cycling.	Either refinish starting with very fine grit, or buff with a pad.		Photo 3

TROUBLESHOOTING

Application	Symptom	Stone Type	Possible Causes	Potential Solutions	Prevention or Cross Reference	Photo Reference
Countertop	Rings or Spots on Outdoor counters	All Natural stones	Commonly caused by the stone's reaction to ponded water on the surface.	Verify that it is a stain and not an etch. True granite can be cleaned with acidic cleaners. Calcareous stones must be resurfaced. These marks will usually reoccur if the exposure is unchanged.		Photo 106
Countertop	Surface staining from heat source	All Natural stones	Staining, discolored sealer, soot, or other stains from heat source such as fireplace or cooktop.	Deep clean all smoke stains (if needed) with an alkaline cleaner or mild acid, (5-6 on the pH scale). Diamond grind and polish back to desired gloss. Grinding may be required to significant depth if stone has been etched due to carbonic acid.		Photo 16
Countertop	White Rings	Granite	Stone had originally been dyed (normally black stones).	Attempt to re-dye to stabilize color.		Photo 85, Photo 86
Countertop	White Rings	Granite	Sealer did not fully penetrate stone.	Remove sealer with an acidic marble polishing compound.		Photo 3
Flooring	Blistered Surface	Granite	Moisture reacting with minerals in stone (this can be confused with spalling).	Stop source of moisture & resurface stone, refilling as necessary.	ANSI A118.10 TCNA F122 Stone or F121 Stone	Photo 36
Flooring	Blotchy, Uneven appearance in Color Enhanced Floor	All Natural stones	Usually caused by nonuniform application as a result of the floor being wet when the color enhancer was applied.	Strip the enhancer off and then start over. In some cases, refinishing will be required.		Photo 61
Flooring	Broken Corners	All Natural stones	Corners are broken, usually as a result of heavy rolling loads over corners that have no support due to voids in the setting bed.	Clean, prep and use preferably a slow curing epoxy with a custom color to rebuild the corners. Following cure of the epoxy diamond grind and refinish to desired gloss. A polyester resin (fast curing) can also be used, but does not have the performance of the epoxy.		Photo 19
Flooring	Cracking	Granite	Improper substrate	Replace tile.		Photo 31
Flooring	Cracking	Granite	Deflection issue	Check joist size, spacing & span.		Photo 31
Flooring	Cracking	Granite	Lack of crack isolation/suppression membrane.	Replace tile and utilize crack isolation membrane.		

TROUBLESHOOTING

Application	Symptom	Stone Type	Possible Causes	Potential Solutions	Prevention or Cross Reference	Photo Reference
Flooring	Cracking	Marble	Seams in cement board not filled.	Tear out and replace.	ANSI 108.5	
Flooring	Cracking	Marble	Improper adhesive coverage.	Tear out and replace.	ANSI 108.5	Photo 27
Flooring	Cracking	Marble	Insufficient joint width at change of plane or other region of discontinuity.	Saw out and open joint with cosmetic repair.	TCNA EJ171	
Flooring	Cracking	Marble or Granite	Improper substrate.	Replace tile and implement correct installation method.	TCNA F250 Stone	Photo 1, Photo 10
Flooring	Cracking	Marble or Granite	Excessive deflection.	Check joist size, spacing and span.	TCNA F250 (Optional)	
Flooring	Cracking	Marble or Granite	Lack of crack isolation/suppression membrane.	Replace tile and utilize crack isolation membrane.	TCNA F125 Stone (Concrete)	Photo 27
Flooring	Cracking	Slate	Lack of bonding adhesive under the tile.	Use appropriate adhesive, reset with a minimum 95% of coverage with the mortar. Many times the stone can be reused.	ANSI 108.5	Photo 9, Photo 107, Photo 108
Flooring	Cracking	Slate	Lack of expansion joints.	Tear out and replace.	TCNA EJ171, F250 Stone	
Flooring	Cracking	Travertine	Lack of bonding adhesive under the tile.	Replace broken tile.	ANSI 108.5	Photo 23
Flooring	Cracking	Travertine	Lack of expansion joints.	Tear out and replace.	TCNA EJ171, F250 Stone	
Flooring	Cracking	Travertine	Lack of alkaline resistant mesh tape.	Tear out and replace.	ANSI 108.5, TCNA EJ171	
Flooring	Difference between covered areas and exposed	All Natural stones	Usually this is due to color change as a result of UV exposure of a wax.	Carefully strip off the wax, neutralize with water and refinish.		Photo 56 Photo 55
Flooring	Dimpled appearance	Travertine, Marble	Polishing compound used too hot resulting in 'orange peel'	Grind and refinish to original surface quality		Photo 125 Photo 124

TROUBLESHOOTING

Application	Symptom	Stone Type	Possible Causes	Potential Solutions	Prevention or Cross Reference	Photo Reference
Flooring	Foot Prints in Sealed Stone	All Natural stones	Foot prints can be seen in certain lighting conditions in the sealed floor, but cannot be cleaned with regular cleaners due to floor having been walked on prior to full cure of the sealer.	Identify the sealer that was used, then try to re-emulsify with the same sealer with a white or hog's hair pad by breaking the surface tension and then wipe it up and buff it out. Or use Mineral Spirits and again break the surface tension. Or use a safe alkaline stripper and break the surface tension, wipe off and buff out. If unsuccessful, then stone must be refinished.		Photo 118 Photo 119
Flooring	Gaps in stone or corners	All Natural stones	Insufficient accommodation for thermal expansion and contraction	Cut grout joints and replace with appropriate movement and/or expansion joint detail per industry standards.	TCNA EJ171	Photo 26, Photo 70, Photo 105
Flooring	Indent Fractures	All Natural stones	Excessive and non-uniform depth of thinset over a membrane, creating uneven shrinkage and suction upon cure	Remove and replace, using proper floor leveling techniques and controlled thinset depth	TCNA F141	Photo 10, Photo 11
Flooring	Lippage on Floors	All Natural stones	One stone unit is higher that adjacent unit (Note: 1/32", or 0.8 mm is acceptable tolerance).	Either remove the tile and set a new one in place with correct alignment, or diamond grind the high tile to match the elevation of the surrounding tiles and refinish to achieve desired level of gloss.	MIA Design Manual, HORIZONTAL SURFACES – LIPPAGE TCNA Handbook, Lippage in Natural Stone Installations	Photo 73
Flooring	Loose Tiles	Slate	Lack of drainage mat and/ or waterproofing.	Tear out required to totally correct the problem. Many times the stone can be reused.	TCNA F122 Stone	
Flooring	Loose Tiles	Slate	Oil content present in slate.	Use appropriate adhesive to rebond and minimum 95% of coverage with the mortar. Apply a burn coat or scratch coat on the back of the tile.	ANSI A118.4	Photo 6
Flooring	Loose Tiles	Granite	Insufficient contact between adhesive and stone.	Achieve minimum of 95% of coverage on the bonding mortar (Dry & Wet Areas).	TCNA Handbook, ANSI 108.5 3.3, TCNA F102 Stone, ANSI 108.5.3.3	Photo 39

TROUBLESHOOTING

Application	Symptom	Stone Type	Possible Causes	Potential Solutions	Prevention or Cross Reference	Photo Reference
Flooring	Loose Tiles	Slate	Lack of expansion joints.	Implement expansion joints.	TCNA EJ171 ANSI 108.1	
Flooring	Loose Tiles	Slate	Presence of bond breaker on concrete slab or substrate.	Remove bond breaker prior to repair.	TCNA F122 Stone	
Flooring	Missing grout or caulking	All Natural stones	Grout has eroded due to normal service exposure, but no other signs of distress exist.	Thoroughly remove all cracked grout and either re-grout or caulk with appropriate joint sealant.		Photo 24
Flooring	Picture Framing after installation	All Natural stones	Excessive moisture in bedding layers wicks into edges of stone, creating a darkened perimeter.	Open the grout and allow to dry or use a commercial dehumidifier to remove the moisture.	ANSI A108.5	Photo 34
Flooring	Plastic Look; Orange Peel	Marble	Over crystallization.	Grind and refinish to original surface quality.		Photo 125
Flooring	Smeared Grout	All Natural stones	Stones were not properly masked or cleaned during original grouting.	Carefully remove the excess grout with the proper cleaner for grout or a razor blade with soapy water to cut down any possible scratching the surfaces.	ANSI A108.10	Photo 126
Flooring	Stone Discoloration	Granite	Stone has lost its color (outdoor application) due to fading of dyes that were applied to original material.	Use enhancer or a colored tint with the enhancer per manufacture's directions.		
Flooring	Tenting	All Natural stones	Inadequate movement and/or expansion joints, causing compression in floor surface to raise, or "tent" two or more courses of tile.	Remove and replace affected stone, adding movement and/or expansion joints per industry recommendations.	TCNA EJ171	Photo 98
Flooring	White, random direction lines in face of material	All stone, specifically soft marble and limestone.	This is referred to as "Indent fracturing," and is caused by non-uniform shrinkage of thinset that has either been used too thick, or too uneven, and typically over a membrane.	Replacement is the only remedy, with attention paid to proper slab leveling prior to installing replacement tiles.		Photo 87, Photo 88

TROUBLESHOOTING

Application	Symptom	Stone Type	Possible Causes	Potential Solutions	Prevention or Cross Reference	Photo Reference
Flooring	Yellow-to-brown blotchy surface on floors.	All calcareous stone types.	Residual wax on stone surface.	Carefully strip off the wax, neutralize with water and diamond grind, then refinish the floor to achieve desired level of gloss. Do a small test area in an inconspicuous area prior to starting balance of work. NOTE: Black or brown stripping pads can hone and open the softer stones.		Photo 54, Photo 55, Photo 56
Flooring	Yellow-to-brown blotchy surface on floors.	All siliceous stone types.	Residual wax on stone surface.	Carefully strip off the wax, neutralize with water and diamond grind, then refinish to achieve desired level of gloss. Do a test in an inconspicuous area before starting balance of work. NOTE: Black or brown stripping pads should not hurt the stones.		
Paving	Calcium deposits on stone surface.	All Natural stones	Lime from mortar has leached through to the surface as a result of the repeatedly saturated bed.	Clean all surfaces with acidic cleaner and refinish if necessary. Eventual failure is likely unless a method of bed drainage can be accomplished.	TCNA F103B	Photo 2
Paving	Erosion or excessive cracking of grout.	All Natural stones	Repeated saturation and/or freeze/thaw cycles of grout due to ponding as a result of insufficient surface slope.	Temporary correction can be achieved by surface cleaning the resultant staining and regrouting, but eventual failure of the system is nearly a certainty if not replaced.	TCNA F103B	Photo 2
Paving	Flaking	Slate, sandstone	Internal expansions within the stone fabric either due to freeze/thaw cycling or minerals with expansive behavior in a saturated state.	Clean up the loose pieces and then sand down the edge if it is a tripping hazard. Blend and feather with a brown and a black hypo pad (wet is better). Then dry and check for correct appearance. If too much breaks off, replace the tile or slab.		Photo 50, Photo 103
Paving	Lifted tiles and extensive grout cracking.	All Natural stones	Moisture trapped below surface layer.	Remove the stone, clean the substrate and the back of the tile and then re-bond them using a hard scratch coat on the back of the tiles.		Photo 116
Paving	Ponding Water	All Natural stones	Insufficient surface slope.	Temporary correction can be achieved by surface cleaning the resultant staining, but eventual failure of the system is nearly a certainty if not replaced.	TCNA F103B	Photo 113, Photo 114 Photo 120

TROUBLESHOOTING

Application	Symptom	Stone Type	Possible Causes	Potential Solutions	Prevention or Cross Reference	Photo Reference
Paving	Water staining on exterior stairs.	All Natural stones	Usually caused by inadequate, or reverse pitch, of treads.	Surface cleaning of the stone will provide temporary cosmetic improvement, but permanent remedy can only be accomplished by removing and re-setting stones.		Photo 103
Showers	Corner area of shower floor is dark.	All Natural stones	This is usually caused by a flat, or reverse sloped area that does not drain properly.	Remove stone and re-set with proper slope. Check that membrane has proper slope and that dry-pack has adequate lateral transfer capability.		Photo 5, Photo 48
Showers	Etching in showers.	All calcareous stone types.	Dull areas due to use of inappropriate (acidic) cleaner.	Diamond grind surface and repolish back to the desired gloss level.		Photo 52
Showers	Extremely warped or exfoliated stone in wet area.	Some limestone, travertine, and onyx.	Selected stone was not appropriate for wet area exposure.	Remove and replace.		Photo 84
Showers	Faint rust colored stains in shower or curb.	Light colored calcareous stones.	Ferrous content indigenous to stone has oxidized.	Test section with rust removing poultice. Repolish surface as necessary. Seal stone with appropriate impregnating sealer. NOTE: Removal of stain is not always successful or permanent!	Current TCNA Handbook, Natural Stone Tile Selection and Installation Guide, "Iron Staining"	Photo 46, Photo 83
Showers	Gaps around tubs or other dissimilar materials.	All Natural stones	The grout is not adhering to the dissimilar material.	Carefully cut out the cracked grout and apply a flexible, non-shrinking sealant. (100% RTV Silicone) In wet areas make sure the substrate is fully dry before applying sealant.	TCNA EJ171	Photo 77
Showers	Growth occurring on shower curb.	All Natural stones	BOG (Bio-Organic-Growth) is present on shower curb.	Upgrade to frameless shower door.		Photo 67
Showers	Hard Water Deposits	All Natural stones	Saturated subsurface allowing hard water to wick to stone surface, depositing hard water deposits on stone surface.	No permanent solution exists. Temporary correction may be achieved by diamond grinding the hard water deposits and removing the grout and allow to air dry. Regrout when dry. An alternate solution is to apply urethane caulk in place of grout.	TCNA F103	Photo 33, Photo 112

TROUBLESHOOTING

Application	Symptom	Stone Type	Possible Causes	Potential Solutions	Prevention or Cross Reference	Photo Reference
Showers	Heavy Water Deposits on Grout Lines in Shower Floor	All Natural stones	There are multiple possible causes for this: The weep holes could be clogged; the dry pack may be too tight and not allowing the water to drain down into the weep holes; or the water proofing membrane is not correctly sloped.	Try the weep holes first. If you cannot get it from the inside of the drain then remove the tiles and mud 4-6 inch around the drain and clean the weep holes from the outside and then set your dry pack again and tile and grout. If the pack is too tight, then the entire shower pan tile and mud must be removed and redone. If it is the water proofing membrane, well then you must remove the shower and start over.		Photo 20, Photo 21, Photo 58, Photo 65, Photo 66
Showers	Mildew Growth in shower walls and grout joints	High Porosity Stones	Inadequate sealing of high porosity stone, inappropriate stone selection, or high humidity is maintained in area when shower is not in use.	Clean with a safe mildew cleaner that will not etch stone, remove the affected grout lines, use a dehumidifier to dry out the substrate, when dry, re-grout, apply the sealer correctly and inform the client to keep the shower door open after use. Check the inside grout lines of the shower curb also.		Photo 122
Showers	Orange, Yellow, or Black Stains in a Wet Area	All Natural stones	This is frequently the growth of mildew as the result of inadequate ventilation	Clean with the proper mildew remover for natural stone. Bleach only puts the mold in dormancy; it does not kill it forever. Refinishing the stone may be necessary in some cases (see diamond grinding).		Photo 117, Photo 122, Photo 123
Showers	Rust bleeding through veins in stone	Light colored calcareous stones	Ferrous content indigenous to stone has oxidized, and is traveling through veins as the path of least resistance.	Test section with rust removing poultice. Repolish surface as necessary. Seal stone with appropriate impregnating sealer. NOTE: Removal of stain is not always successful or permanent!		Photo 81
Showers	Rusting at Shower Drain	All Natural stones	Corrosion protection on shower drain has been breached, allowing rust to bleed into surrounding stone.	Test section with rust removing poultice. Seal stone with appropriate impregnating sealer. Replace drain.		Photo 83
Showers	Rusting on Walls, benches, or floors	Light colored calcareous stones	Ferrous content indigenous to stone has oxidized.	Test section with rust removing poultice. Repolish surface as necessary. Seal stone with appropriate impregnating sealer. NOTE: Removal of stain is not always successful or permanent!	Current TCNA Handbook, Natural Stone Tile Selection and Installation Guide, "Iron Staining"	Photo 89, Photo 91, Photo 92

TROUBLESHOOTING

Application	Symptom	Stone Type	Possible Causes	Potential Solutions	Prevention or Cross Reference	Photo Reference
Showers	Shower floor and walls are darkening	All Natural stones	This is frequently caused by clogged weep holes in the drain.	Clean out the inside of the drain and then clear the weep holes of white bar soap residue, hair, hair conditioner, hard water buildup, and body oils. This is for cast Iron drains. Check to verify that the weep holes are not plugged. Cut around the tar or membrane if necessary so the weep holes are clear.		Photo 62
Showers	Spalling of Stone	Limestone	Surface spalling, usually due to expansion of some mineral content during saturated state.	Grind and fill as necessary. Encapsulate limestone with penetrating epoxy.		Photo 82, Photo 97
Showers	Tiles becoming dislodged from wall surface	All Natural stones	Improper substrate typically "greenboard" gypsum board.	Moisture Resistant Gypsum Board, a.k.a. "Greenboard" is not an appropriate substrate for direct application of tiles in wet areas. Remove and replace.	Current TCNA and MIA documents	Photo 32
Showers	Water penetrating sheetrock backing	All Natural stones	Most commonly, this is leaking at the shower curb due to inadequate membrane overlap.	Take out the shower door and cut the grout line on the shower curb on both sides and now into the pan. Replace with epoxy grout or a polyurethane sealant. Another option is to tear it out and start over but slope the shower curb membrane back to the shower at a rate of ¼ inch per ft. Dry the substrate toughly before re-grouting.		Photo 5, Photo 25
Showers	White area or surface degradation in green marble	Certain green marble and serpentine.	Many green marbles and serpentine do not perform well in wet environments.	Removal and replacement per MIA guidelines is best permanent solution. Use proper setting materials recommended for serpentine and green marble. Use of an impregnating sealer is also helpful.		Photo 49
Showers	White Spots on Mosaic Tiles	All Natural stones	This is caused by water evaporation when the shower is holding water.	Check weep holes, density of dry-pack, and slope of membrane.		Photo 109

TROUBLESHOOTING

Application	Symptom	Stone Type	Possible Causes	Potential Solutions	Prevention or Cross Reference	Photo Reference
Walls	Lippage on Walls	All Natural stones	One stone unit face is proud of adjacent units (Note: 1/32", or 0.8 mm is maximum acceptable tolerance).	Either remove the stone and re-set in place with correct alignment, or diamond grind the proud stone to match the elevation of the surrounding stones and refinish to achieve desired level of gloss.	DSDM, VERTICAL SURFACES – RELATED COMPONENTS Section 2.6 Lippage Current TCNA Handbook, Natural Stone Installations, "Lippage"	Photo 90, Photo 93, Photo 94
Walls	White Residue (Efflorescence)	All Stone Types	Moisture migrating from sub layers carrying salts, which are then deposited on stone surface.	Mechanically remove as much residue as possible with a dry brush. Then clean the area with a mild acid for slate, sandstone, and granite. For marble, a slightly alkaline chemical can be used. (8-9 on the pH scale). Note: Don't let it run down a vertical area as it may etch. Some neutral cleaners may also work.	TCNA F122 Stone (Concrete) or F101 Stone	Photo 57, Photo 69

Photo # 1

Spot bonding - improper coverage

Photo # 2

Bonded to flashing - not suitable bonding substrate

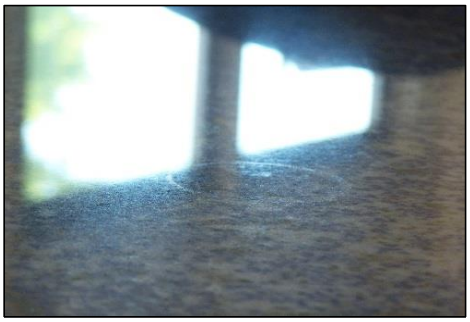


Photo # 3

Etch ring (resin enhancer disturbed) - correct: use final granite buff pad or powder

Photo # 4

Resin enhanced slab faded by UV exposure - correct: refinish; use a UV resistant enhancer/colorant

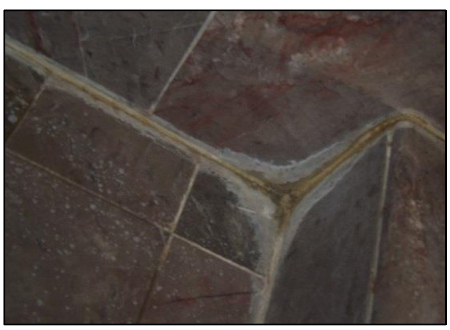


Photo # 5

Shower curb floor corner waterproof membrane improperly sloped to drain - cracked grout on shower curb (mineral deposits) - correct: remove grout, dry substrate with dehumidifier and regrout with epoxy

Photo # 6

Improper bonding coverage & improper bonding substrate (flashing)

Photo # 7

Sandstone improperly sealed (oil stain) - correct: remove stain and seal with multiple applications of appropriate sealer

Photo # 8

Improperly sealed granite (oil stain) - correct: remove stain with poultice and use multiple applications of sealer

Photo # 9

Improper bonding, hollow slate tiles - correct: apply scratch to backs of slate & use a proper notched trowel method (per TCNA guidelines)

Photo # 10

Indent fractures - substrate (rubber soundproof material) - stone cannot take deflection

Photo # 11

Indent fractures, different cause - builder did not wait 28 days for thinset to cure

Photo # 12

Improper edging technique - correct: redo the edge correctly

Photo # 13

Another view of Photo 12

Photo # 14

Edge not polished to match factory finish

Photo # 15

Pits/holes in stone - correct: clean, prep and fill with the correct patching material

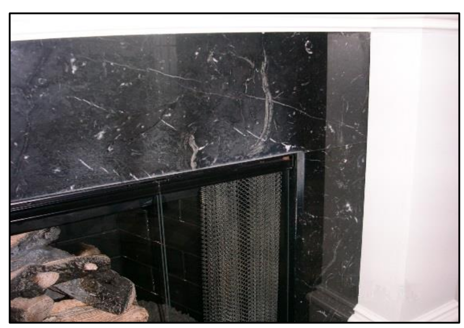


Photo # 16

Damage from heat - correct: clean soot and smoke with degreaser. Will need refinishing if etched.

Photo # 17

Countertop edge not polished to factory finish - correct: break the seam, relevel the tops with proper support and polish the edges

Photo # 18

Copper stain (caused by copper gutters) - Correct: use mild acid, then neutralize the acid or use a copper poultice & refinish area

Photo # 19

Chipped outcorner - correct: replace with matching material or clean, prep and fill with a slow-curing epoxy (not polyester)

Photo # 20

Shower pan holding water and corner improperly sloped to drain - correct: remove grout & drain and clean the weep holes. Dry thoroughly, regrout and seal

Photo # 21

Improper slope to drain, lacking two-stage drain function

Photo # 22

Calcium deposit on granite - correct: remove deposit with a straight-edge razor balde and soapy water (acid can damage plumbing fixture)

Photo # 23

Structural crack (foundation crack) - correct: replace broken tile

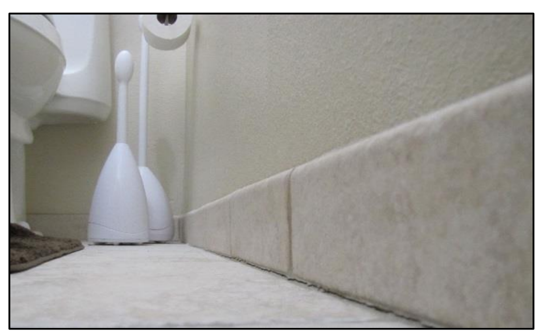


Photo # 24

Different expansion and contraction rates between floor and wall - correct: use the correct flexible material for this application

Photo # 25

Waterproofing membrane on the shower curb is not properly sloped to the drain - correct: redo per TCNA guidelines

Photo # 26

Cracked grout between tile and concrete - correct: install proper expansion joint material (no latex caulk)

Photo # 27

Crack (at tape) due to improperbond or excessive deflection. Also etched. Correct: check floor rigidity,

Photo # 28

Copper stain on natural stone - Correct: use mild acid, then neutralize the acid or use a copper poultice & refinish the area

Photo # 29

Blown rod from using metal in wet area and not encapsulated properly (fiberglass preferred)

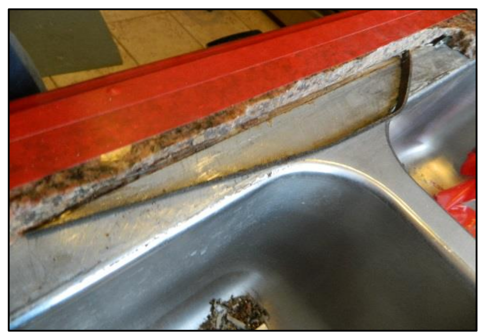


Photo # 30

Blown rod from using metal in wet area and not encapsulated properly (fiberglass preferred)

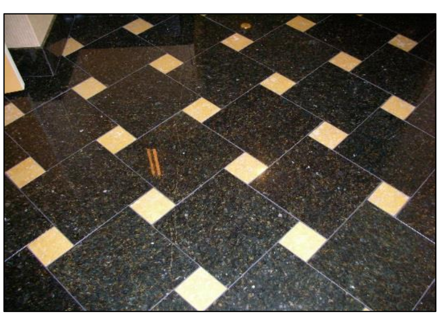


Photo # 31

Structural crack (foundation crack) - floor joists too far apart and cannot properly support the weight (live-load and dead-load specification - see TCNA guidelines)

Photo # 32

Water intrusion - improper substrate

Photo # 33

Water intrusion into the substrate and permanently staining the tile on the way out

Photo # 34

Moisture in granite floor - partially hollow - caused by stripping wax & voids in substrate - correct: replace with proper TCNA methods or remove the grout, thoroughly dry and regrout (inject with adhesives to fill voids before grouting)

Photo # 35

Pitting in granite from high mica content in the stone - correct: clean, prep and fill with epoxy or CA glue

Photo # 36

Pitting similar to that shown in Photo 35

Photo # 37

Poor quality stone (close up) - correct: replace the countertop

Photo # 38

Poor quality stone (different view) - correct: replace the countertop

Photo # 39

Poor quality installation methods and lack of bonding material - correct: clean the back of tile and substrate and reinstall using proper TCNA installation methods

Photo # 40

Swirl marks - correct: Start refinishing from the least abrasive diamond grit until the swirl marks are removed. Proceed to finer grits until the desired gloss level is achieved.

Photo # 41

Oil staining in granite countertop - correct: use oil poultice and seal thoroughly with multiple applications

Photo # 42

Tape residue - correct: use acetone and a white pad - if the stone is stained below, then refinishing may be needed

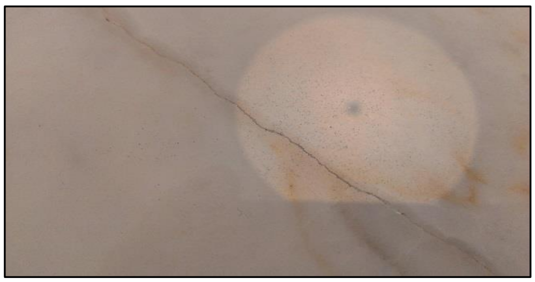


Photo # 43

Natural seams in the stone that have fully opened to be repaired like a crack or fracture

Photo # 44

Soap residue or surfactants from using the wrong cleaners - correct: remove with warm water and a good rinseless cleaner and a white pad

Photo # 45

Etch marks on polished travertine - correct: refinish the stone back to the factory polish

Photo # 46

Iron stain in white marble (white stones have iron content which oxidizes with moisture over time) - correct: use a rust poultice and refinish the stone

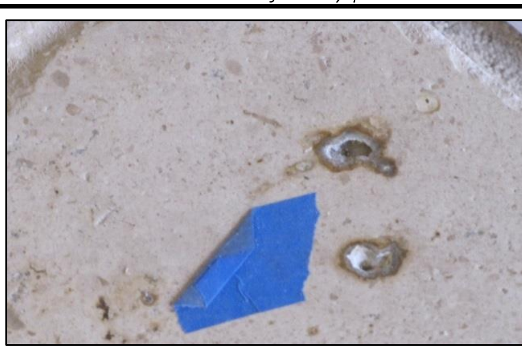


Photo # 47

Natural voids in some limestone - correct: clean, prep and fill with epoxy

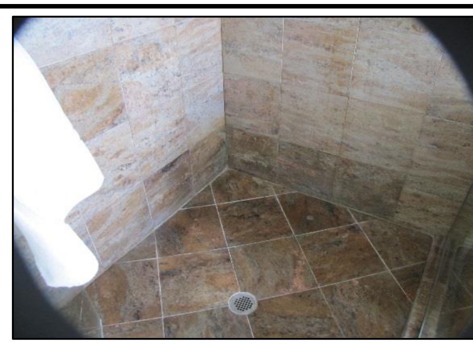


Photo # 48

Shower pan holding water - correct: remove grout in critical areas, clean weep holes, thoroughly dry, grout and seal

Photo # 49
Lack of slope, moisture evaporation causing spalling - correct: remove and replace using TCNA guidelines

Photo # 50
Pressure on edges causing cleavage in stone to break off - partially hollow tile at the edge - correct: wet or dry sand the slate until smoother and fill void in with adhesive, then regrout

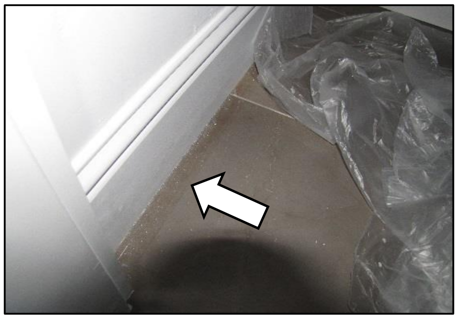


Photo # 51
Tape stain - oils from adhesive staining the stone - correct: vigorously clean with acetone and a white pad, grinding and refinishing may be necessary

Photo # 52
Badly etched stone shower - correct: grinding, refinishing and seal

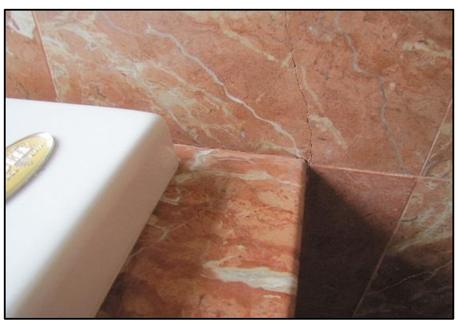


Photo # 53
Substructural crack on wall - correct: replace tile or clean, prep and repair tile and refinish as necessary to smooth out repair

Photo # 54
Multiple coats of topical sealer on a textured granite floor - correct: carefully strip the floor, allow to thoroughly dry and use an impregnator

Photo # 55
Another view of too many coats of topical sealer on a textured granite floor

Photo # 56
Another view of too many coats of topical sealer on a textured granite floor

Photo # 57

Hollow installation, efflorescence from joint resulting from moisture trying to escape

Photo # 58

Shower pan holding water and wicked off the walls past the membrane

Photo # 59

Holes in travertine - correct: clean, prep and fill with epoxy

Photo # 60

Blown rod from using metal in wet area and not encapsulated properly

Photo # 61

Using an enhancer on a moist floor - correct: strip the old enhancer, allow the floor to thoroughly dry and reapply enhancer correctly

Photo # 62

Inadequate waterproofing membrane installation leading to potentially clogged weepholes - correct: redo the the process according to TCNA guidelines and plumbing code

Photo # 63

Granite countertop edge not properly polished to match factory finish - correct: repolish the edge correctly

Photo # 64

Improper specification of material - very porous material in a wet area - correct: multiple sealing applications on multiple days

Photo # 65

Shower pan with clogged weepholes - correct: carefully remove grout, clear out the weepholes and allow substrate to thoroughly dry, then regrout and seal

Photo # 66

Inside of drain in MIA Photo 65

Photo # 67

Lack of slope on shower curb

Photo # 68

Spalling - correct: replace or clean, prep and repair

Photo # 69

Efflorescence - face of a waterfall in a pool - correct: use a mild acidic cleaner and neutralize

Photo # 70

Grout cracked - correct: cut out the grout and install an expansion joint material (driveway)

Photo # 71

Possible spacer used when resining stone slab leaving a stain within the resin - correct: completely refinish or replace

Photo # 72

Holes in a travertine - correct: clean, prep and refill

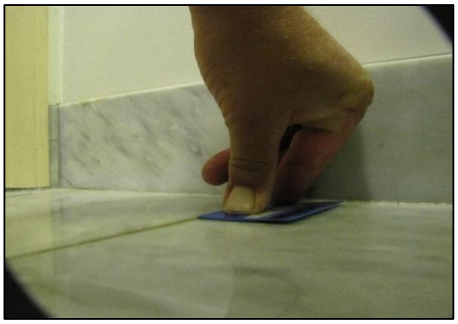


Photo # 73

Lippage - Maximum accepted lippage for the stone industry - correct: replace or grind and refinish back to specs

Photo # 74

Sealer streaking - correct: break down the sealer and follow manufacturer's recommendations

Photo # 75

Hollow edge - correct: replace tile or repair using the proper amount setting material to support the hollow areas, then clean, prep and fill

Photo # 76

Blown rod from using metal in wet area and not encapsulated properly (fiberglass preferred)

Photo # 77

Different expansion and contraction rates between rigid and flexible materials - correct: use the correct flexible material for this application

Photo # 78

Excess sealer

Photo # 79

Chip - correct: clean, prep and fill with epoxy or CA glue

Photo # 80

Spalling - correct: replace

Photo # 81

Iron oxidation - use a rust poultice, then seal thoroughly

Photo # 82

spalling on limestone shower floor - correct: replace floor

Photo # 83

Rust stain on limestone shower floor - rusted drain

Photo # 84

Spalling - correct: replace stone

Photo # 85

Dyed stone

Photo # 86

Dyed stone - another view

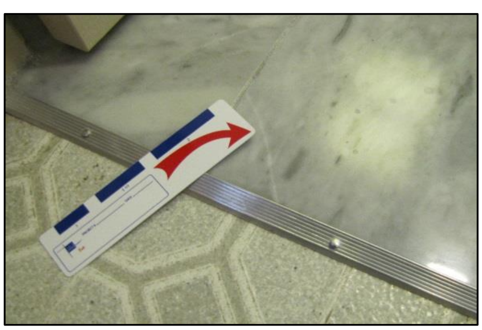


Photo # 87

Indent fracture - lack of bonding adhesive in the corner - correct: replace tile

Photo # 88

Shrinkage cracks - too much thinset adhesive used - correct: replace

Photo # 89

Same as MIA 91 & 92 - defective material for a wet application - correct: replace the material

Photo # 90

Excessive lippage - correct: replace the material

Photo # 91

Same as MIA Photo 89 & 92 - defective material for a wet application - correct: replace the material

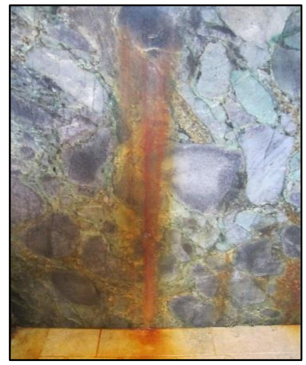


Photo # 92

Same as MIA Photo 89 & 91 - defective material for a wet application - correct: replace the material

Photo # 93

Misaligned, hollow and incorrectly spaced - correct: remove and replace

Photo # 94

Hollow tiles and spalling

Photo # 95

Stone not properly sealed

Photo # 96

Stone not properly sealed

Photo # 97

Spalling - moisture intrusion behind the wall - correct: replace it

Photo # 98

Tenting - remove and replace affected tiles. Add movement and/or expansion joints per industry

Photo # 99

Blown rod from using metal in wet area and not encapsulated properly (fiberglass preferred)

Photo # 100

Oil staining in granite countertop - correct: use oil poultice and seal thoroughly with multiple applications

Photo # 101

Soap staining granite countertop - correct: use towel saturated with mineral spirits. Repeat as necessary.

Photo # 102

Oil staining in granite countertop - correct: use oil poultice and seal thoroughly with multiple applications

Photo # 103

Efflorescence in slate

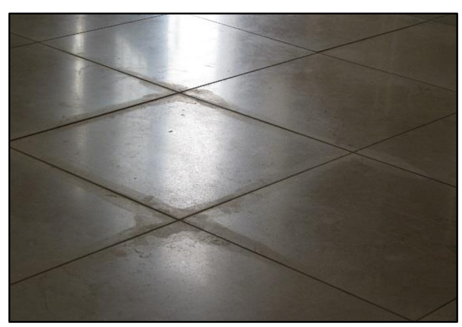


Photo # 104

Green (environmental) citrus cleaner on a marble floor used to clean the grout - correct: refinish the floor

Photo # 105

Tile separation due to lack of expansion joint - correct: cut grout and replace with appropriate expansion joint detail.

Photo # 106

Stain from planter - correct: mild acid wash, neutralize, refinish (blend and feather out)

Photo # 107

Project in Photo 108 after installation of expansion joints and proper bonding

Photo # 108

Lack of bonding adhesive under the tile - correct: use correct type and amount of bonding.

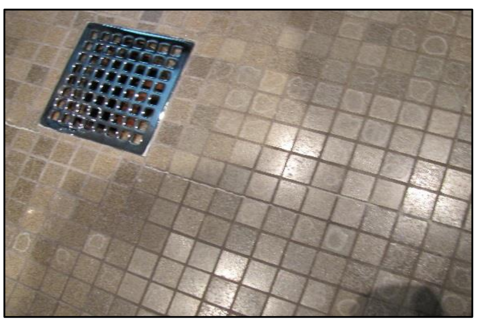


Photo # 109

Ceramic tile - pan is holding water - correct: remove tiles, clear the weepholes and replace per TCNA guidelines

Photo # 110

Etch mark on 'marble' - correct: refinish

Photo # 111

Spalling - wrong thinset on a large format tile - latex, modified thinset instead of a medium bed mortar - correct: replace

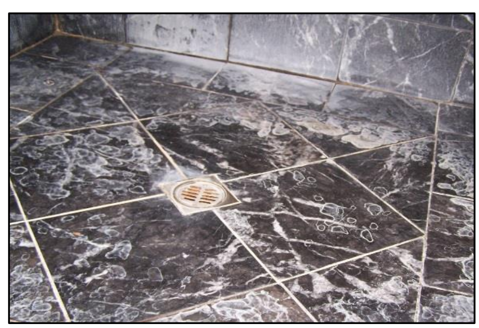


Photo # 112

Hard water deposits on black marble - correct: temporary fix: diamond grind, remove & replace grout when dry, or replace stone

Photo # 113

Another view of Photo 114

Photo # 114

Demonstrating surface slope. Ball bearings roll downhill.

Photo # 115

Moisture in substrate permanently staining slate pavers - tile sloped but the membrane is not

Photo # 116

Close-up of Photo 115

Photo # 117

Fungus - the start of mold in the grout line - correct: use a mildew cleaner that will not damage marble

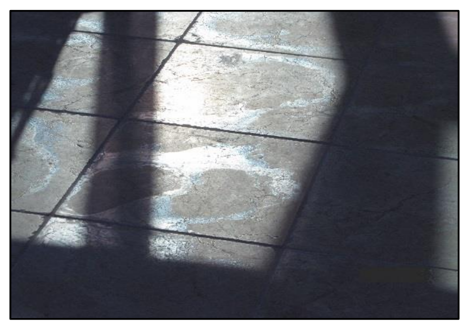


Photo # 118

Sealing in hot dry environment - dries too quickly

Photo # 119

Sealer walk on before dry - correct: re-emulsify sealer and buff. May have to refinish.

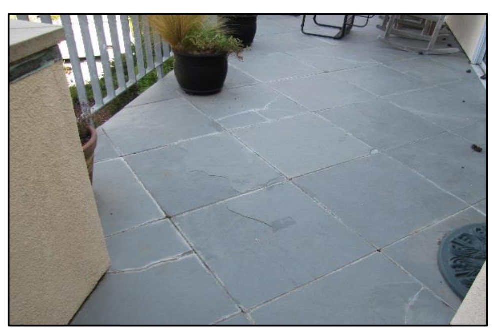


Photo # 120

Deck insufficiently sloped away from building - correct: remove and reinstall properly

Photo # 121

Cracks caused by material handling, substrate deformation, or vibration from field cutting

Photo # 122

Same as MIA Photo 123 - lack of proper maintenance, lack of proper sealing and keeping shower door closed after use (not allowing moisture to escape)

Photo # 123

Same as MIA Photo 122 - lack of proper maintenance, lack of proper sealing and keeping shower door closed after use (not allowing moisture to escape)

Photo # 124

Polishing compound too hot (orange peel) - correct: refinish with 'cold' powder.

Photo # 125

Close up of 124: Polishing compound too hot (orange peel) - correct: refinish with 'cold' powder.

Photo # 126

Excessive grout haze - correct: carefully clean excessive grout off of calcium based stone (if an acid is used, neutralize the acid and refinish the stone)

Photo # 127

Settling and chipped edges (caused by butt joint installation - minimum 1/16" gap)

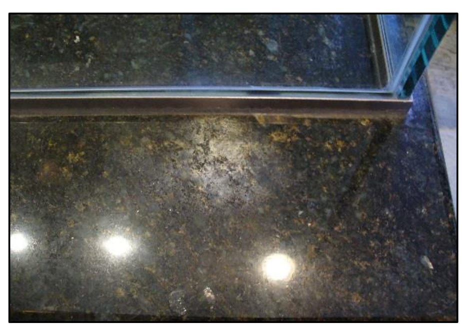


Photo # 128

Spalling on outside of shower

RESTORATION AND MAINTENANCE –
ADDITIONAL LEARNING RESOURCES

Stone Behavior Groups, pp. 21-10–16

- For more information about Crema Marfil and the company and quarries that produce it, see, http://www.levantina.com/us/.
- Online Resource: http://www.natural-stone-database.com, type “Crema Europa” in the search box.
- Online Resource: http://www.bempe.com/en/crema-europa-limestone
- Stone Care Guide, Ted McFadden. 2008.

Restorative Processes, pp. 21-51–66

- Stone Care Guide, Ted McFadden. 2008.
- Online Resource, http://www.stonerefinishing.com

Maintenance, pp. 21-75–84

- ASTM C1515, Standard Guide for Cleaning of Exterior Dimension Stone, Vertical and Horizontal Surfaces, New or Existing.
- Cleaning Masonry – Review of the Literature by Grimm, Clayford T., P.E. Construction Research Center, and University of Texas at Arlington, 1988.
- Cleaning Stone and Masonry, Clifton, James R., Editor. ASTM Special Technical Publication 935, American Society for Testing and Materials, 1983.
- Keeping It Clean by Grimmer, Anne E. U.S. Department of the Interior, National Park Service, Washington, DC: U.S. Government Printing Office, 1988
- “Cleaning of Masonry Interiors of Public Buildings,” Cleaning Stone and Masonry by Roth, J.W., ASTM STP 935, 1986.
- “Chemical Cleaning of Historical Structures – A Practical Approach,” Cleaning Stone And Masonry by Rudder, T.H., ASTM STP 935, 1986.
- “A Case Study of the Cleaning of Marble at the Schenectady, New York, City Hall,” Cleaning Stone and Masonry, by Waite, J.C. and R.J. Chen, ASTM STP 935, 1986.
- “A Macrosteriogrammetric Technique for Measuring Surface Erosion Losses on Stone,” Cleaning Stone and Masonry by Winkler, E.M., ASTM STP 935, 1986.

Commercial and Historic Restoration, pp. 21-85–88

- Occupational Safety and Health Administration (OSHA): https://www.osha.gov/law-regs.html

- Occupational Safety and Health Administration (O.S.H.A.) – Guide to *Controlling Silica Exposure:* https://www.osha.gov/Publications/3362silica-exposures.pdf
- Union Requirements – National Labor Relations Board: http://www.nlrb.gov/rights-we-protect/employerunion-rights-and-obligations
- Federal Labor Requirements – United States Department of Labor: http://www.dol.gov/whd/programs/dbra/wh347.htm
- National Park Service – Historic Rehabilitation Guidelines: http://www.nps.gov/tps/standards/rehabilitation/rehabilitation-guidelines.pdf
- National Park Service – The Secretary of the Interior's Standards for Rehabilitation: http://www.nps.gov/tps/standards/rehabilitation/rehab/stand.htm
- National Park Service – Tax Incentives: http://www.nps.gov/tps/tax-incentives.htm
- National Park Service – Register of Historic Places Database: http://www.nps.gov/history/nr/research/
- Milan Restoration Triumph – InfoTile.com http://www.infotile.com/pdfFile/Product/ProductFile/1604201343759.pdf
- Historic Preservation – Technical Procedures: http://www.gsa.gov/portal/content/111858
- National Trust for Historic Preservation: http://www.preservationnation.org

DSDM VIII (2016)

- ASTM International, ASTM C119, Standard Terminology Relating to Dimension Stone. West Conshohocken, PA: ASTM International.
- National Tile Contractors Association, NTCA Reference Manual. 2022. Jackson: NTCA.
- Tile Council of America, Tile Council of North America Installation Handbook. Princeton: TCA, 2022.
- International Code Council, 2012 International Plumbing Code. ICC, 2020.

TOLERANCES IN THE DIMENSION STONE INDUSTRY

1.0 Nothing in manufacturing, construction, or commerce is exact. Whether it's the weight of a product purchased at the market, the concentration of a chemical solution, or the length of a stone panel, none of them will measure exactly what they are specified to measure. More sophisticated methods, machines and controls will produce results with lesser amounts of error, yet no techniques will produce exact results. For these reasons, all things must have a tolerance, which is an allowable deviation from a specified, or designed value. In some cases, like the machining of critical machine parts, that allowable deviation may be so small that it is measured in micro-inches or microns. While the stone industry does not have tolerances requiring this level of precision, there exist critical dimensions that directly affect visual appearance and structural integrity of stone installations.

1.1. Tolerances are established to protect both the buyer and seller of a product or service. The buyer is protected by knowing that the workmanship must result in products that fall within the range of the prescribed tolerances. The seller is protected by having an accepted variation from the specified values or measurements, so as not to be held to unattainable expectations.

1.2. Units of measure in this document are expressed on both United States Customary Units and SI units. The values stated in each system are not exact equivalents of each other, as the conversions have been "rationalized" to provide rounded, convenient numbers in both systems. Each system of measurement shall be used exclusively and independently of the other, as combining values from both systems may result in incompatibilities.

2.0 Tolerances should not be confused with the difference between nominal and actual dimensions. Perhaps the best known example of nominal dimensions exists in the dimension lumber industry, where the common 2 by 4 does not measure 2 inches by 4 inches, but instead has an actual cross-section of 1½ inches by 3½ inches. A similar situation exists in stone supply, where a nominal paver size of 12 inches by 24 inches might have an actual size of 11¾ inches by 23¾ inches, allowing for ¼ inch joints while still maintaining a 12 inch by 24 inch installed grid. The fabrication tolerances in these cases, would be applied to the actual dimensions, and not the nominal.

3.0 There are several different types of tolerance expressions:

3.1. **Bilateral Tolerance**. This is the most frequently encountered type of tolerance in the stone industry. A bilateral tolerance is one that expresses an allowable deviation that can be either greater or lesser than the desired value. These are often referred to as "plus or minus" tolerances.

3.1.1. Bilateral tolerances are usually symmetrical. A **symmetrical bilateral** tolerance is one that allows the same amount of deviation for both greater and lesser than the target value. For instance, considering a 1¼" (30 mm) thick slab, a tolerance of plus or minus ⅛" (3 mm) is considered to be a symmetrical bilateral tolerance. Most often these types of tolerances are expressed using the "±" symbol, and would be written as ±⅛", or ±3 mm.

3.1.2. Some bilateral tolerances are asymmetrical. An **asymmetrical bilateral** tolerance is one that describes a condition where the actual value is allowed to deviate both greater and lesser than the specified, but not to the same extent. For instance, the depth of a continuous kerf is allowed to be either deeper or shallower than specified, but it is only allowed to be $^1/_{16}$" (1.5 mm) shallower, while it is allowed to be ⅛" (3 mm) deeper. This would be an asymmetrical bilateral tolerance, and is expressed as -$^1/_{16}$", +⅛" (-1.5, +3 mm).

3.2. Unilateral Tolerance. This term is used where deviation is allowed only in one direction. For example, the depth of a back anchor is allowed to be $^1/_{16}$" (1.5 mm) deeper than specified, but never shallower. This tolerance is expressed as -0, +$^1/_{16}$" (-0, +1.5 mm).

3.3. Limit tolerances are those that simply prescribe the minimum and maximum dimensions allowable, without defining an actual target dimension. This method is sometimes referred to as a "Go – No Go" expression. A limit tolerance would typically be written as "1⅛" min, 1⅜" max". Limit tolerances are infrequently used in the stone or construction industries.

3.4. Percentage tolerances are sometimes used when the allowable deviation varies with the value of the target dimension. Percentage tolerances can be either bilateral or unilateral, and simply state the percentage of variation that is acceptable. These types of tolerances are most often used for things that affect visual characteristics only. For example, one's eye may be able to detect an error in the width of a ⅛" (3 mm) joint when it approaches $^1/_{32}$" (0.8 mm), but on a ½" (12 mm) joint, the error would need to be much greater to be visually detectable. Stating that the allowable tolerance is ±25% is a simple way of having a self-adjusting tolerance which gets larger as the specified dimension gets larger.

3.5. Percentage tolerances are frequently coupled with an absolute dimensional limit, either a maximum or a minimum. Such limits are typically referred to as "Not Less Than" (NLT) or "Not to Exceed" (NTE). These limits are used when the percentage tolerance represents a very small or very large tolerance at either end of the target value range. Joint width variation, for example, is allowed to be ±25%. But that would mean that a stone setter working with $^1/_{16}$" joints has an acceptable variation of only $^1/_{64}$", which would be unattainable in most scenarios. To address this, the tolerance is expressed as ±25%, NLT $^1/_{32}$". This means that the setter is allowed to have joint widths that are 25% larger or smaller than the specified, but in no case shall he/she be held to a tolerance of less than ±$^1/_{32}$".

3.6. The same tolerance can be communicated by writing it as a bilateral, unilateral, or limit tolerance. The only difference is the format of the expression. For example, the five examples below describe exactly the same allowable range of dimension:

Examples of Tolerance Formatting Differences		
Tolerance Type	**Unit of Measure**	**SI Equivalent**
Bilateral (symmetrical)	1¼" ±⅛"	30 ±3 mm
Bilateral (asymmetrical)	1$^3/_{16}$" -$^1/_{16}$", +$^3/_{16}$"	29 -2,+4 mm
Unilateral	1⅛" -0, +¼"	27 -0, +6 mm
Limit	1⅛" min, 1⅜" max	27 mm min, 33 mm max
Percentage	1¼" ±10%	30 mm ±10%

5.0 Measurement of stone units to determine compliance with published tolerances shall be done with instruments that are appropriate for the level of precision required. A common tape measure is adequate for most dimension checks, but when a feature must be measured to fine degrees of accuracy, a caliper or feeler gauge may be necessary. All instruments used for measuring should be calibrated, or checked for accuracy, prior to use. Normal usage of a tape measure, for example, will frequently result in the loosening or bending of the end hook, which will produce significant errors in linear measurements.

6.0 Applicability of this Document.

6.1. There are a variety of sources from which stone fabrication and installation tolerances can be obtained. This document was cross-referenced with tolerances published by a variety of organizations. While most of the published tolerances are in agreement or exhibit only slight differences, some conflicts may exist between this document and those published by other organizations.

6.2. This document is considered to be a voluntary standard. It has been drafted and reviewed by industry stakeholders and represents a consensus opinion of industry participants. When specified as the enforceable standard, it becomes part of a binding agreement.

6.3. When no document has been specified to govern the tolerances of a stone project or a stone purchase, this document, by default, may be cited as the appropriate industry standard for those products.

6.4. More or less stringent tolerances may be specified or adopted for any particular product or purchase. When alternate tolerances have been agreed upon between the buyer and seller, those tolerances supersede the tolerances listed herein.

6.5. The natural stone industry works with a nearly limitless variety of products in a nearly limitless variety of installation methods. Extreme circumstances may exist for which the tolerances listed herein are either not appropriate or not attainable. Tolerances for such conditions shall be established on a project specific basis.

7.0 A chart of stone fabrication, installation, and substrate condition tolerances is provided following these pages.

8.0 Some of the tolerance expressions included in the chart require a graphic to ensure correct and uniform interpretation. These graphics are provided immediately following the chart in drawing D-22-1.

NOTES:

STONE INDUSTRY TOLERANCES

SECTOR	ISSUE	ITEM	TOLERANCE	
FABRICATION	Thickness	Thickness ranging from $^1/_4$" to $^5/_8$" (6 mm to 15 mm) with Smooth Finishes sold as "Calibrated"	±$^1/_{32}$"	±0.8 mm
		Thickness ranging from $^1/_4$" to $^5/_8$" (6 mm to 15 mm) with Flame or Textured Finishes sold as "Calibrated"	Depth of Finish Relief, NTE $^1/_8$"	±1.5 mm
		Thickness ranging from >$^5/_8$" to 1¼" (>15 to 30 mm) with Smooth Finishes	±$^1/_8$"	±3 mm
		Thickness ranging from >$^5/_8$" to 1¼" (>15 to 30 mm) with Flamed or Sanded Finishes	Depth of Finish Relief, NTE $^3/_{16}$"	Depth of Finish Relief, NTE 5 mm
		Thickness ranging from >$^5/_8$" to 1¼" (>15 to 30 mm) Finished 2 Faces with Smooth Finishes	±$^1/_{16}$"	±1.5 mm
		Slab thickness of >1¼" to 2" (>30 to 50 mm)	±$^1/_8$"	±3 mm
		Slab thicknesses over 2" (>50 mm)	±$^1/_4$"	±6 mm
	Face Size	Face Dimension of Calibrated Tiles (see graphic)	±$^1/_{32}$"	±0.8 mm
		Face Dimension of Pieces with Lengths up to 6'-0" (2 m) (see graphic)	±$^1/_{16}$"	±1.5 mm
		Face Dimension of Pieces with Lengths > 6'-0" (2 m) and Areas ≤ 50 ft² (5 m²) (see graphic)	±$^3/_{32}$"	±2.5 mm
		Face Dimension of Pieces with Areas > 50 ft² (5 m²) (see graphic)	±$^1/_8$"	±3 mm
	Squareness	Maximum Deviation from Square - Calibrated Tiles (see graphic)	Governed by Face Dimension Tolerance - See Graphic	
		Maximum Deviation from Square - Cut-to-Size Dimension Stone (see graphic)	Governed by Face Dimension Tolerance - See Graphic	
		Perpendicularity Error of Edge to Face, Exposed Edge with Smooth Finish	±1.0° (about $^1/_{64}$" per in)	±1.0° (about 0.18 mm in 10 mm)
		Perpendicularity Error of Edge to Face, Concealed Edge with Smooth Finish	±2.0° (about $^1/_{32}$" per in)	±2.0° (about .35 mm in 10 mm)
	Flatness	Maximum Deviation from Flat Plane - Calibrated Tile with Smooth Finish	±$^1/_{32}$" in 2'-0"	0.8 mm in 600 mm
		Maximum Deviation from Flat Plane - Back Surface of Calibrated Tile	±$^1/_{32}$" in 2'-0"	0.8 mm in 600 mm
		Maximum Deviation from Flat Plane - Cut-to-Size Dimension Stone with Smooth Finish	±$^1/_{16}$" in 4'-0"	±1.5 mm in 1.2 m
		Maximum Deviation from Flat Plane - Cut-to-Size Dimension Stone with 4-Cut, 6-Cut, 8-Cut Finish	±$^1/_8$" in 4'-0"	±3 mm in 1.2 m
		Maximum Deviation from Flat Plane - Cut-to-Size Dimension Stone with Flamed or Coarse Stipple Finish	±$^3/_{16}$" in 4'-0"	±5 mm in 1.2 m
		Maximum Deviation from Flat Plane - Cut-to-Size Dimension Stone with Pointed or Rough Cut Finish	±1" in 4'-0"	±25 mm in 1.2 m
		Maximum Deviation from Flat Plane - Cut-to-Size Dimension Stone with Splitface Finish	Per Stock	Per Stock

STONE INDUSTRY TOLERANCES

SECTOR	ISSUE	ITEM	TOLERANCE	
FABRICATION (Continued)	Edge Conditions	Exposed Heads/Calibrated edges (see graphic)	$\pm^{1}/_{16}$"	±1.5 mm
		Quirk miters (when width of nose ≤ ¼"; ≤6 mm) (see graphic)	-0, +25% of dim	-0, +25% of dim
		Quirk miters (when width of nose > ¼"; >6 mm) (see graphic)	-0; $+^{1}/_{16}$"	-0; +1.5 mm
		Chamfers (when dimension ≤ ¼"; ≤6 mm) (see graphic)	-0, +25% of dim	-0, +25% of dim
		Chamfers (when dimension > ¼"; >6 mm) (see graphic)	-0; $+^{1}/_{16}$"	-0; +1.5 mm
		Bullnose, Semi-Bullnose, & Rounds for thickness up to 1¼" (30 mm) (see graphic)	$\pm^{1}/_{32}$" from Theoretical Surface	±0.8 mm from Theoretical Surface
		Bullnose, Semi-Bullnose, & Rounds for thickness greater than 1¼" (30 mm) (see graphic)	$\pm^{1}/_{16}$" from Theoretical Surface	±1.5 mm from Theoretical Surface
	Anchor Preps	Plunge Cut Anchor Slots: From face to C/L of slot	$\pm^{1}/_{16}$"	±1.5 mm
		Plunge Cut Anchor Slots: Lateral placement	$\pm^{1}/_{4}$"	±6 mm
		Plunge Cut Anchor Slots: Width of Slot	-0; $+^{1}/_{16}$"	-0; +1.5 mm
		Plunge Cut Anchor Slots: Depth of Slot at maximum	$\pm^{1}/_{8}$"	±3 mm
		Back Anchors: Location	$\pm^{1}/_{8}$"	±3 mm
		Back Anchors: Depth	-0; $+^{1}/_{16}$"	-0; +1.5 mm
		Anchor Holes: From face to C/L of slot	$\pm^{1}/_{16}$"	±1.5 mm
		Anchor Holes: Lateral placement	$\pm^{1}/_{8}$"	±3 mm
		Anchor Holes: Diameter	$\pm^{1}/_{16}$"	±1.5 mm
		Anchor Holes: Depth	$\pm^{1}/_{8}$"	±3 mm
		Anchor Holes: Depth of Anchor Sinkages:	-0, $+^{1}/_{8}$"	-0, +3 mm
		Continuous Kerfs: From face to C/L of kerf	$\pm^{1}/_{16}$"	±1.5 mm
		Continuous Kerfs: Maximum bow in 4'-0"	$\pm^{1}/_{16}$"	±1.5 mm
		Continuous Kerfs: Width of Kerf	-0; $+^{1}/_{16}$"	-0; +1.5 mm
		Continuous Kerfs: Depth of Kerf	$-^{1}/_{16}$", $+^{1}/_{8}$"	-1.5, +3 mm
		Rebated Kerfs: Elevation of Bearing Surface	$\pm^{1}/_{16}$"	±1.5 mm
		Bearing Checks: Elevation of Bearing Surface	$\pm^{1}/_{16}$"	±1.5 mm
		Bearing/Clearance Checks: Lateral Location	$\pm^{1}/_{2}$"	±13 mm
		Bearing/Clearance Checks: Setback from Face	$\pm^{1}/_{16}$"	±1.5 mm

STONE INDUSTRY TOLERANCES

SECTOR	ISSUE	ITEM	TOLERANCE	
INSTALLATION	Lippage	Lippage, Maximum on Calibrated Tile (Smooth Surfaces)	$^{1}/_{32}$"	0.8 mm
		Lippage, Maximum on Calibrated Tile (Flamed or Textured Surfaces)	Depth of Finish Relief, NTE $^{3}/_{16}$"	Depth of Finish Relief, NTE 5 mm
		Lippage, Maximum on Stone Pavement Walking Surfaces (smooth surfaces)	$^{1}/_{32}$"	0.8 mm
		Lippage, Maximum on Stone Pavement Walking Surfaces (Flamed or Textured surfaces)	Depth of Finish Relief, NTE $^{3}/_{16}$"	Depth of Finish Relief, NTE 5 mm
		Lippage, Maximum on Interior Vertical Panels ≤20 ft² (≤2 m²) (smooth surfaces)	$^{1}/_{32}$"	0.8 mm
		Lippage, Maximum on Interior Vertical Panels ≤20 ft² (≤2 m²) (Flamed or Textured surfaces)	Depth of Finish Relief, NTE $^{3}/_{16}$"	Depth of Finish Relief, NTE 5 mm
		Lippage, Maximum on Interior Vertical Panels >20 ft² (>2 m²) (smooth surfaces)	$^{1}/_{16}$"	1.5 mm
		Lippage, Maximum on Interior Vertical Panels >20 ft² (>2 m²) (Flamed or Textured surfaces)	Depth of Finish Relief, NTE $^{3}/_{16}$"	Depth of Finish Relief, NTE 5 mm
		Lippage, Maximum on Countertop @ Front	0	0
		Lippage, Maximum on Countertop @ Back	$^{1}/_{32}$"	0.8 mm
		Lippage, Maximum on Island Top @ Center	$^{1}/_{32}$"	0.8 mm
	Joint Width	Joint Width, Variation from Specified	±25% of Specified Dimension, NLT ±$^{1}/_{32}$"	±25% of Specified Dimension, NLT ±0.8 mm"
		Seam (Joint) Width, Countertop (Stone to Stone)	±25%, NLT ±$^{1}/_{64}$"	±25%, NLT ±0.4 mm
		Seam (Joint) Width, Countertop (Stone to Other)	±$^{1}/_{16}$"	±1.5 mm
		Seam (Joint) Width, Countertop (Full-Height Backsplash to Upper Cabinet)	±$^{1}/_{8}$"	±3 mm
		Joints, Variation from Straight Line	$^{1}/_{8}$" in 10'-0" $^{1}/_{4}$" in 20'-0" $^{3}/_{8}$" Maximum	3 mm in 3 m 6 mm in 6 m 10 mm Maximum
	Alignment	Maximum Variation from Flat & Level, Interior Flooring	$^{1}/_{8}$" in 10'-0" $^{1}/_{4}$" in 20'-0" $^{3}/_{8}$" Maximum	3 mm in 3 m 6 mm in 6 m 10 mm Maximum
		Maximum Variation from Flat & Level, Flooring underneath a Revolving Door	±$^{1}/_{16}$"	±1.5 mm
		Maximum Variation from Plumb, Walls & Vertical Lines , Interior Cladding	$^{1}/_{8}$" in 8'-0" $^{1}/_{4}$" Maximum	3 mm in 2.5 m 6 mm Maximum
		Maximum Variation from Level (Sills, Lintels, Etc.), Interior Cladding	$^{1}/_{8}$" in 10'-0" $^{1}/_{4}$" in 20'-0" $^{3}/_{8}$" Maximum	3 mm in 3 m 6 mm in 6 m 10 mm Maximum

STONE INDUSTRY TOLERANCES

SECTOR	ISSUE	ITEM	TOLERANCE	
INSTALLATION (Continued)	ALIGNMENT (Continued)	Maximum Variation from Building Line Position, Interior Cladding	$^1/_8$" in 10'-0" $^1/_4$" in 20'-0" $^3/_8$" Maximum	3 mm in 3 m 6 mm in 6 m 10 mm Maximum
		Maximum Variation from Flat & Level, Countertop	$^1/_8$" in 10'-0"	3 mm in 3 m
		Maximum Variation of Riser Height in Stairs	$^3/_8$" Max Difference Between Largest & Smallest Risers; NTE $^3/_{16}$" Difference Between Consecutive Risers	10 mm Max Difference Between Largest & Smallest Risers; NTE 5 mm Difference Between Consecutive Risers
		Maximum Variation from Plumb, Walls & Vertical Lines , Exterior Cladding	$^1/_4$" in 10'-0" $^3/_8$" in 20'-0" $^1/_2$" Maximum	6 mm in 3 m 10 mm in 6 m 12 mm Maximum
		Maximum Variation from Plumb, Exterior Corners or Conspicuous Lines	$^1/_8$" in 10'-0" $^1/_4$" in 20'-0" $^3/_8$" Maximum	3 mm in 3 m 6 mm in 6 m 10 mm Maximum
		Maximum Variation from Level (Sills, Lintels, Etc.), Exterior Cladding	$^1/_8$" in 10'-0" $^1/_4$" in 20'-0" $^3/_8$" Maximum	3 mm in 3 m 6 mm in 6 m 10 mm Maximum
		Maximum Variation from Building Line Position, Exterior Cladding	$^1/_4$" in 20'-0" $^1/_2$" Maximum	6 mm in 6 m 12 mm Maximum
SUBSTRATES	Surface Plane	Maximum Variation from Flat & Level; Substrate for Thinset Interior Flooring	$^1/_8$" in 10'-0"	3 mm in 3 m
		Maximum Variation from Flat & Plumb, Adhered Interior Wall	$^1/_8$" in 10'-0"	3 mm in 3 m
		Maximum Variation from Flat & Plumb, Adhered Exterior Cladding	$^1/_4$" in 10'-0"	6 mm in 3 m
		Maximum Variation from Flat & Level, Countertop	$^1/_8$" in 10'-0"	3 mm in 3 m

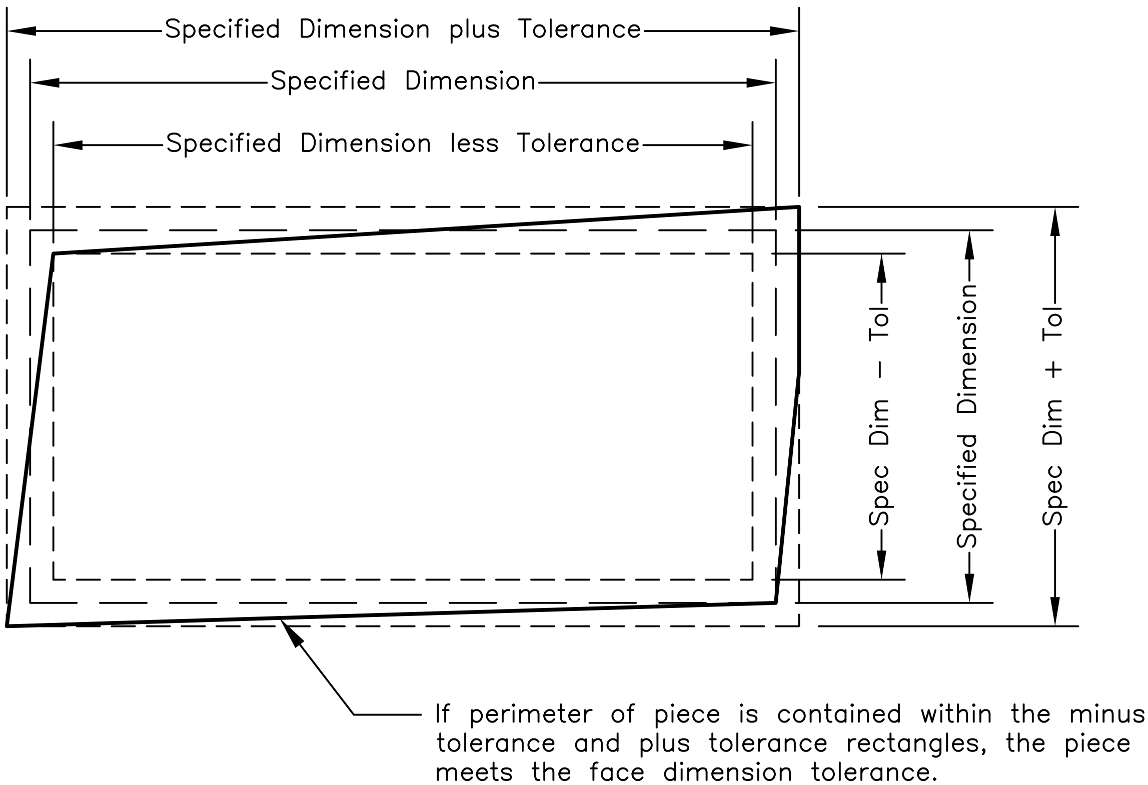


FIGURE 1: FACE SIZE TOLERANCE

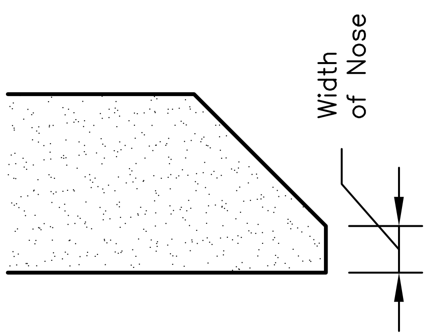


FIGURE 2
QUIRK MITER

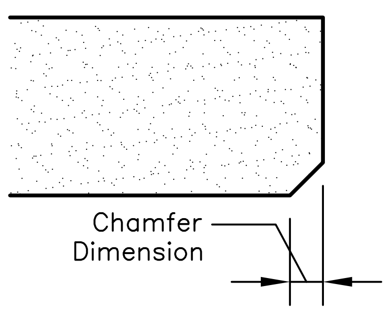


FIGURE 3
CHAMFER

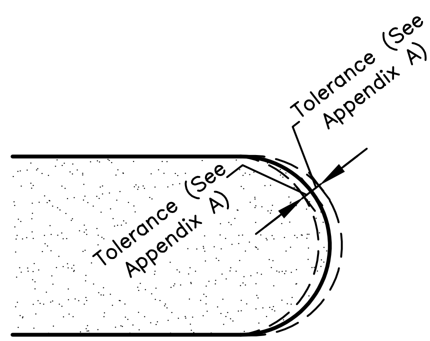


FIGURE 4
BULLNOSE

NATURAL STONE INSTITUTE
380 East Lorain Street, Oberlin, OH 44074 USA
www.naturalstoneinstitute.org

REV	DATE
0	MAR 2022

GRAPHIC INTERPRETATION OF TOLERANCES

DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 22-D-9

SCALE: NOT TO SCALE

NOTES:

GLOSSARY OF STONE INDUSTRY TERMS

Additional references are listed at the end of this glossary.

A

Abate
In stone carving, to cut away material, leaving parts in relief.

Abrasive Finish
A non-reflective surface finish. An abrasive finish may be defined by the grit size of the abrasive.

Abrasive Hardness (H_a)
A measure of the wearing performance of stone for floors, stair treads, and other areas subjected to abrasion by foot traffic. Refer to ASTM C241 and C1353.

Absorption
The amount of water absorbed by a stone, expressed as a percentage by weight. Refer to ASTM C97.

Abutment
A solid stone “springer” at the lowest point of an arch or vault.

Accelerator
In masonry, any ingredient added to mortar or concrete to speed the curing process.

Acid Wash
A treatment applied to the face of a stone to achieve a texture or finish that is distressed. Most acidic chemical treatments are effective only when applied to calcareous stone varieties.

Adhered
Used in reference to stone veneer, secured and supported by adhesion of an approved bonding material over an approved backing.

Admixture
A material other than water, aggregates, lime or cement, added to concrete or mortar at the time of mixing. Admixtures are typically added to function as water repellents, coloring agents or to adjust the curing rate of the concrete or mortar.

Adoquin
A volcanic, quartz based stone containing a variety of colored aggregates and pumice in a quartz matrix. Quarried in Mexico.

Agate
A variegated, **translucent**, cryptocrystalline variety of quartz showing colored bands or other markings (clouded, moss-like, etc.).

Agglomerated Stone
A manmade product composed of crushed stone combined with resin. See also **engineered stone** and **cultured stone**.

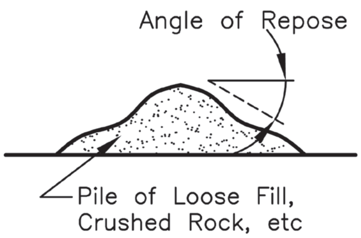
Aggregate
A small mass of rock, having occurred naturally (as in sand or gravel) or by means of manufacture (as in a crushed aggregate product), used either in a loose, noncohesive state, or as an ingredient in mortar or concrete products.

Alabaster
A fine grained and **translucent** variety of gypsum, generally white in color. Commonly used in decorative applications as it is can be cut and carved easily with a knife or saw. Term is often incorrectly applied to fine grained marble.

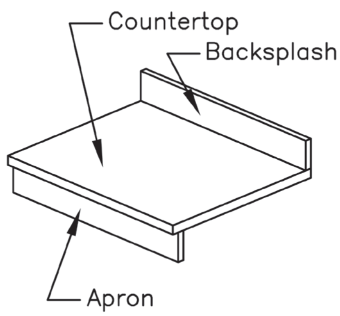
Alkaline
Pertains to a highly **basic**, as opposed to acidic, substance; for example, hydrogen or carbonate of sodium or potassium.

Allowable Capacity
The safe load that can be resisted by a stone anchor, determined by dividing the ultimate capacity by the factor of safety.

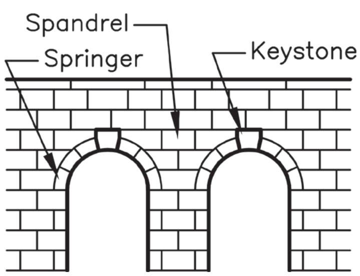
Ambient Temperature
Temperature of the surrounding environment.



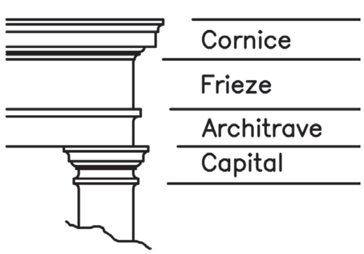
Angle of Repose



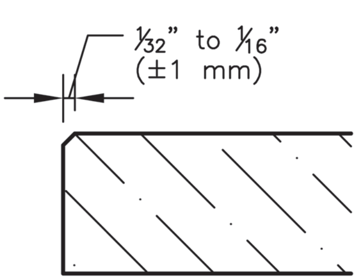
Apron



Arch



Architrave



Arris

Anchor
A corrosion resistant metal fastener used for securing dimension stone to a structure or adjacent stone units. Anchor types for stonework include those made of flat stock (straps, dovetails)and round stock (rod cramp, rod anchor, eyebolt and dowel).

Anchorage
The means by which slabs are secured to a self supporting structure.

Angle of Repose
The angle a normal pile of loose material makes to the horizontal. Used as an indicator of flowability; the steeper the slope, the more sluggish the flow.

Anisotropic
Having properties, either visual or mechanical, that differ based on the direction in which they are measured. All stones are anisotropic to some degree, but the sedimentary stones typically have the greatest degree of anisotropy.

Anorthosite
A dark-colored igneous rock consisting mostly or entirely of calcic plagioclase.

ANSI
American National Standards Institute

Antique Finish
A finish that replicates rustic or distressed textures. Produced through mechanical or chemical means to simulate the naturally occurring effects of the aging process.

Apex Stone
Uppermost stone in a gable, pediment, vault or dome.

Apron
A trim piece under a projecting stone top, stool, etc.

Arch
The curved or pointed construction over a doorway or opening. Arch shapes range from flat to semicircular or semielliptical to acutely pointed.

Architrave
The beam or lowest division of the entablature in the classical orders, spanning from column to column. The decorated surrounds of a window or door at the head and jamb.

Argillite
A weakly metamorphosed compact rock composed mainly of clay and shale. Used locally as building stone, although rarely produced commercially.

Arkose
A feldspar-rich sandstone containing 10% or more clastic grains of feldspar. Also called "arkosic sandstone" and "feldspathic sandstone."

Arris
A slight, although measurable, chamfer where two surfaces meet

Artificial Stone
A manmade product attempting to replicate the look of natural stone. This term is actually a misnomer, as it includes an obvious contradiction of terms. Stone is naturally occurring earth material. See **engineered stone** and **cultured marble**.

Ashlar
A stone façade of generally square or rectangular units having sawed or dressed beds. There are three generally recognized distinctions:

1. **random ashlar:** ashlar set with stones of varying length and height so that neither vertical nor horizontal joints are continuous.
2. **coursed ashlar:** Ashlar set to form continuous horizontal joints.
3. **stacked ashlar:** Ashlar set to form continuous vertical joints.

ASI
(Allied Stone Industries)
The Allied Stone Industries is made up of stone quarriers, fabricators, and the suppliers of natural building materials and related machinery and tools.

ASTM International
A consensus standards authoring organization originally founded 1896 as American Society for Testing Materials.

Axed Work (British)
Hand-dressed stone surface showing fine-to-course, generally linear toolmarks made by axe, pick or bush hammer.

B

Back Anchor
Any of a variety of anchors that extends from the back surface of a stone panel, as opposed to anchors that penetrate the edges of a stone panel.

Backer Rod
A flexible and compressible type of closed cell foam polyethylene, butyl rubber, or open-cell or closed-cell polyurethane, rounded at surface to contact sealant. The backer rod is positioned within the joint so as to maintain appropriate depth and crosssectional shape of the bead.

Back-parging
The process of slathering the back of an adhered stone unit with an adhesive material to reduce or eliminate voids in adhesive contact. Also used in travertine or with the application of damp proofing. Also referred to as "back-buttering."

Backsplash
A vertical covering of the wall where a countertop surface meets the wall surface, designed to protect the wall from moisture. Backsplashes range from a few inches in height to "full height backsplashes" that extend from the countertop surface to the underside of the upper cabinets.

Back-up Structure
A structural support wall erected behind stone or brick facing.

Baluster
A short post or vertical member in a series that supports a railing or coping forming a balustrade. Balusters are traditionally decorative forms that are turned on a lathe.

Balustrade
A railing system with top rail, balusters and bottom rail.

Band Course
See **string course**.

Banker
Bench of timber or stone (may be a single block) on which stone is worked.

Basalt
A dark colored, igneous rock commercially known as granite when fabricated as dimension stone. The fine-grained and extrusive equivalent of **gabbro**.

Base
In masonry, the bottom course of a stone wall, or the vertical first member above grade or a finished floor.

Basic
In geology, one of four subdivisions used to classify igneous rocks based on silica content: acidic, intermediate, basic and ultra-basic. Said of igneous rock containing relatively low silica content (approx. 45 to 50%).

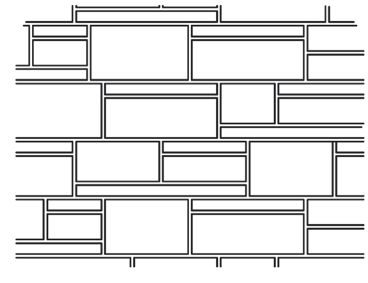
Batted Work (British)
Hand-dressed stone surface scored top to bottom in narrow parallel strikes, using a batting tool. Strokes may be vertical (in which case the surface may be called tooled) or oblique, and may range from 8 to 10 per inch. Batting is also called "broad tooling," "droving," or "angle dunting."

Bearing Check
A slot, generally not continuous, cut into the back or bed of dimension stone to allow entry of a supporting angle or clip.

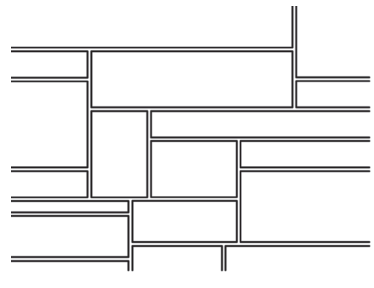
Bed Joint
A horizontal joint between stones, usually filled with mortar or sealant.

Bed
1. The top or bottom of a joint, natural bed; surface of stone parallel to its stratification.
2. In granites and marbles, a layer or sheet of the rock mass that is frequently horizontal, commonly curved and lenticular, as developed by fractures. Sometimes also applied to the surface of parting between rock sheets.
3. In stratified rocks, the unit layer formed by sedimentation; of variable thickness, and commonly tilted or distorted by subsequent deformation.It generally develops a rock cleavage, parting, or jointing along the planes of stratification.

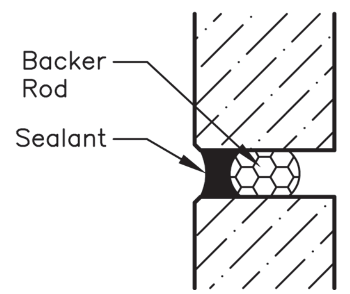
Bedding Plane
Plane of sedimentary stone in the position of its original formation. This plane may be horizontal, coincident with mountain slopes, or random.



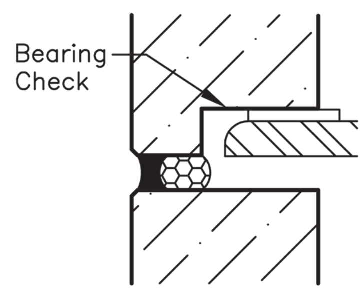
Coursed Ashlar



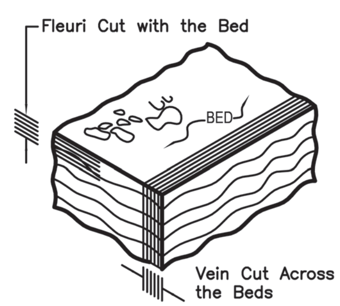
Random Ashlar



Backer Rod



Bearing Check



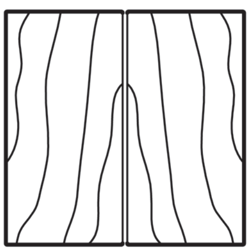
Bedding Plane

Bedrock
General term referring to the rock underlying other unconsolidated material, such as soil.

Belt Course
A continuous horizontal course, marking a division in the wall plane.

Bench
Steps formed in a quarry by removal of stone. Also, a long seat of cubic stone. bevel. A term describing the intersection of two surfaces meeting at an angle other than 90 degrees.

Black Granite
Rock species known to petrologists as diabase, diorite, gabbro and other varieties quarried as dimension stone. As dimension blocks or slabs, they are valued specifically for their dark grey to black color when polished. Scientifically, they are far removed in composition from true granites though they may be satisfactorily used for some of the purposes to which commercial granites are adapted. They possess an interlocking crystalline texture, but unlike granites, they contain little or no quartz or alkalic feldspar, and are characterized by an abundance of one or more of the common black rock-forming minerals (chiefly pyroxenes, hornblende, and biotite).



Book Match Pattern

Blade Dressing
A maintenance process required periodically to restore optimum performance of diamond abrasive cutting tools. The process consists of cutting or grinding into a softer material which will abrade at the matrix and expose new diamond surfaces. Dressing is frequently done with manufactured dressing sticks, soft brick, and some abrasive sandstones.

Bleed
Staining caused by corrosive metals, oil based putties, mastics, caulking, or sealing compounds.

Blending
The random positioning of adjacent veneer panels, floor slabs, or tiles, to prevent large regions of uniform color, contrasted by adjacent large regions of dissimilar uniform color.

Block
See **quarry block.**

Bluestone
A fine- to medium-grain, quartz based stone of the U.S. Appalachian Plateau. The stone is well known for relatively easy cleavage along generally flat planes, making it a common choice for naturally cleft products such as flagstone. The term "bluestone" may be used in other parts of the world to describe very dissimilar regional products.

Bollard
A free standing stone post or guard.

Bond
1. Pattern of joints in successive courses.
2. To stick or adhere.

Book Match Pattern
A vein matching technique where opposite faces of adjacent slabs are exposed, producing a repeating mirror image of the veining trend of the material. Book-matched material is most commonly polished to allow the greatest visibility of the veining character of the stone.

Border Stone
Usually a flat stone used as an edging material. A border stone is generally used to retain or define the pattern around the field of paving.

Boss
In masonry, a roughly shaped stone set to project for carving in place. A carved ornamentation to conceal the jointing at the junction of ribs in a Gothic vault.

Boulder
Naturally rounded rock fragment larger than 256 mm diameter. Used for crude walls and foundation, generally in mortar.

Bowing
A warping or curving of a stone unit.

Breccia
Rock characterized by course, angular fragments, either the result of crushing and recementing essentially in place, or deposition of angular pieces that become consolidated. Numerous marbles owe

their distinctive appearance to the brecciation caused by metamorphism. Italian for, “broken stones, rubble.”

Brecciated Marble
Any marble composed of angular fragments.

Bridge Crane
A hoisting system that consists of a hoist, normally using cables, which moves on a beam or “bridge” spanning an opening between two rails. The hoist moves laterally along the bridge and the bridge moves longitudinally along the rails, allowing the hoist to be over any position within the rectangle contained within the lengths of the two rails.

Bridge Polisher
A single spindle polishing machine that travels along a beam, or “bridge”, which travels atop two rails. Also known as a “gantry” polisher.

Bridge Saw
A saw that travels along a beam, or “bridge”, which travels atop two rails. These saws are typically powerful and fitted with large diameter blades. A rotating table is positioned below the saw, allowing for skew cuts, and the saw arbor typically rotates, allowing for angled cuts.

Broach
1. To drill or cut out material left between closely spaced drill holes.
2. A mason’s sharp-pointed chisel for dressing stone.
3. An inclined piece of masonry filling the triangular space between the base of an octagonal spire and the top of a square tower.
4. A type of chisel used for working narrow surfaces.

Brownstone
A trade term applied to ferruginous dark brown and reddish-brown arkosic quartz based stone extensively used for construction in the U.S. during the 19th century.

Brushed Finish
A subtly textured surface finish achieved by wet brushing a stone with a coarse rotary-type abrasive brush.

Bugged Finish
A smooth finish produced in limestone by grinding with power sanders.

Building Stone
Rock material in its natural state of composition and aggregation as it exists in the quarry and is usable in construction as dimension building stone. Also used interchangeably with the term dimension stone.

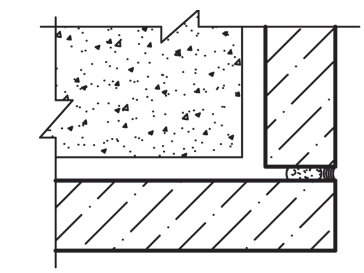
Building Stone Institute (BSI)
Founded in 1919, BSI was a trade association of quarriers, fabricators, dealers, and others working with natural stone. In 2018, BSI merged with the Marble Institute of America to form the Natural Stone Institute.

Bullnose
Convex rounding of a stone edge, such as a stair tread or countertop.

Bullnose

Bush Hammering
A process which produces textured surfaces with small evenly spaced pits produced by hand or pneumatic hammer. The spacing between the pits is often defined as “6-cut,” “4-cut,” etc.

Butt Joint
An external corner formed by two stone panels with one finished edge in a lap joint configuration.

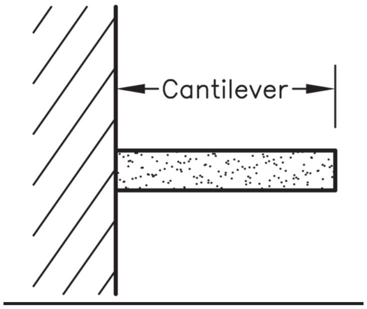

Butt Joint

Buttering
Placing mortar on stone units with a trowel before setting them into position.

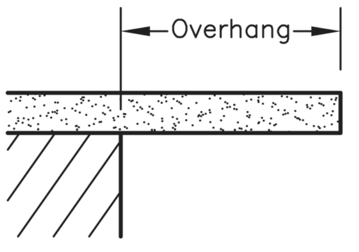
C

Calcarenite
Limestone composed predominantly of cemented sand-size grains of the mineral calcite (more rarely aragonite), usually as fragments of shells or other skeletal structures. Some calcarenites contain oolites (small, spherical grains of calcium carbonate that resemble fish eggs) and may be termed oolitic limestone. Calcareous sandstones, in which the calcium carbonate is present chiefly as bonding material, are not included in this category.

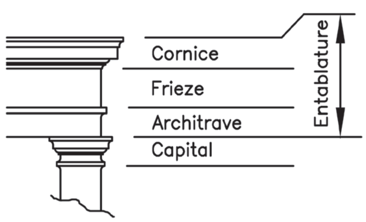
Calcareous
Refers to substances containing or composed of calcium carbonate.



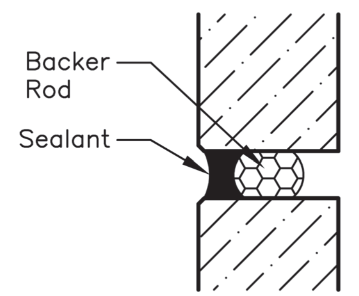
Cantilever



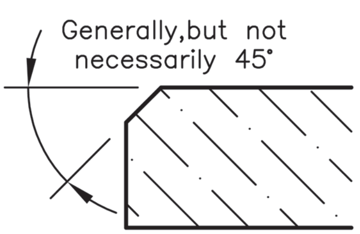
Overhang



Cap or Capital



Caulk



Chamfer

Calcite
A common rock forming mineral. The chief constituent of limestone and most marble.

Calcite Limestone
Limestone containing not more than five percent of magnesium carbonate.

Calcite Marble
A crystalline variety of limestone containing not more than 5% of magnesium carbonate.

Calcite Streaks
White or milky streaks occurring in stone. It is a joint plane usually wider than a glass seam which has been recemented by deposition of calcite in the crack. It is structurally sound.

Calibration
Within the stone industry, the process in which stone slabs or units are abraded to achieve a more precise thickness tolerance (±1mm) than what would normally be produced by standard sawing techniques. The term is most frequently used in the production of stone tile, which must have limited thickness variation to allow installation using thinset adhesive. The term gauge is essentially synonymous, although is more commonly used to describe less precise techniques.

Canopy
A sheltering roof, as over a niche or a doorway.

Cantera
A volcanic, quartz based stone with qualities similar to adoquin, but not as dense. Quarried in Mexico.

Cantilever
A structural member supported at only one end. The term is loosely used, although not technically correct, to describe an overhang.

Cap or Capital
The culminating stone at the top of a column or pilaster, often richly carved.

Carbonic Acid
A weak acid with the formula H_2CO_3. It is also a name sometimes given to solutions of carbon dioxide in water.

Carve
To shape a solid material such as stone by precisely cutting it with a tool.

Caulk
To seal a joint with an elastomeric, adhesive compound.

Cavity Vent
An opening in joints of stone veneer to allow the passage of air and moisture from inside the wall cavity to the exterior. The vents may be weep holes, plastic tubing, or wicks.

Cavity Wall
A multi-wythe masonry wall built with a continuous cavity between the outer masonry, typically brick or stone, and the inner wall, typically concrete block or frame construction. The cavity is vented to reduce the amount of condensate that will collect in the space, and is wept to provide an evacuation path for any moisture that collects within the space.

Cement Putty or Butter
See **neat cement**.

Chamfer
A flat treatment, produced by either grinding or cutting, to eliminate the sharp edge where two surfaces meet.

Chat Sawn Finish
A rough, gang-sawn finish produced by sawing with coarse abrasives.

Chert
Hard, dense sedimentary rock composed of interlocking quartz crystals and possibly amorphous silica (opal). Synonymous with “flint”.

Chiseled Edge
The rustic, aged appearance produced by mechanically chipping the stone edge.

Cladding
Exterior veneer stone covering. Non-load bearing stone veneer used as the facing material in exterior wall construction.

Clast
An individual grain or constituent of a sedimentary rock.

Cleavage
The ability of a rock mass to break along natural surfaces; a surface of natural parting.

Cleavage Plane
Plane or planes along which a stone may likely break or delaminate.

Cleft Finish
Rough-surfaced stones such as slates or sandstones that are cleaved or separated along a natural seam are referred to as natural cleft.

Closer (British)
1. In equidimensional stone masonry, a stone trimmed to non-uniform length to close a course next to a quoin or other end unit.
2. A stone course running from one window sill to another (a variety of string course).

CNC Machine
A computer numeric controlled, multi-axis, vertical spindle machine designed to use rotating milling and profiling tools to produce shapes, cut outs, holes, finishes, and various other operations in stone that are otherwise accomplished by more labor intensive techniques.

Cobblestone
A dimension stone large enough for use in paving. A term commonly used to describe paving blocks, usually granite, and generally cut or cleft to approximately rectangular prisms.

Colonnade
A range of columns supporting an entablature or one side of a roof.

Color Enhancer/Sealer
A product that is designed to enrich, brighten and enhance the color and/or character of the stone. Stone enhancers are more frequently used on honed or textured surfaces where the stone color and/or character are muted by the finish. Enhancers are also used to match the color of an exposed slab edge to that of a resin treated slab face.

Column
A vertical support, usually consisting of a base, shaft, and capital.

Compressive Strength (ASTM C170)
A measure of the resistance of the stone to crushing loads, generally tested per ASTM C170.

Conglomerate
A coarse-grained sedimentary rock, with clast grains larger than 2 mm.

Construction (cold) Joint
The joint between two separate placements of concrete.

Contractor, stone
Company or person that erects and installs fabricated dimension stone.

Control Joint
A partial depth joint that is either formed or sawed in concrete to control the location and frequency of shrinkage cracking.

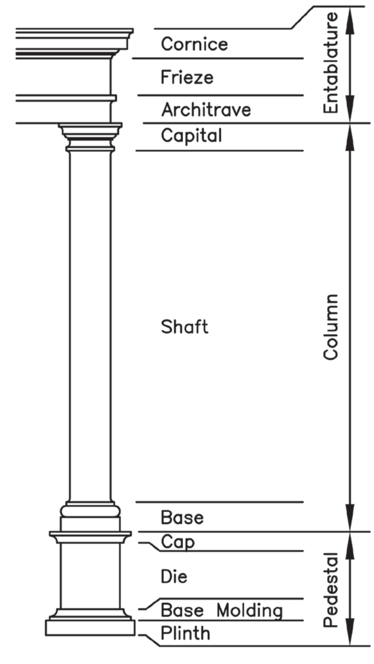
Conveyor
A general term, often used interchangeably with belt conveyor, but applicable to all conveyor types including pans, screws, buckets, pneumatics, radial stackers and others.

Coping
A stone used as a cap on freestanding walls.

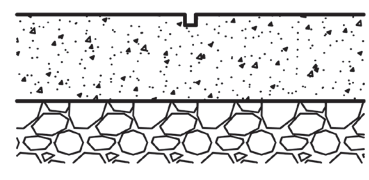
Coquina
Limestone composed predominantly of shells or fragments of shells loosely cemented by calcite. Coquina is coarse textured and has a high porosity. The term is applied principally to a very porous rock quarried in Florida.

Corbel
A projection or bracket extending from the face of a wall to support an element above it.

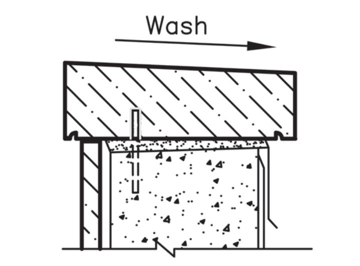
Core
The cylindrical mass of stone that results from drilling a hole in stone with a hollow core bit, often times is used as a sampling technique in quarries.



Column



Control Joint



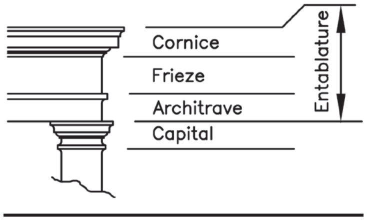
Coping

Core bit
A hollow cylindrical drilling tool that bores a hole by abrading only the perimeter of the core, utilizing less abrasive than a bit that would abrade the entire diameter of the hole.

Core sampling
A drilling process by which a section of rock is taken for the purposes of testing and evaluation.

Cornerstone
A ceremonial stone at an exterior corner of a building, generally engraved with pertinent information about the building's construction, including the date. Also used to describe a masonry stone unit erected at an exterior corner from which lines can be strung to control the linear position of subsequent stone units.

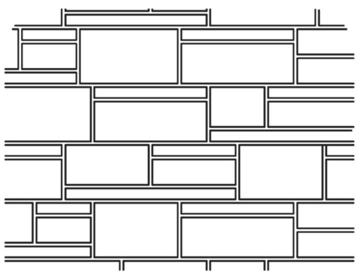
Cornice
Any projecting ornamental molding that crowns or finishes the top of a building or wall.



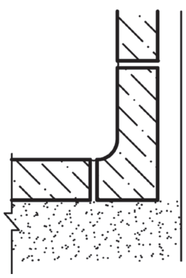
Cornice

Course
A horizontal range of stone units the length of a wall.

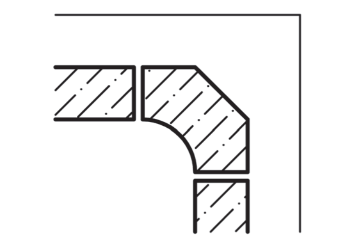
Coursed Veneer
A veneer achieved by using stones of the same or approximately the same height with stones that achieve that height in multiple courses. Some horizontal joints run the entire length of the veneered area. Vertical joints are constantly broken, so that no two joints will be over one another.


Coursed Veneer

Cove Base
A concave stone molding. See **base**.

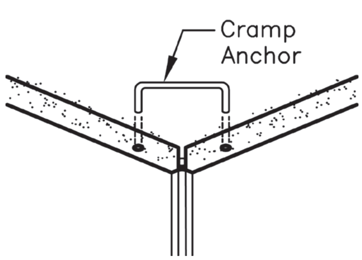

Cove Base

Cove Molding
A concave molding, typically found at the sloped or arched junction of a wall and ceiling.


Cove Molding

Crack
A man-made break, split, fracture, separation, cleavage, or elongated narrow opening, visible without magnification to the human eye and extending from the surface into the stone, which must extend through the grain or matrix of the stone.

Cramp
A U-shaped metal anchor used to hold two adjacent units of stone together.



Cramp

Cross-bedding
The arrangement of laminations of strata transverse or oblique to the main planes of stratification.

Cross-cut
The process of cutting the initial block of stone parallel to the natural bedding plane. The effect is a mottled or cloudlike appearance. Synonymous with fleuri cut, although the term cross cut is most often used when describing travertine materials.

Crowfoot
See **stylolite**.

Cubic Stone
Dimension units more than 2 inches thick e.g., cubic limestone, cubic marble.

Cultured Marble
An artificial, manmade product somewhat resembling marble.

Cup Wheel
Shop tool used to remove large amounts of material from the edge of a stone. These can be used to aid in the creation of edge profiles and larger radii.

Curbing
Stone, generally in cubic forms, bordering streets, walks, etc. Sometimes spelled "kerbing."

Cure Time
The time required for a chemical reaction (polymerization or hydration) to be completed in a sealant, concrete, mortar, or other construction element until the finished visual and performance attributes are developed.

Curtain Wall
A non-bearing exterior stone cladding supported by an anchoring system. Used to protect a building from the elements.

Cushion
A resilient pad placed between adjoining stone units and other materials to absorb or distribute loads.

Cut Stone
Currently, stone that has been fabricated to a finished size and configuration and ready to be installed. Historically, the term "cut stone" was used to describe limestone products.

Cycle Time
Time for a machine to complete one cycle, i.e., load, haul, dump, return.

D

Damp Proofing
One or more coatings of a compound that is impervious to water. Usually applied to the back or face of the stone or the back of the wall at or near grade.

Dead Load
Permanent gravity induced loads, such as those developed by the structure, finishes, and permanently affixed elements. See also **live load**.

Dentil
Block projections on an entablature.

Dentil Course
Mold course immediately below the cornice, comprising of small, uniformly spaced blocks referred to as "dentils."

Derrick
A hoisting device, usually made up of a guyed mast and hinged boom with pulleys and cables.

Diamond
A carbon based mineral, usually man-made, used as an abrasive in stone cutting equipment.

Diamond Match
A vein matching technique in which contiguous faces of adjacent slabs are "unfolded" about two perpendicular axes, producing a vein pattern which has approximate symmetry about a point.

Diamond Wire Saw
A machine using cable of various diameters and lengths, impregnated with diamond dust or more commonly fitted with cylindrical diamond coated segments. Diamond wire saws are used in quarrying, slabbing, and contour sawing operations.

Die
A covering layer of interior stone from wainscot to ceiling.

Digital Inventory Management
A software and camera system allowing fabricators and distributors to have a photographic inventory of their materials.

Digital Layout Application
Software designed to allow CAD drawing files to be used with scaled digital photographs to allow a fabricator to preplan the layout of his slab or tile project prior to cutting.

Digital Templating
A process for virtual, digital measurement of site conditions which eliminates the need to make physical templates. Digital templating information can be interfaced with various CAD and CNC systems to allow rapid transfer and utilization of the information.

Dimension Stone
A natural stone product that has been cut, machined, and/or finished to specific size or shape.

Dolomite
1. The mineral form of calcium-magnesium carbonate. Constituent of some building limestones.
2. A crystalline variety of limestone containing in excess of 40 percent magnesium carbonate as the dolomite molecule.
   Also called "dolostone".

Dolomitic Limestone
Limestone that contains more than 10 percent but less than 80 percent of the mineral dolomite.

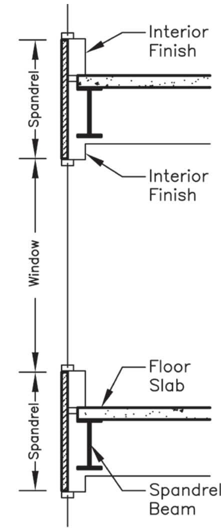
Dolostone
See entry 2 under **dolomite**.

Dovetail Slot
A continuous groove with a trapezoid section resembling a dove's tail.

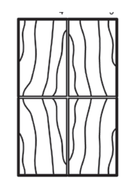
Dowel
A short piece of cylindrical nonferous metal used as a stone anchor.

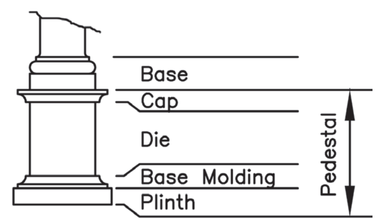
Drafted Margin (British)
Tooled border around the face of a stone. Also called "margin draft".

Dressing
The shaping and squaring of natural stone blocks for storage and shipment. Sometimes called "scabbing".

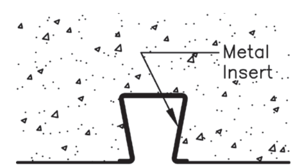


Curtain Wall

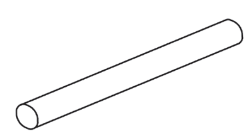

Diamond Match

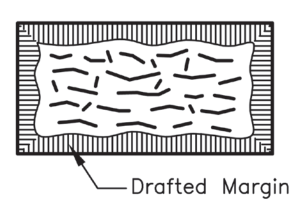


Die



Dovetail Slot

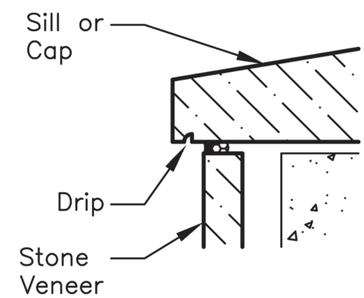

Dowel



Drafted Margin

Drill Rigs
Machines used in quarry operations to bore holes in a linear path to facilitate separation of the stone loaf from its insitu position.

Drip
A groove or slot cut beneath and slightly behind the forward edge of a projecting stone member, such as a sill, lintel or coping to cause water to drop at that location and prevent water from running down the face of the wall

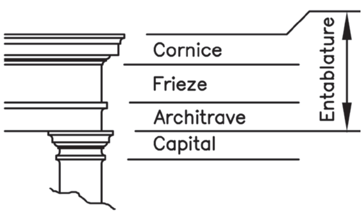


Drip and Drip Stone

Drip Stone
A projecting molding over the heads of doorways, windows and archways to throw off the rain. Also known as a "hoodmold" and, when rectangular, as a "label".

Dry Seam
A naturally occurring unhealed fracture in stone which may be a plane of weakness.

Dry Stack
In rubble masonry construction, a self-supporting wall erected without mortar.

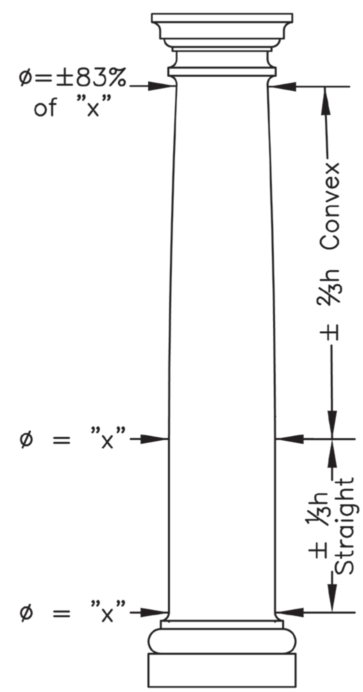


Entablature

Dual Finish
Multiple contrasting finishes, such as thermal and polished, on one piece of stone.

Durability
The measure of the ability of natural building stone to endure and to maintain its essential and distinctive characteristics of strength, resistance to decay, and appearance, while exposed to the elements encountered in its application environment.

Dutchman
1. A small piece of stone inserted as a patch in a larger piece of dimension stone.
2. A small piece of stone inserted in an **ashlar** wall.



Entasis

E

Eased Edge
A slightly arrised, chamfered, or radiused edge to eliminate the sharpness of the fabricated stone edge.

Eaves
The underside of a sloping roof that overhangs a wall.

Edge Chiseling Tool
Tool with carbide jaws used to create a "pitched", "quarry", or "chiseled" edge without using a hammer and chisel.

Edge Profile
The specific contour to which an exposed edge has been shaped, normally for decorative purposes.

Efflorescence
A salt deposit, in the form of a white powder residue that forms on the surface of stone, brick, or mortar. It is caused by alkalis leached from the masonry or soil and carried to the surface by moisture

Elevation
A drawing of the vertical faces and elements of a structure, either interior or exterior.

Encrinal Marble
Marble deriving decoration from fossils (encrinites) or shells.

Engineered Stone
A manmade product composed of a blend of natural minerals (generally quartz) and manmade agents (such as polyester, glass, epoxy, and other such ingredients).

Entablature
A composite beam member carried by columns and made up of an architrave (bottom), frieze (middle), and cornice (top).

Entasis
The slight convexity designed in a column shaft for aesthetic purposes. This is done intentionally to offset the perceived illusion of concavity of a perfectly straight shafted column.

Epoxy Resin
A flexible, usually exothermic curing resin made by the polymerization of an epoxide; used as an adhesive.

Erection
The process of setting vertical dimension stone into place.

Etched
A decorative surface pattern created by a variety of methods, produced either by chemical or mechanical methods.

Exfoliation
Peeling or scaling of stone surfaces caused by chemical or physical weathering.

Expansion Anchor or Bolt
A socket that grips a drilled hole in concrete by expanding as a tapered bolt is drawn into it.

Expansion/Contraction Joint
A flexible joint between stone units designed to expand or contract to accommodate movements due to temperature change or dynamic structural movement.

Exposed Face
The visible side of any stone element.

F

Fabricated
Used in reference to dimension stone, it means having undergone cutting, machining, or other processes in order to refine the product for its intended application manufactured and ready for installation.

Face
The exposed surface of stone on a structure.

Fascia
Any flat horizontal member, generally between moldings, most frequently used when referring to elements of a classical architecture cornice.

Feed Rate
The rate of speed with which routing, cutting, or sawing blades and bits travel as they are cutting the material.

Feldspar
A group of crystalline minerals, all silicates of aluminum with potassium, sodium, calcium, or barium. An essential constituent of nearly all crystalline rocks.

Ferruginous
Said of limestone or sandstone containing a high proportion of iron oxide.

Fiberglass Backing
A fine grid mesh reinforcement that is adhered to the back surface of stone slabs which have limited stability. The primary intent of this reinforcement is to reduce safety risks in the handling of fragile slabs.

Fieldstone
A naturally occurring, irregularly shaped stone, as found in a field, used for various building applications without further fabrication. Field stone are commonly used in freestanding walls, veneers, walkways, and garden bed linings.

Filler Strip
See **backer rod**.

Filling
A trade expression used to indicate the filling of natural voids in stone units with cements or synthetic resins and similar materials.

Fines
The powder, dust, and silt- or sand-sized material resulting from processing, usually crushing, stone.

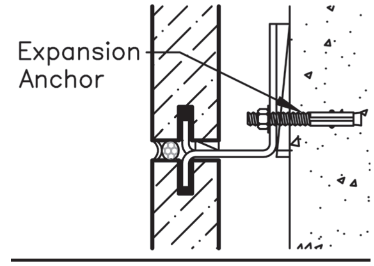
Finish
Process applied to the exposed surfaces of dimension stone during fabrication to achieve the desired aesthetic and/or performance characteristics of the stone. The finish may be applied early or late in the fabrication sequence.

Fissure
An industry term describing any naturally occurring separation along crystalline boundaries visible in exposed surface of the stone. Note that the industry use of this term is different than the scientific, geological use of this term.

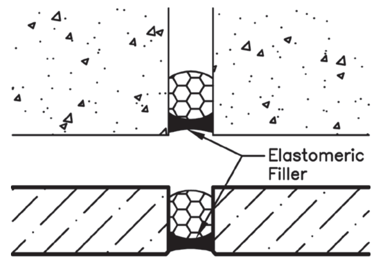
Flagstone
Thin slabs of stone with irregular shapes and split edges used for paving surfaces such as walks, driveways, and patios. The term is used to describe any stone used in this pattern, although is most often used to describe sedimentary stones that have been cleft into their final thickness.

Flamed Finish
See **Thermal Finish**.

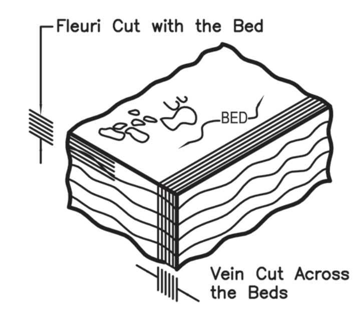
Fleuri
The mottled random effect obtained when slabs of certain stone varieties are sawn parallel to their natural bedding planes. See also **Cross Cut**.



Expansion Anchor or Bolt



Expansion/Contraction Joint

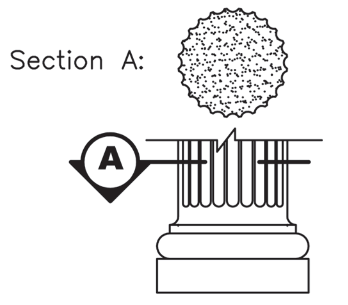


Fleuri

Fleuri Cut
To cut slabs of quarried stone parallel to the natural bedding plane.

Flexural Strength
A bending strength test, normally performed per the ASTM C880 test method, in which a sample of stone of the project thickness is supported by two support rods creating a span of at least 10 times the thickness, and loaded to failure by two rods positioned at quarter points of the span. The results are reported as the stress experienced by the stone sample at the time of specimen failure, and expressed as a force per unit area (lbs/in² or pascals). See also **modulus of rupture**.

Flooring
Stone used as an interior pedestrian walking surface.

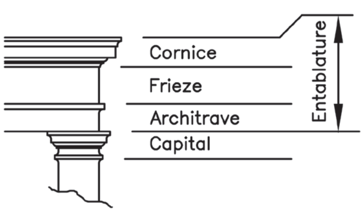


Flute

Flute
One of series of shallow, concave, parallel grooves running vertically on the shaft of a column, pilaster, or other surface.

Fracture
Any break or separation of fabric within the stone as a result of mechanical stress.

Freestone
A stone that may be cut freely in any direction without fracture or splitting. Also called "universal stone." See **isotropic**.



Frieze

Frieze
1. A decorated band along the upper part of an interior wall.
2. The middle member of the entablature, located above the architrave and below the cornice.

Front-end Loader
A heavy equipment earth moving machine with a hydraulically powered bucket on two booms (or arms) extending in front of the tractor portion of the machine. The bucket may be replaced with other devices to accomplish specific tasks in stone quarrying operations.

G

Gabbro
A group of dark-colored basic intrusive igneous rocks composed chiefly of labradorite or bytownite and augite. It is the approximate intrusive equivalent of basalt.

Gallet (British)
A stone chip or **spall**.

Gang Saw
A mechanical device employing a series of parallel reciprocating saw blades to cut stone blocks into slabs of predetermined thickness. The most common variety of gang saw used in the stone industry uses a slurry containing steel shot as the abrasive medium; but diamond segments mounted to steel blades are commonly used in gang sawing softer stone such as marble or limestone.

Gauge
Any process, although most frequently grinding, done to reduce the effects of the tolerances of stone slab thickness. Gauging may be done to a precise thickness with a specific tolerance, or may simply be done to two or more stones until the thickness of the lot is uniform.

See also **calibrate**.

Glass Seam
A trade term in the limestone industry for a former fracture or parting that has been naturally recemented and annealed by deposition of transparent calcite. Similar to **calcite streak**, but transparent. Compare with **dry seam**.

Gloss Meter
An instrument designed to measure the reflectivity of a surface.

Gneiss
Coarse-grained, metamorphic rock with discontinuous foliation caused by planar alignment of plate and lath-shaped minerals. When used for building stone, generally classed as trade granite. Most gneiss is dark and composed mainly of quartz, feldspar, mica and ferromagnesian mineral (iron-magnesium silicates).

Grain
1. A quarry term for a plane of parting in a metamorphic rock, e.g. slate; the direction along which a stone is more easily broken, split, or cut. The main direction of the mineral composition and arrangement in stone.
2. A very small (less than a few millimeters diameter) particle of rock, such as a sand grain.

3. A general or descriptive term used to describe the relative size of crystalline rock components, as in "fine-grained" and "course-grained."

Granite (commercial definition)

A term that includes granite (as defined below) plus gneiss, gneissic granite, granite gneiss, and the rock species known to petrologists as syenite, monzonite, and granodiorite, species intermediate between them, the gneissic varieties and gneisses of corresponding mineralogic compositions and the corresponding varieties of porphyritic textures. The term commercial granite shall also include other feldspathic crystalline rocks of similar textures, containing minor amounts of accessory minerals, used for special decorative purposes, and known to petrologists as anorthosite and larvikite.

Granite (scientific definition)

A visibly granular, crystalline rock of predominantly interlocking texture composed essentially of alkalic feldspars and quartz. Feldspar is generally present in excess of quartz, and accessory minerals (chiefly micas, hornblende, or more rarely pyroxene) are commonly present. The alkalic feldspars may be present (1) as individual mineral species, (2) as isomorphous or mechanical intergrowths with each other, or (3) as chemical intergrowths with the lime feldspar molecule, but 80 + 3% of the feldspar must be composed of the potash or soda feldspar molecules.

Granite

A very hard, crystalline, igneous rock, gray to pink in color, composed of feldspar, quartz, and lesser amounts of dark ferromagnesium materials. Gneiss and black "granites" are similar to true granites in structure and texture, but are composed of different minerals. Commercial and scientific definitions of the granite group are explained in detail in ASTM C119.

Granular

Stones having a texture characterized by particles that are apparent to the unaided eye. For sedimentary rocks, particles less than 4 inches in diameter and approximately equal in size.

Greenstone

A metamorphic rock, typically with poorly defined granularity, ranging in color from medium-green or yellowish-green to black. Refer to greenstone group in ASTM C119.

Grind

To remove portions of stone material by any abrasive method. Grinding may be part of producing a finish, shaping a profile, achieving a specific dimension, creating flatness between adjacently installed pieces, or part of a restorative effort.

Grout

1. A mixture of cementitious material and water, with or without aggregate, proportioned to produce a plastic consistency without segregation of the constituents; also a mixture of other composition but of similar consistency.
2. To place and tool grout in the joints of stonework.
3. In quarrying: a term describing the product of the quarry which is unusable for dimension stone, often piled near the extraction site.

Guillotine

A device used for cutting stone slabs to sizes by means of wedges driven by hydraulic pressure. The resultant fracture is of low precision, with a ragged, chipped appearance.

H

Halite

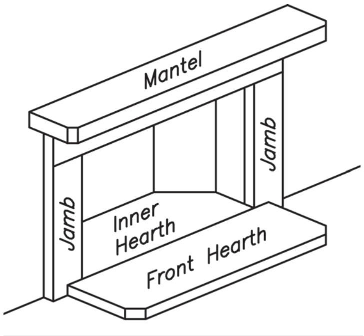
Rock salt; the mineral form of sodium chloride (NaCl); a sedimentary rock.

Hardness

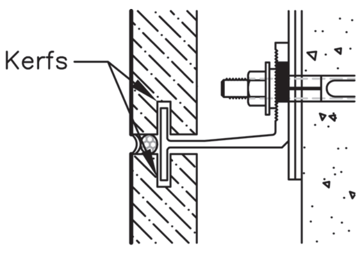
In stones, hardness most frequently refers to stone's resistance to abrasion, particularly abrasion due to foot traffic, as tested by either ASTM C241 or C1353. In minerals, hardness generally refers to the mineral's rank within the Moh's Scale of Mineral Hardness.

Head

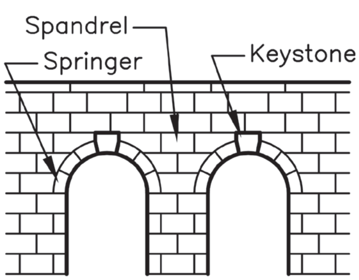
The exposed surface of the jointed end of any given piece of stone with a gauged dimension not more than the minimum thickness of the material specified. Also known as "return head."



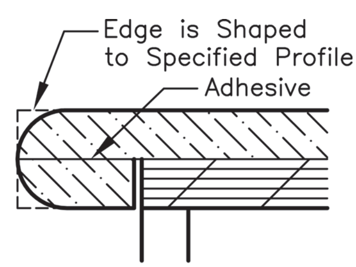
Hearth



Kerf



Keystone



Lamination

Hearth

1. The floor of a fireplace together with an adjacent area of fire-resistant material that extends into the room.
2. An area permanently floored with fire-resistant material beneath and surrounding a stove.

Hearth Stone

Originally the single large stone or stones used for the hearth, now most commonly used to describe the stone in front of the fire chamber and many times extending on either or both sides of the front of the fire chamber.

Honed

A satin-smooth surface finish with little or no gloss.

Hysteresis, thermal

A residual or permanent volume change in stones after the temperature has been normalized, generally causing the stone panel to bow. Most commonly associated with fine grained true marbles used in thin panel applications.

I

Igneous

Any of the various volcanic rocks, solidified after the molten state, such as granite. Igneous is one of the three main rock classifications. Compare with metamorphic and sedimentary.

ILIA

(Indiana Limestone Institute of America)
A trade organization established for the dissemination of information on limestone standards, recommended practices, grades, colors, finishes, and all technical data required for specifying, detailing, fabricating, and erecting Indiana Limestone. Publishers of the Indiana Limestone Handbook and other technical publications, founded in 1928.

Impregnators

Any applied repellent that penetrates the stone and resides below the plane of the finished surface. Impregnators may be hydrophobic (water-repellent), oliophobic (oil repellent), or both, and are used in some stone varieties to increase stain resistance.

Incise

To cut inwardly or engrave, especially in a "V" shaped profile, as in an inscription.

Inscription

Lettering cut in stone.

Isolation joint

A joint separating a concrete slab from another element, such as a column or wall.

J

Joint

A space between installed stone units or between a dimension stone and the adjoining material.

Jointing Scheme

The intentional pattern created by the direction and position of stone joints as determined by the design professional for aesthetic reasons.

K

Kaolinite

A hydrous aluminum silicate mineral.

Kerf

1. A slot, either local or continuous, cut into the edge of a stone with a saw blade for insertion of **anchors**.
2. The width of a cut when sawing through stone blocks or jointing slabs.

Keystone

The central stone of an arch, sometimes sculpted or otherwise embellished.

L

Lamination

Two or more thicknesses of stone slab adhered together at an exposed edge, usually in decorative work such as countertops, creating an aesthetic effect that suggests that the stone is thicker than it actually is. Laminated edges may be dressed or profiled to a variety of shapes for additional decorative value.

Laser

An acronym for Light Amplification by Stimulated Emission of Radiation, which produces an intense narrow beam of coherent, monochromatic light. Lasers are used in the stone industry for a variety of cutting machine alignment aids, layout aids, and leveling instruments.

Lathe
Any machine that spins a block or multiple blocks of material about a horizontal axis for the purposes of creating shapes that have symmetry about the axis of rotation, such as columns, balusters, and urns.

Lead Buttons
Although not often used in modern masonry construction, these were small shims made of lead or similar malleable metal alloys used in horizontal joints to support the stones until the mortar has set.

Lewis
A lifting device consisting of multiple sections of metal forming a tapered shape which is inserted into a dovetail shaped preparation cut into the stone. Although uncommon in current industry use, lewis lifters were frequently used for hoisting quarry blocks or for heavy, cubic sections of finished stone work. Also known as "box lewis."

Lewis Pin
A pin, usually with an eye at the upper end, used in pairs and fitted to holes drilled at opposing angles in cubic stones for hoisting purposes.

Limestone
A sedimentary rock composed primarily of calcite or dolomite. The varieties of limestone used as dimension stone are usually well consolidated and exhibit a minimum of graining or bedding direction. See definition of limestone group in ASTM C119.

Line (edge) Polisher
A large production machine which utilizes one or more spindles to achieve a finished edge profile on a piece of stone as it is fed through a conveying line.

Liners
An additional block or strip of stone adhered and doweled to the back face of a stone panel for the purpose of providing a horizontal surface which can be supported by a shelf angle. The liner material may or may not be of the same stone species as the panel. Also known as "liner block" or "cleat."

Lintel
A horizontal stone spanning over the opening of a door, window, or other opening that acts as a beam to carry the weight of the wall above it.

Lippage
The planar offset of the finished surfaces of two adjacent stone units.

Live Load
The portion of a load on a structural member that is variable, such as occupants, furniture, traffic, and wind.
See also **Dead Load**.

Load Cell
An electronic device (transducer) that emits an electric signal based on the force applied to the device.

Lug Sill
In stone masonry, a sill that projects into the jambs of a window or door opening (compare **slip sill**).

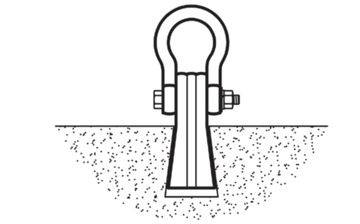
M

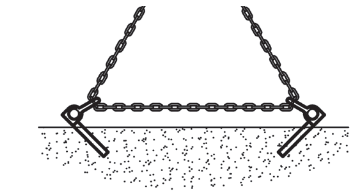
Machine Finish
In limestone, the generally recognized standard machine finish produced by the planers. Also known as "machine smooth" or "planar" finish.

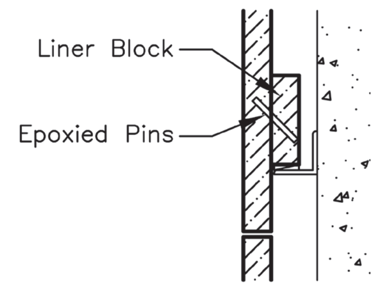
Maintenance
Cleaning and/or other remedial activity performed on a scheduled basis: daily, weekly, etc. in order to remove dirt, dust and other contaminants that degrade the stone's appearance and/or performance.

Marble
A metamorphic crystalline rock composed predominantly of crystalline grains of calcite, dolomite, or serpentine, and capable of taking a polish. Commercial and scientific definitions of the marble group are explained in detail in ASTM C119.

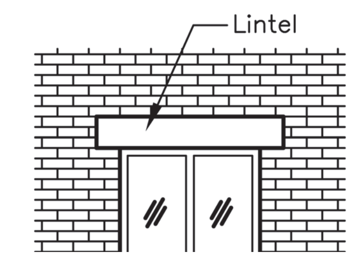
Marble (commercial definition)
A crystalline rock, capable of taking a polish, and composed of one or more of the minerals calcite, dolomite, and serpentine. Commercial and scientific definitions of the marble group are explained in detail in ASTM C119.


Lewis

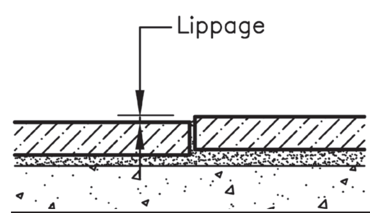

Lewis Pin



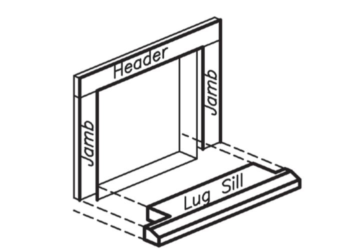
Liner



Lintel



Lippage



Lug Sill

Masonry

1. Built up construction, usually individual units set in mortar.
2. That branch of construction dealing with plaster, concrete construction, and the laying up of stone, brick, tile and other such units with mortar.

Metamorphic Rock

Rock altered in appearance, density, crystalline structure, and in some cases, mineral composition, by high temperature and intense pressure. Includes slate derived from shale, quartz based stone from quartzitic sand, and true marble from limestone.

Metamorphism

The change or alteration in a rock caused by exterior agencies, such as deep-seated heat and pressure, or intrusion of rock materials.

Microcrystalline

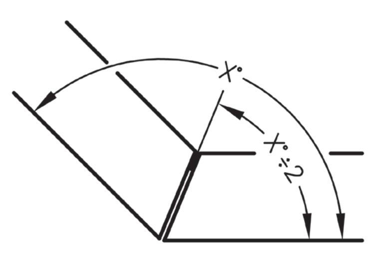
Said of a stone that consists largely or wholly of crystals that are so small as to be recognizable only under magnification.

Milling

In the stone industries, comprehensive term for processing quarry blocks through sawing, planning, turning and cutting techniques to finished stone.

Miter

Any condition of stone veneer, coping, paving strips, etc, where a corner condition is accomplished by two stones with angular cuts, with the angles of the cuts being equal to the bisection of the total angle. See also **quirk miter**.



Miter

Mockup

A sample section of stonework that is installed, often including other related construction components, for the purpose of obtaining designer and owner approval prior to commencement of quarrying, fabricating, or installation of stonework. The mockup may be independent of the project or may be part of the project and remain in place as part of the completed work.

Modular

Refers to standard patterns used throughout the stone industry that are usually based on multiples of a given height or size.

Modulus of Elasticity

Tested per ASTM C1352, the ratio of stress to corresponding linear strain of a material, expressed as a force per unit area (lbs/in² or pascals), and used as a measure of a material's stiffness. Also known as "Young's Modulus."

Modulus of Rupture

A bending strength test, normally performed per the ASTM C99 test method, in which a small sample of stone (8" x 4" x 2¼") is supported by two support rods, and loaded to failure by a third rod positioned at the center of the span. The results are reported as the stress experienced by the stone sample at the time of specimen failure, and expressed as a force per unit area (lbs/in² or pascals). See also **flexural strength**.

Moh's Scale

A relative scale of mineral hardness developed by German Mineralogist Friedrich Mohs in 1822 ranking ten common minerals by their scratch resistance.

Moldings

Decorative stone deviating from a plane surface by projections, curved profiles, recesses or any combination thereof.

Monolithic

Shaped from a single block of stone, in contrast to a unit that was created by using multiple units of stone.

Mortar

A mixture of cement paste and fine aggregate used in setting stone units or filling joints between stone units. Mortar may contain masonry cement, or may contain hydraulic cement with lime (and possibly other admixtures) to afford greater plasticity and workability than are attainable with standard portland cement mortar.

Mosaic

A decorative installation, usually a graphic or artwork display, made up of an assemblage of small units of different colored stones or glass to create the total image or pattern.

Movement Joint

In tile installations, a joint where only the finish material is separated by an elastomeric filler, and the substrate is uninterrupted. Also known as a "generic movement joint."

MSDS

The abbreviation for Material Safety Data Sheet. The information required by OSHA's Hazard Communication Standard (HCS) to convey hazardous information to downstream customers.

Mullion

A structural unit that separates two window units

N

Natural Bed

The horizontal stratification of stone as it was formed in the deposit.

Natural Cleft

Stone that is split (cleaved) parallel to its stratification, yielding a surface that is irregular to a degree that corresponds with the flatness of the material's layering.

Natural Stone

A product of nature. A stone such as granite, marble, limestone, slate, travertine, or sandstone that is formed by nature, and is not artificial or manmade.

Natural Stone Institute

The Natural Stone Institute was formed in 2018 as a merger of the Marble Institute of America and the Building Stone Institute. The Natural Stone Institute is a trade association representing every aspect of the natural stone industry. The association serves as the authoritative source for safety and technical standards and information regarding the use of natural stone. It operates an industry accreditation program and two prestigious awards programs, as well as a continuing education program for architects and designers. The association offers a wide array of technical and training resources, professional development opportunities, regulatory advocacy, and networking events.

NBGQA

The abbreviation for the National Building Granite Quarries Association, a trade association whose membership is composed of granite producers in the United States. Collectively, these companies provide a major portion of the domestically quarried architectural granite produced in the U.S.

Neat Cement

A fluid mixture of portland cement and water, with or without other ingredients; also the hardened equivalent of such mixture. Commonly used in a thick, creamy consistency to parge the stone surfaces and strengthen the bond between a stone and a setting bed. Also called "cement butter," "cement paste" and "cement cream." See also **back parging** and **parge**.

Niche

A recess in an interior or exterior wall usually for a statue or an urn, often semicircular in design.

NIOSH

The National Institute for Occupational Safety and Health

Nonstaining Mortar

Mortar composed of materials which individually or collectively do not contain material that will stain the adjacent materials to which it comes in contact.

Notch

A V-shaped cut made on the edge or head of a stone.

NTCA

(National Tile Contractors Association)

A trade association whose active membership consists of ceramic and stone tile installation contractors in the United States, with an associate membership of those who supply products and services to the industry. Founded in 1947.

O

Obsidian

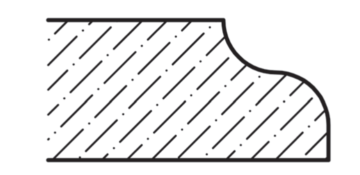
A glassy phase of lava.

Off Fall

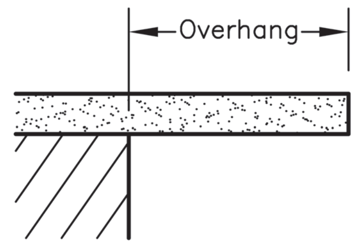
Also "fall off." See **Remnant**.

Ogee

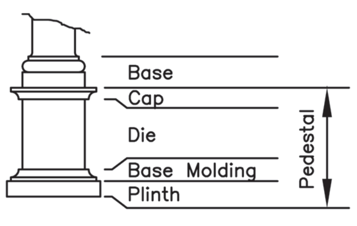
A stone molding roughly resembling an "S" shape, with a reverse curved edge: concave above, convex below.



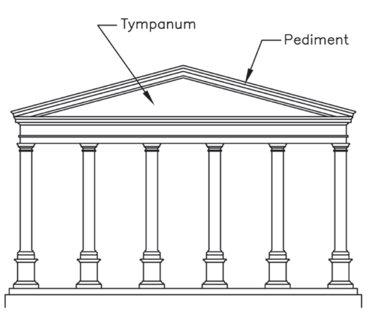
Ogee



Overhang



Pedestal



Pediment

Onyx
A frequently translucent and generally layered, cryptocrystalline calcite with colors in pastel shades, particularly off white, yellow, tan, and green. Commercial definitions of onyx are given in ASTM C119 as part of the marble group.

Oolitic Limestone
A calcite-cemented calcareous stone formed of shells and shell fragments, practically noncrystalline in character. It is found in massive deposits located almost entirely in Lawrence, Monroe, and Owen Counties, Indiana; and in Alabama, Kansas, and Texas. This limestone is characteristically a freestone, without cleavage planes, possessing a remarkable uniformity of composition, texture, and structure.

Open-faced Quarry
A quarry with relatively large lateral expanse when compared to its depth, in contrast to traditional derrick quarries which had relatively short lateral dimensions and great depths.

OSHA
The acronym for Occupational Safety and Health Administration.

Out-crop
That part of a geologic formation or structure that protrudes above or at ground level.

Outriggers
A temporary support extending from machinery, such as cranes, to provide greater stance width and improve stability when handling loads with extended boom lengths.

Overburden
Waste stone, earth or other material covering the deposit of stone which must be removed to gain access to the desired stone.

Overhang
The portion of a stone that protrudes past the surface on which it is set.

Oxalic Acid
A relatively strong acid that is used, typically as an additive to other polishing compounds, in the polishing of many marbles and limestones.

P

Palletize
To stack and secure stone units to a pallet for ease, safety, and efficiency in handling and transport.

Panel
A term used to describe either a single unit of fabricated stone veneer, or a preassembled panel including multiple stone units affixed to a structural panel framework.

Parapet
A low wall along the edge of a terrace, roof, or balcony, which is usually simply the extension of the exterior wall below it.

Parge
To apply a thin coat of mortar, thin-set, neat cement, or other bonding agent to the back of stone units, or to the face of the backup material, normally for the purpose of reducing the voids, increasing bond strength, or waterproofing. See also **back parging** and **neat cement**.

Patina
The change in color or texture of the surface of natural stone due to age or exposure to various elements

Paver
A single unit of fabricated stone for use as an exterior paving material.

Paving
Stone used as an exterior wearing surface, as in patios, walkways, driveways, etc.

Pedestal
In classical architecture, the support for a column or statue, consisting of a base, dado, and cap.

Pediment
The gable end of a roof in classical architecture. Located above a horizontal cornice member, it comprises the raking cornices and the tympanum. It is typically triangular, but can also be curved when applied as a decorative element over windows.

PEL
Permissible Exposure Limit: PELs are established and enforced by OSHA to protect workers against the health effects of overexposure to hazardous substances.

Percussion Drilling
Any method of drilling that includes a combination of hammering blows along the longitudinal axis of the bit with rotation of the bit. Also called "hammer" drilling.

Perforated Wall
One which contains a considerable number of relatively small openings, often called pierced wall or screen wall.

Pergola
Garden structure formed by two rows of posts or pillars with joists and open framing above, often covered by climbing plants and shading a walkway.

Phenocryst
One of the relatively large and ordinarily conspicuous crystals of the earliest generation in a porphyritic igneous rock.

Pilaster
A shallow, engaged pier or column projecting from a wall, only decorative in function.

Pillowed
A tile finish that features softly rounded edges, thus giving the tile a pillowed look.

Pit Quarry
Below ground-level quarry.

Pitch Faced
A rustic finish for veneer stone created with a split or chiseled face, and dressed along the stone's perimeter to produce convex projection. See also **rock faced**.

Pitched Stone
See **pitch faced**.

Plinth
1. The base block at the junction of the stone base and trim around a door or other opening.
2. The bottom stone block of a column or pedestal.

Plucked Finish
A stone surface produced by setting a planer blade so deep that it removes stone by spalling rather than by shaving.

Plutonic
Applies to igneous rocks formed beneath the surface of the earth, typically with large crystals owing to the slowness of cooling.

Pointing
The final filling and finishing of mortar joints that have been **raked**.

Polished Finish
A glossy, highly reflective surface finish that brings out the full color and character of the stone.

Polishing
A process utilizing abrasives in combination with specific polishing powders and/or chemicals to produce a glossy, highly reflective surface finish on the stone.

Polishing Compounds
Any of the powders or chemicals used in addition to the abrasive machine heads that are used to achieve a polished finish.

Polishing Cream
A polishing compound that is supplied in a cream or paste consistency.

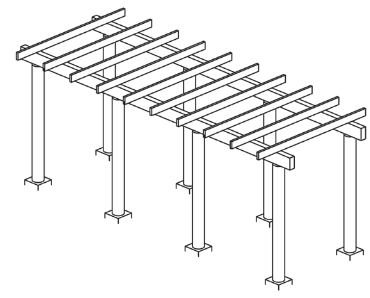
Polishing Pads
Small diameter flexible disks with embedded abrasives used with handheld tools or small portable machines for polishing of stone. These pads may be used in combination with compounds, and may be used either wet or dry.

Porphyry
An igneous rock characterized by distinct and contrasting sizes of coarse and fine-grained crystals. Used as a decorative building and/or paving stone.

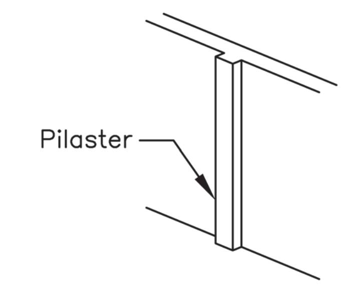
Portico
A porch formed by a roof supported with columns, similar to a temple front.

Poultice
Any absorbent material (powder, cloth, etc) used in a saturated condition with water or solvent based fluids and applied to a stone surface for the purpose of removing embedded stains.

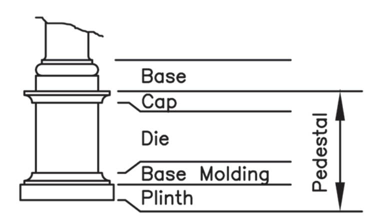
PPE
The abbreviation for Personal Protective Equipment, such as protective clothing, safety toe shoes, helmets, goggles, etc.,



Pergola



Pilaster



Plinth

designed to protect the wearer's body from injury from exposures in the work environment.

Preassembled Units
A composite unit consisting of a structural backing, usually steel or concrete, multiple panels of stone, and necessary anchorage and connection hardware that is built off-site and transported to the construction site for erection.

Precast
In stone facades, refers to a bi-material panel consisting of multiple stone face units and a concrete backer panel. The panel is cast off-site, then transported to the construction site for erection.

Pressure Relieving Joint
See **expansion joint**.

Primer
1. A unit or package of ignition devises used to initiate other explosives or blasting agents in the quarry.
2. A liquid coat applied to increase bond strength of a joint sealant.

Privacy Partition
A thin stone panel between urinals.
See **urinal screen**.

Producer
Company or person that quarries and supplies dimension stone to the commercial market.

Profile Wheel
Any grinding wheel that has convex or concave shapes and can be adapted to a router, hand held grinder, or CNC machine for the purpose of producing a desired shape to a stone edge.

Projections
Any stone that is installed in a position outward of the balance of the wall for aesthetic or water control purposes.

Prospecting
The practice of locating mineral deposits of commercial value.

Pumice
Exceptionally cellular, glassy lava resembling a solid froth.

Q

Quarried Stone
Stone which has been extracted from the earth by means of man power and machines.

Quarrier
Company or person that extracts natural stone from a quarry.

Quarry
1. The physical site, open or underground, where stone is extracted from the earth.
2. The process of extracting stone from open pit or underground mine.

Quarry Block
Generally, a piece of rough stone as it comes from a quarry, generally dressed or wire sawed to the shape of a rectangular prism (having three pairs of roughly parallel faces) for shipment.

Quarry Run
A term used by some producers to mean the lot of material has not been culled or otherwise limited for range of color and/or features, and includes the entire spectrum of material that is yielded by that particular deposit.

Quarry Sap
A term used by the limestone industry to describe the natural moisture in freshly quarried stone.

Quartz
A silicon dioxide mineral that occurs in colorless and transparent or colored hexagonal crystals or in crystalline masses. One of the hardest minerals of abundance in stones such as sandstone, granite, and quartzite.

Quartz Based Stone
A dimension stone group that includes both sedimentary (as in sandstone) or metamorphic (as in quartzite) stones and are characteristically high in free silica content. Definitions of the classes of stone which form the quartz based stone group are explained in ASTM C119.

Quartzite
A dense, hard metamorphic quartz based stone typically formed from sandstone. In some deposits, intrusion of minerals during the formation process creates unusual coloration. See ASTM C119.

Quartzitic Sandstone
A variety of sandstone including higher content of free silica and siliceous cements than typical quartz-based sandstones.

Quirk Miter
An external corner formed by two stone panels with beveled (usually 45°) edges and blunted, finished noses to reduce the chipping vulnerability of the sharp edges that occur with a common miter.

Quoin
One of the decorative dressed stones or bricks used at the corner of a building. Quoins are usually laid so their faces are alternately large and small.

R

Rabbet
A groove cut into the surface along an edge so as to receive another piece.

Rain Screen
A curtain wall system in which the outer façade shields, or "screens," rain from infiltrating the wall cavity, but is not actually sealed. The cavity is pressure equalized with the outside air, avoiding pressure differences that would otherwise draw water into the cavity. Minor amounts of water that penetrate the rain screen are evacuated via weep systems designed into the system.

Raked Joint
A mortar joint in which the mortar, while still soft, has been scraped back to a specified dimension with a square-edged tool. It is generally used to accentuate the joint due to the pronounced shadow line produced.

Random Slab
A stone slab of length and width that are not prespecified, but rather determined by the size of the block from which it was cut.

Rebated Kerf
A kerf that includes a second cut at 90° to the kerf axis which accommodates position of the anchor so that it doesn't occupy any of the joint region, allowing full movement capability of the joint dimension.

Recess
Any feature cut into a stone that is set back or indented from the balance of the stone surface, either to accommodate another element, such as anchorage, or for aesthetic appeal.

Recrystallized Limestone
A limestone in which a new pattern of crystallinity has pervasively replaced the crystal orientation in the original clastic particles, fossils, or fossil fragments, and interstitial cement.

Refinishing
The process of insitu finishing of existing stonework to return it to its near original appearance.

Reglet
A narrow groove cut in stone to receive flashing.

Reinforcement
Any element, metal, fiberglass, stone, etc. that is embedded in or applied to the stone panel for the purpose of increasing strength.

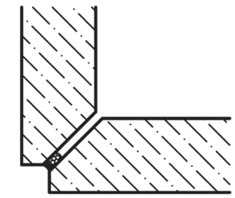
Relief
Carving or embossing raised above a background plane, as in a bas-relief.

Relieving Arch
One built over a lintel, flat arch or smaller arch to divert loads, thus relieving the lower member from excessive loading.

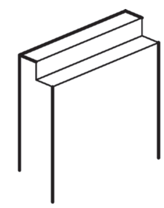
Remnant
A leftover portion of a slab that cannot be utilized in the primary project, but is salvaged for possible use in another project.

Reprise
The line formed by the intersection of two like profiles upon meeting at an interior corner.

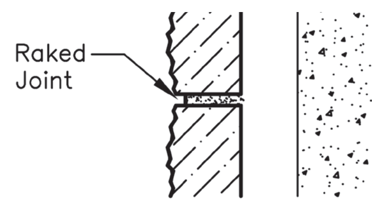
Resin
Any of a number of clear or translucent substances, either from plant origin or synthetics, used in producing lacquers, adhesives, plastics, polyesters, epoxies, silicones, etc.



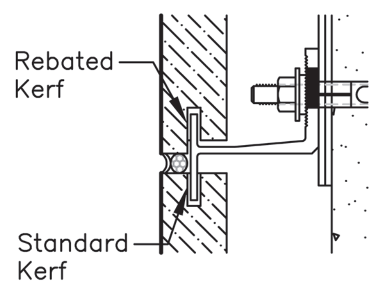
Quirk Miter



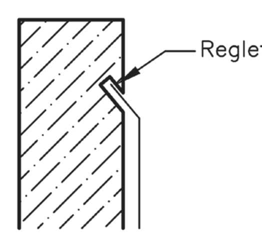
Rabbet



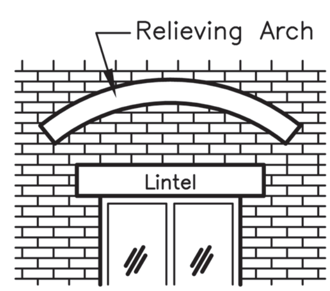
Raked Joint



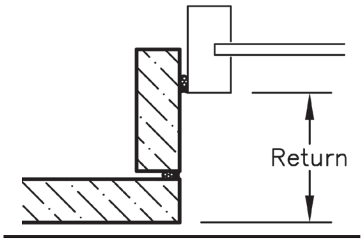
Rebated Kerf



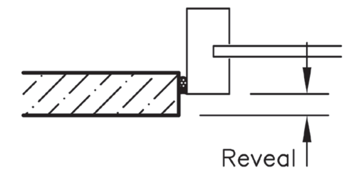
Reglet



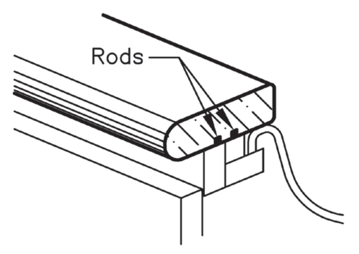
Relieving Arch



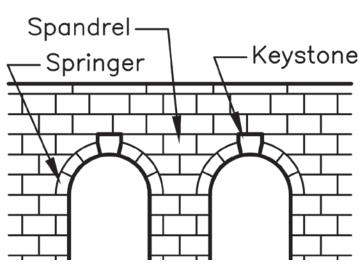
Return



Reveal



Rodding



Roman Arch

Resin Patching Sticks

A stone patching material supplied as a solid substance and installed in a heated condition to facilitate flowing into surface imperfections to be filled.

Resin Polishing

A reference to abrasive pads used for hand tool polishing, in which abrasives are embedded in a resin matrix.

Resined Slab

Slabs that have been treated with a cosmetic improvement process prior to polishing, in which a resinous adhesive, usually epoxy, is applied to the face of the slab, filling various voids in the stone surface. The resin is cured at elevated temperature, after which it is polished, allowing the resin to remain in the voids. This produces a more cosmetically attractive surface without the interruptions of the natural defects.

Restoration

Remedial action taken to return an existing installation of stone to its original or acceptable "near original" condition.

Return

The right-angle turn of a stone surface, either a molding or flat, as in a window jamb condition.

Return Head

See **head**.

Reveal

The exposed portion of a stone between its outer face and a window or door set into an opening.

Ribbon

Narrow bands of rock within the quarry deposit of contrasting color and/or texture due to varying mineralogical composition

Rift

Direction in which stone splits most readily. Term is most commonly used for granite or other stone without visible stratification or foliation.

Riprap

Large, irregular shaped stones randomly placed on an embankment to prevent or minimize soil erosion

Rock Faced

A rustic finish for veneer stone created with a split or chiseled face, and dressed along the stone's perimeter to produce convex projection. See also **pitch faced**.

Rock

1. Geologically, any natural mass of earth material that has appreciable extent.
2. In engineering, solid natural material that requires mechanical or explosive techniques for removal.
3. In the quarry industries, the term stone is more common and means firm, coherent, relatively hard earth material.

Rodding

A reinforcement technique used principally in countertop fabrication wherein metal or fiberglass rods are embedded into shallow kerfs in the underside of the stone slab at narrow regions of the countertop, such as the portion in from of a sink. See **reinforcement**.

Roman Arch

A semicircular arch. If built of stone, all units are wedge shaped.

Rough Back

The outermost slab produced when slabs are sawn from a block, having one side sawed and the other rough from the original quarry block face. Also known as "skin."

Rough Sawn

A surface finish resulting from the gang or wire sawing process.

Rubbed Finish

A stone finish between smooth machine finish and honed, obtained by mechanical rubbing to a very smooth surface.

Rubble

A term applied to dimension stone used chiefly for walls and foundations, consisting of stone units that may be highly irregular or partly trimmed or squared, generally with one or more split faces, and selected and specified with a size range. Rubble stone may be installed randomly or coursed.

Rustication
Any embellishment done to the joints in stonework, either chamfers or grooves, for the purpose of visually accentuating the joint by increasing the shadowline.

S

Saddles
See **thresholds**.

Sample
An actual piece of dimension stone in a small size used to demonstrate the general color, markings, and finish of a given variety of stone.

Sandblasted
A matte-textured surface finish produced by small particles ("sand") striking the stone surface at high velocities.

Sandstone
Sandstones are sedimentary rocks usually composed of quartz cemented with silica, iron oxide or calcium carbonate. Sandstones range from very soft and friable to very hard and durable, depending on the depth at which it was buried and the nature of the cement. Generally, the most durable sandstones are cemented with silica.Sandstone has a wide range of colors or textures. See **quartz based stone**.

Sawed Edge
A clean-cut edge generally achieved by cutting with a diamond blade.

Sawed Face
A finish obtained from the process used in the cutting of the blocks, slabs, or other units of building stone without further embellishment. It varies in texture from smooth to rough, and is typically named for the type of material used in sawing, e.g. diamond sawn, sand sawn, chat sawn, and shot sawn.

Sawyer
One who operates a saw.

Scabbing
See **dressing**.

Schist
A loose term applying to foliated metamorphic (recrystallized) rock characterized by thin foliae that are composed predominately of minerals of thin platy or prismatic habits and whose long dimensions are oriented in approximately parallel positions along the planes of foliation. Because of this foliated structure, schists split readily along these planes and so have a pronounced rock cleavage. The more common schists are composed of mica-like minerals (such as chlorite) and generally contain subordinate quartz and/or feldspar of a comparatively fine-grained texture; all gradations exist between schist and gneiss (coarsely foliated feldspathic rocks).

Scotia
A deep concave molding

Screed
A flat board or other straight piece used to level freshly placed concrete, mortar, or sand by sliding it over prepositioned guides that determine the height of the concrete or mortar.

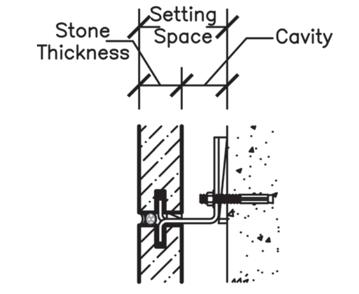
Sculpture
A three-dimensional art form cut or chiseled from a monolithic block of stone.

Sealant
An elastic adhesive compound used to seal stone veneer joints while still allowing differential movement between the stone units.

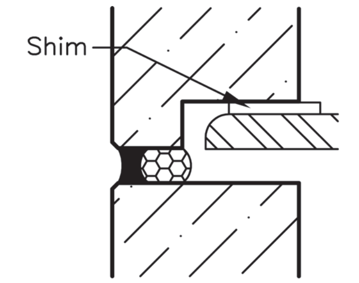
Sealer
A protective coating or treatment which prevents or retards foreign liquid or matter from penetrating the stone by closing the pores in the surface.

Sealing
The process of applying a sealer.

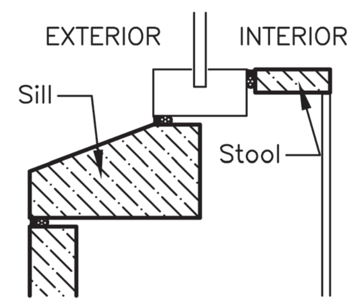
Seam Setter
A tool designed to pull two pieces of stone together and make the surfaces flat with each other. The tools are made with suction cups and attached with a set of steel glides. The tool will allow the installer to apply adhesive, pull the stone together, shim if necessary to make flat, while the tool is holding the pieces together until the adhesive dries.



Setting Space



Shim



Sill

Sedimentary
Rocks formed by deposition of particles, or "sediments" laid down in successive strata and cemented together by another agent. The materials of which they are formed are derived from preexisting rocks or the skeletal remains of sea creatures.

Serpentine
A common hydrous magnesium silicate rock-forming mineral; generally dark green in color with markings of white, light green, or black. Rocks composed predominantly of such minerals are correctly called "serpentinites", and are commercially sold as a marble because they can be polished. The definition of serpentine is given in ASTM C119 under the marble group.

Setter
A field mechanic who specializes in the installation of dimension stone.

Setting Space
The distance from the finished face of a stone unit to the face of the backup material. (Note: in some regions, the term is used to describe the distance between the back of the stone and the face of the backup material. See also "cavity")

Setting
The installation of dimension stone units.

Shale
A fine grained sedimentary stone formed by the compaction of clay, silt, or mud.

Shear
A force that causes, or attempts to cause, internal adjacent planes of material to slide along one another.

Shim
A piece of plastic or other non-corrosive, non-staining material used to temporarily or permanently adjust the position of a stone unit.

Shop Drawing
A detailed fabrication and installation drawing showing layout, joinery, dimensions, materials, finishes, methods of anchorage, and/or any other information pertinent to the fabrication or installation of the stone material.

Shop Ticket
A document used by a stone fabricator describing the fabrication details of an individual piece of dimension stone, most commonly employing graphics in addition to text, and possibly including production and/or quality control monitoring. Also referred to as a "cutting" or "cut" ticket.

Shot Sawed
Description of a finish resulting from using steel shot abrasive in the gang sawing process without further embellishment. This surface will normally have random linear markings for a rough surface texture.

Silica
An oxide of silicon with the chemical formula SiO_2, found abundantly in nature as sand quarts, or other rock components, The dry cutting or grinding of silica will produce silica dust, which when airborne in particles of respirable size, are a well known health hazard to those exposed to it without adequate PPE.

Siliceous
A rock bearing abundant silica.

Sill
The bottom horizontal part of a window or opening in a structure.

Siltstone
A fine-grained, non-carbonate clastic rock composed of detrital grains of quartz and silicate minerals of silt size. Siltstones are rarely marketed as such but commonly are considered as fine-grained quartz-based stones (sandstones). Siltstone is texturally transitional between quartz-based stones and shales (mudstones). Many bluestones and siliceous flagstones fall within this category. The term is included in these definitions chiefly to explain the relationship of some siliceous flagstones to the quartz-based stone category.

Simulated Stone
An artificial manmade product that attempts to resemble natural stone.

Slab
A flat "sheet-like" section of natural stone sawn to a prescribed thickness, with length and width determined by the size

of the quarry block from which it was sawed. Slabs will generally receive a face finish and further fabrication processes to become usable dimension stone products.

Slate
A very fine grained metamorphic rock derived from sedimentary shale rock, with excellent parallel cleavage, and entirely independent of original bedding, slate may be split easily into relatively thin slabs. See definition of slate in ASTM C119.

Sling
A type of strap, typically in the form of a "loop", made of high-density cloth and rated for the intended load, which is wrapped around an object that is being lifted.

Slip Joint
A connection which permits vertical or horizontal movement of a stone unit relative to the adjacent unit.

Slip Sill
A stone sill set between jambs. (compare **lug sill**).

Slurry
A suspension of insoluble particles in a liquid.

Smooth Finish
A finish of minimum textural quality, presenting the least interruption of surface. Smooth finish may be applied to any surface, flat or molded. It is produced by a variety of machines.

Snapped Edge
See **Guillotine**.

Soapstone
A talc-rich stone with a "soapy" feel, used for hearths, tabletops, chemical-resistant laboratory tops, stove facings, and cladding; known for its heat, chemical, and stain resistant properties.

Soffit
The underside of any architectural element, such as an arch, beam, lintel, or balcony.

Soundness
A property of stone used to describe relative freedom from cracks, faults, voids, and similar imperfections found in untreated stone. One of the characteristics encountered in fabrication.

Spall
A chip or splinter separated from the main mass of a stone. Also known as sprawl.

Spandrel
1. The often-decorated triangular area between an arch and a wall, or between two arches.
2. In modern high-rise construction, the panel area between the head of one window and the sill of the one above it. Can be clad in stone, metal, or glass.

Splay
A surface that makes an oblique angle with another surface, such as the non-vertical riser face frequently seen on steps.

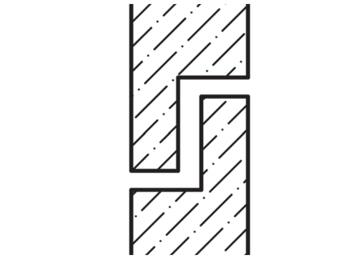
Split
Division of a rock by cleavage.

Split-faced Stone
Stone on which the face has been broken to an approximate plane.

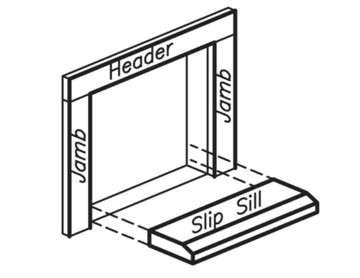
Split-stone Finish
In building stone, a rough face formed by splitting slabs in a split-face machine. Generally the slabs are sawed parallel to bedding in stratified stone, so that the split face exposes the bedding in natural orientation or overturned, but some stone is sawed perpendicular to bedding and then split with the bedding vertical, either exposed as a cleft surface or vertical.

Spot or Spotting
The mortar applied to the back of dimension stone veneer to bridge the space between a stone panel and the backup wall. Often used to describe the plaster or mortar spot used with wire tie anchorage.

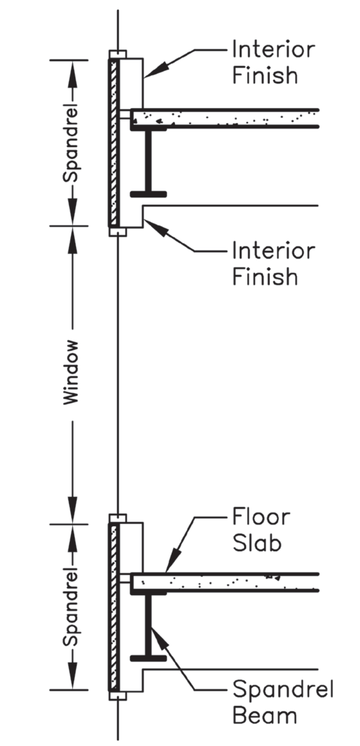
Spreader Bar
A beam with two lifting slings or cables, one on each end, intended to spread the lifting points while the bar is hoisted from its center.



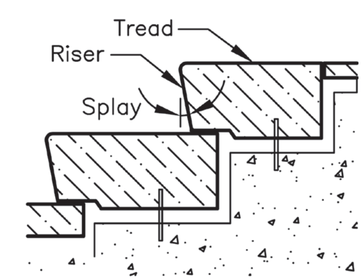
Slip Joint



Slip Sill



Spandrel



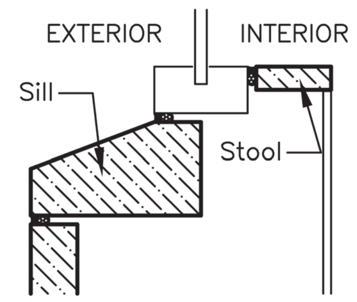
Splay

Stacked Bond
Stone that is cut to one dimension and installed with unbroken vertical and horizontal joints running the entire length and height of the veneered area.

Sticking
The butt edge repair of a broken piece of stone, now generally done with dowels, cements, or epoxies. The pieces are "stuck" together; thus "sticking."

Stone
Sometimes synonymous with rock, but more properly applied to individual blocks, masses or fragments taken from their original formation or considered for commercial use. In commercial use, the term stone is more frequently used, while scientifically, geologists and petrographers more frequently use the term rock.

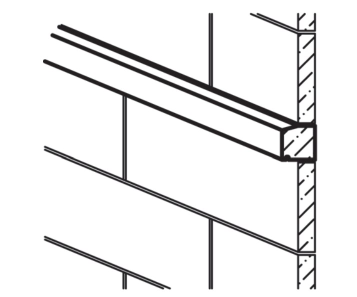
Stool
The interior sill of a window.



Stool

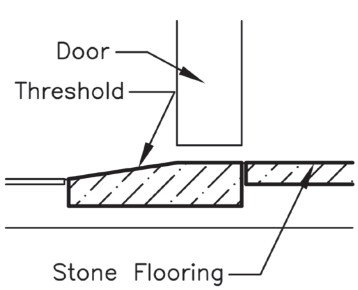
Stratification
The layered structure in sedimentary stone deposits as a result of the deposition of sediments in beds or layers (also "strata" or "lamina").

String Course
A horizontal band of masonry, generally narrower that other courses, extending across the façade of a structure and in some structures encircling such decorative features as pillars or engaged columns. May be flush or projected, and flat surfaced or decorated. Also called **belt course** or band course.


String Course

Stripping
To remove coatings that block a stone's ability to breathe which may cause spalling (when the stones crack, pop, or shale). Some examples of common coatings are topical acrylic sealers, janitorial waxes, and polyurethanes.

Stylolite
In limestone and marble, generally a bedding plane, along with differential solution of the material on each side has caused interpenetration of points, cones, or columns, forming a contact surface that is rough when separated. Also known as **crowfoot**.



Threshold

Support
An angle, plate or other stones which carry a gravity load.

T

TCNA
(Tile Council of North America)
An organization of manufacturers serving the ceramic tile industry, with overlapping interest in the stone tile industry, particularly in installation. The TCNA publishes the Handbook for Ceramic Tile Installation and serves as the Secretariat for the ANSI accredited A108 and A118 committees. Established in 1945 as the Tile Council of America (TCA), it became the Tile Council of North America (TCNA) in 2003 to reflect its membership expansion to all of North America - Canada, Mexico and the United States.

Template
A pattern for a repetitive marking or fabricating operation.

Terrazzo
A flooring surface of marble or granite chips in a cementitious or resinous matrix, which is ground and finished after setting.

Texture
Surface quality of stone independent of color.

Textured Finish
Any of the rough surface finishes used in dimension stone, selected for aesthetic reasons or as friction performance for walking surfaces.

Thermal Finish
A textured surface treatment applied by brief exposure to intense heat.

Thin Stone
Dimension stone units that are 2" (50 mm) or less in thickness.

Threshold
A flat or profiled strip of stone projecting above the floor between the jambs of a door, often marks the transition between two different flooring materials. Also known as a "saddle."

Tile
A thin modular stone unit, less than ¾" (20 mm) thick, and not exceeding 24" (600 mm) in its greatest dimension.

Tilt Shop Cart
A device used in stone fabrication areas to move slabs and/or cut-to-size pieces within the shop. The cart has a bed that tilts, allowing it be loaded with a slab in a vertical orientation but unload the same slab in a horizontal orientation.

Tin Oxide
A powder used in the polishing of granite with a talc-like appearance and applied with a felt pad and slow speed buffer.

Tolerance
The permissible limit of variation from the specified dimension.

Tooled Finish
A finish that customarily has four, six, or eight parallel, concave grooves to the inch. See also **bush hammered**.

Translucence
A characteristic of light colored onyxes and some light colored marbles allowing light to diffuse as it passes through.

Travertine
A variety of limestone formed by chemical precipitate from hot springs. Some varieties of travertine take a polish and are known commercially as marble. ASTM C119 classifies travertine in both the limestone and the marble groupings.

Tread
A flat stone used as the top (horizontal) walking surface on steps.

Trim
The framing or edging of openings and other features on the interior or exterior of a building, including baseboards, picture rails, cornices, and casings.

Tumbled Finish
A weathered, aging finish created when the stone is tumbled with sand, pebbles, or steel bearings.

U

Ultimate Capacity
The load resisted by a stone anchor at failure. This load must be divided by the factor of safety to determine a safe load, or **allowable capacity**.

Undercut
Cut so as to present an overhanging part.

Unit
A piece of fabricated cubic or thin dimension stone.

Urinal Screen
A thin stone panel used as a privacy partition between urinals.

V

Vacuum Cups
A device used in the handling of smooth surfaced stone which secures itself to the stone surface using vacuum contained within an enclosed chamber that is sealed against the stone via gasketing.

Vacuum Lifter
Any stone handling device using vacuum cups as a means of securing itself to the stone.

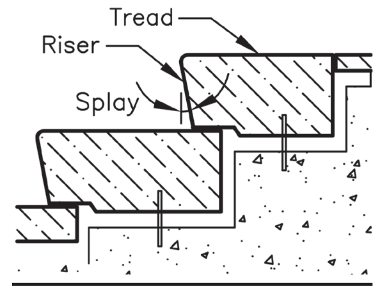
Vein Cut
A cut in quarried stone that is perpendicular to the natural bedding plane, exposing the veining of the material.

Vein
A layer, seam, or narrow irregular body of mineral material contrasting the surrounding material in either color, texture, or both.

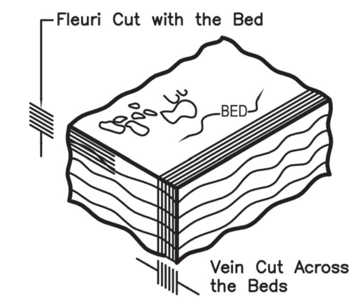
Veneer
A non-structural facing of stone, interior or exterior, serving as ornamentation and a weather barrier.

Venting
See **Cavity Vent**.

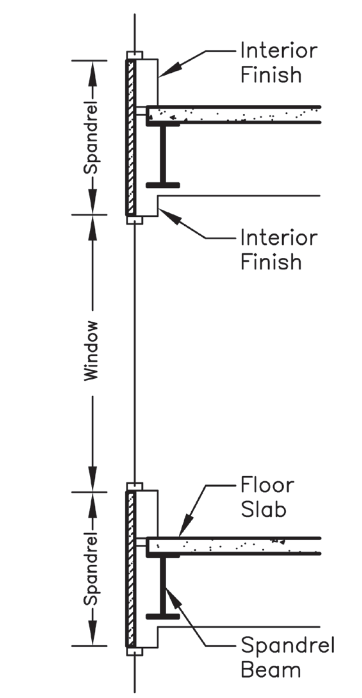
Vug
A pocket-like natural cavity in stone, generally the result of solution or recrystallization. Size not limited, but most are between a small fraction of 1 inch and a few inches in average diameter. May be



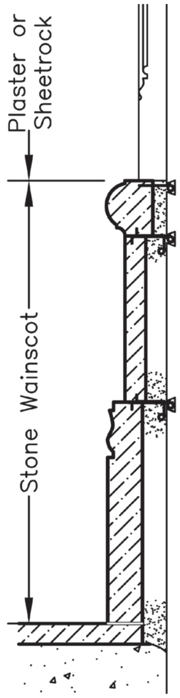
Tread



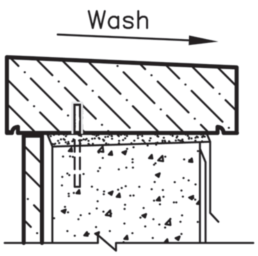
Vein Cut



Veneer



Wainscot



Wash

lined with crystals or botryoidal layers of mineral materials. Most common in dolomite, limestone and marble. Adj.: vuggy

W

Wainscot
An interior veneer of stone covering the lower portion of an interior wall.

Wall Tie
In masonry, a type of anchor, generally a metal strip, used to secure facing to backup wall or to connect the wythes of a cavity wall. Ties are mortared into joints during setting, and thus do not require that slots or anchor holes be cut.

Walls, bearing
A wall supporting a vertical load in addition to its own weight

Walls, cavity
A wall in which the inner and outer wythes are separated by an air space but tied together with metal ties.

Wash
The slope on the top of a stone unit intended to shed water.

Water Jet
A machine which uses extremely high pressure water and an abrasive to cut stone material in complex and exacting shapes from slabs or tile.

Water Recycling System
Any system that recovers water used in shop fabrication machinery and restores it to a reusable condition by filtering and/or chemical neutralization, after which it is returned to service.

Water Repellent
Any of several types of liquid-applied formulations used to render masonry walls less absorptive. These treatments are said to maintain a material's ability to breathe away moisture, as distinct from "sealers" which form impervious, non-breathing coatings.

Water Table
A course that projects from the face of a wall, generally near grade and having a beveled top and a drip cut in the projecting underside, to deflect water.

Water-jet Finish
A surface treatment performed by using water under extreme high pressure.

Waterproofing
See **Damp Proofing**.

Waxing
The practice of filling minor surface imperfections such as voids or sand holes with melted shellac, cabinetmaker's wax, or certain polyester compounds. In the dimension stone industry, it does not refer to the application of paste wax to make surfaces shinier.

Wear
The removal of material or impairment of surface finishing through friction or impact use.

Weathering
Natural alteration by either chemical or mechanical processes due to the action of constituents of the atmosphere, soil, surface waters, and other ground waters, or by temperature changes.

Wedging
Splitting of stone by driving wedges into planes of weakness or holes in the stone.

Weep Holes
Openings for drainage in veneer joints or in the structural components supporting the veneer.

Wire Sawing
A method of cutting stone by a wire or cable. Traditionally, the term applied to the use of a twisted wire carrying an abrasive slurry as the cutting agent. Currently, the term is more frequently used to describe the use of a cable that is fitted with diamond abrasive segments at regular intervals, cooled with water.

Wythe
The inner or outer part of a cavity wall.

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CONVERSION TABLES

Inches to Millimeters

Inches	Millimeters
1/32 in	0.794 mm
1/16 in	1.588 mm
3/32 in	2.381 mm
1/8 in	3.175 mm
5/32 in	3.969 mm
3/16 in	4.763 mm
7/32 in	5.556 mm
1/4 in	6.350 mm
9/32 in	7.144 mm
5/16 in	7.938 mm
11/32 in	8.731 mm
3/8 in	9.525 mm
13/32 in	10.319 mm
7/16 in	11.113 mm
15/32 in	11.906 mm
1/2 in	12.700 mm
17/32 in	13.494 mm
9/16 in	14.288 mm
19/32 in	15.081 mm
5/8 in	15.875 mm
21/32 in	16.669 mm
11/16 in	17.463 mm
23/32 in	18.256 mm
3/4 in	19.050 mm
25/32 in	19.844 mm
13/16 in	20.638 mm
27/32 in	21.431 mm
7/8 in	22.225 mm
29/32 in	23.019 mm
15/16 in	23.813 mm
31/32 in	24.606 mm
1 in	25.400 mm

Feet	Millimeters
1 ft	304.8 mm
2 ft	609.6 mm
3 ft	914.4 mm

Note: Some of the SI International System of Units (metric) conversions listed in these tables are rounded numbers at the third decimal place.

Centimeters to Inches

Centimeters	Inches
0.2 cm	1/16 in
0.3 cm	1/8 in
0.5 cm	3/16 in
1.0 cm	3/8 in
1.4 cm	9/16 in
1.5 cm	5/8 in
2.0 cm	3/4 in
2.5 cm	1 in
3.0 cm	1-3/16 in
3.5 cm	1-3/8 in
4.0 cm	1-9/16 in
4.5 cm	1-3/4 in
5.0 cm	2 in

NOTE: Centimeters (cm) have been rounded off to the nearest tenth of a cm.

Square Feet to Square Meters

Square Feet	Square Meters
1 sq ft	0.093 sq m
2 sq ft	0.186 sq m
3 sq ft	0.279 sq m
4 sq ft	0.372 sq m
5 sq ft	0.465 sq m
6 sq ft	0.558 sq m
7 sq ft	0.651 sq m
8 sq ft	0.744 sq m
9 sq ft	0.837 sq m
10 sq ft	0.930 sq m

Square Meter to Square Feet

Square Meters	Square Feet
1 sq m	10.764 sq ft
2 sq m	21.528 sq ft
3 sq m	32.292 sq ft
4 sq m	43.056 sq ft
5 sq m	53.820 sq ft
6 sq m	64.583 sq ft
7 sq m	75.348 sq ft
8 sq m	86.111 sq ft
9 sq m	96.875 sq ft
10 sq m	107.639 sq ft

CONVERSION TABLES

Conversion Ratios

Length and Area

Convert from	To	Multiply by
millimeter	inch	0.04
centimeter	inch	0.3937
centimeter	foot	0.03281
meter	inch	39.37
meter	foot	3.281
square meter	square foot	10.763
inch	millimeter	25.4
inch	centimeter	2.54
inch	meter	0.0254
foot	meter	0.3048
yard	meter	0.9144
square inch	square meter	0.000645
square foot	square meter	0.092990
square yard	square meter	0.836127

Weight

Convert from	To	Multiply by
pound	kilogram	0.4536
ounce	gram	28.3495
long ton	pounds	2240
short ton	pounds	2000
gram	ounces	0.0353
kilogram	pounds	2.2046

Volume

Convert from	To	Multiply by
cubic cm	cubic inch	0.061
cubic meter	cubic feet	35.3198
cubic inch	cubic cm	16.387
cubic feet	cubic meters	0.028
liter	gallons	0.2642
lb/ft^3	kg/m^3	16.02
MPa	lbf/in^2 (psi)	145
lbf/in^2 (psi)	pascals (Pa)	6895
lbf/in^2 (psi)	kg/sq m	4.882
kg/m^2	pascals (Pa)	9.807

Mohs Scale

In 1812, the Mohs Scale of mineral hardness was devised by the German mineralogist Friedrich Mohs (1773-1839), who selected the ten minerals because they were common or readily available. The scale is not a linear scale, but somewhat arbitrary.

Hardness	Mineral
1	Talc or mica
2	Gypsum
3	Calcite
4	Fluorite
5	Apatite
6	Orthoclase
7	Quartz
8	Topaz
9	Corundum
10	Diamond

Source:
American Federation of Mineralogical Societies, Inc.

Slab Production Table

Blocks	Slabs/Foot	Slab Thickness
1 cu ft	10	3/4"
1 cu ft	8	1-1/4"
1 cu ft	7	1-1/2"
1 cu ft	5	2"
1 cu ft	4	2-1/2"
1 cu ft	3½	3"
1 cu ft	3	3-1/2"
1 cu ft	2½	4"

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Residential Stone Countertop Installations *

Safety in the Stone Business (also available in Spanish)

Silicosis: An Industry Guide to Awareness and Prevention

Stone Selection & Stone Testing *

Wet Areas*

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*Information contained in these technical publications was taken directly from the *Dimension Stone Design Manual*. Additional illustrations and pictures have been added in these stand-alone publications.

ASTM Classification Index

ASTM	Dimension Stones	C97 Density lb/ft³ (minimum)	C97 Absorption (max %)	C99 Modulus of Rupture psi (min)	C120 Flexural Strength (Slate) psi (min)	C121 Water Absorption (Slate) (max %)	C170 Compressive Strength psi (min)	C241 Abrasive Resistance (minimum)	C880 Flexural Strength psi (min)
C503	Marble Calcite	162	0.20	1,000	na	na	7,500	10	1,000
C503	Marble Dolomite	175	0.20	1,000	na	na	7,500	10	1,000
C1526	Serpentine	160	0.20 exterior 0.60 interior	1,000	na	na	10,000	10	1,000
C1527	Travertine (exterior)[3]	144	2.50	700	na	na	7,500	10	500
C1527	Travertine (interior)[3]	144	2.50	700	na	na	5,000	10	500
C568	Limestone (low density)[1,2]	110	12.00	400	na	na	1,800	10	none est.
C568	Limestone (med density)[1,2]	135	7.50	500	na	na	4,000	10	none est.
C568	Limestone (high density)[1]	160	3.00	1,000	na	na	8,000	10	none est.
C615	Granite	160	0.40	1,500	na	na	19,000	25	1,200
C629	Slate (interior)	170-190[4]	na	na	5,500 along grain 7,200 across grain	0.45	none est.	8	none est.
C629	Slate (exterior)	170-190[4]	na	na	7,200 along grain 9,000 across grain	0.25	none est.	8	none est.
	Quartz-based Stones								
C616	Sandstone	125	8.00	350	na	na	4,000	2	none est.
C616	Quartzitic Sandstone	150	3.00	1,000	na	na	10,000	8	none est.
C616	Quartzite	160	1.00	2,000	na	na	20,000	8	none est.

Notes:

1. Limestone shall be sound, durable, and free of visible defects or concentrations of materials that will cause objectionable staining or weakening in normal environments of use.
2. Limestone that is of low or medium density may not be suitable for use in all interior and exterior applications.
3. Travertine that is fleuri-cut (cross cut) can be vulnerable to certain problems because some areas of the exposed surface will consist of only a thin layer of stone covering a void in the stone.
4. Historical data not established by ASTM.

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Note: Page numbers in *italics* refer to figures. Page numbers that refer footnotes include the number of footnote (for example, 10-7 n2).

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