Dimension Stone Design Manual

Version VIII

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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 Marble Institute of America, provides products that satisfy contemporary design concepts while retaining all the outstanding qualities for which the industry has always been respected.

Dimension Stone Design Manual

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THE MIA+BSI

In 2016, the memberships of the Marble Institute of America (MIA) and the Building Stone Institute (BSI) entered into 2-year joint venture to operate as a consolidated organization.

Together, MIA and BSI serve more than 1900 members in 55 countries who represent every aspect of the natural stone industry, offering them a wide array of technical and training resources, professional development, regulatory advocacy, and networking events.

During the 2-year joint venture (2016-17), each organization will maintain its individual identity but will be working together to incorporate a number of BSI technical papers/topics into the next DSDM version (9.0).

HISTORY - THE MARBLE INSTITUTE OF AMERICA

MIA traces its roots back to the National Association of Marble Dealers, founded in 1907, which joined with the National Association of Marble Producers in 1944 to form the Marble Institute of America (MIA). The National Association of Marble Builders merged with MIA in 1962.

HISTORY - THE BUILDING STONE INSTITUTE

BSI traces its roots back to 1919 and has undergone several name changes. The National Cut Stone Contractor's Association was changed to The International Cut Stone Contractors and Quarrymen's Association in 1952 and then in 1955 became the Building Stone Institute.

DIMENSION STONE DESIGN MANUAL

The purpose of the *Dimension Stone Design Manual* is to present reliable performance data and design information in one volume in order 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.

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The MIA 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 MIA staff. We are grateful for their combined commitment to the MIA and the dimension stone industry.

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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 the MIA.

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.

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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 MIA.

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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

Building Stone Institute (BSI)
www.buildingstoneinstitute.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

Marble Institute of America, Inc. (MIA)
www.marble-institute.com

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

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

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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

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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]

[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

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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

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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

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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

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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 (MIA 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.

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Additional GREEN References

Quarry Reclamation Site List

Quarry Park and Nature Preserve
County of Stearns, MN
www.co.stearns.mn.us/1450.htm

Halibut Point State Park
Gloucester, MA
www.mass.gov/dcr/parks/northeast/halb.htm

The Quarry Golf Club
San Antonio, TX
www.quarrygolf.com/

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

Crystal Springs Quarry Golf Club
Maryland Heights, MO
crystalspringsquarry.com/

Old Quarry Nature Center
Danbury, CT
www.danbury.org/oldquarry/

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

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

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SUGGESTED CONTRACT WARRANTY PROVISION/ DISCLAIMER

The following warranty is provided as a guide only to Marble Institute of America 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. MIA 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.

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SUGGESTED RESIDENTIAL CONTRACT (INSTALLATION OF DIMENSION STONE)

The following residential contract is provided as a guide only to Marble Institute of America 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. MIA 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 stone work:

     _____
     (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 stone work shall pass to Purchaser until full price has been paid, regardless of the location of the stone work, and whether it has been installed or not installed in the residence.

7. **Standards and Guidelines**. Installation of the stone work by the Seller shall be in strict accordance with the Marble Institute of America'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 nonassigned party.

PURCHASER: _____
Print Name: _____
Date Signed: _____

PURCHASER: _____
Print Name: _____
Date Signed: _____

SELLER: _____
Print Name: _____
Date Signed: _____

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MIA CODE OF ETHICS

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

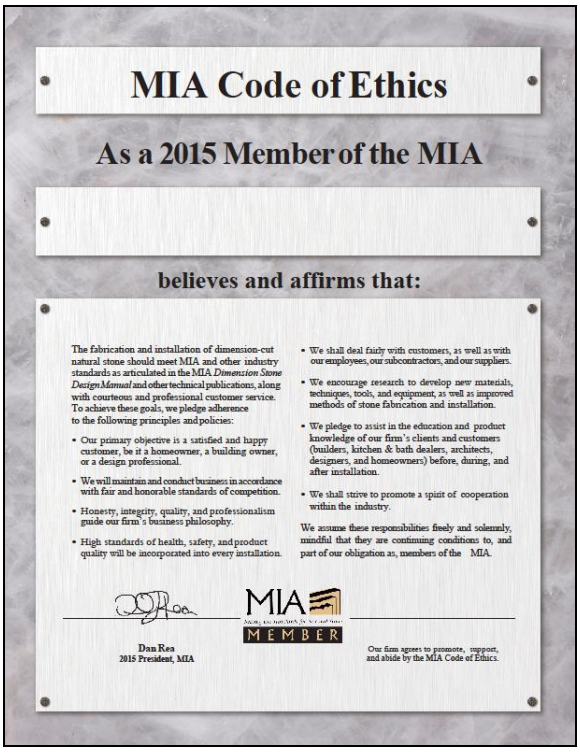
Members of the Marble Institute of America believe and affirm that:

The fabrication and installation of dimension-cut natural stone should meet MIA and other industry standards as articulated in the MIA *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 Marble Institute of America.

NOTE: A copy of the MIA 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.



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MIA MEMBERSHIP

Membership in the Marble Institute of America provides you with outstanding advocacy, networking, marketing & publicity, information & education, and professionalism and stone craftsmanship — benefits that continue to make MIA 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 MIA and its member-friendly, cost-saving services you can save money on collections, credit card transactions, office supplies, lead referrals, shipping, and utility costs.

MIA Member Benefits Include:

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

MIA Credit Card Processing Program
MIA 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
MIA 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 MIA's Technical Director.

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

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

MIA Receivables Management Solutions
MIA 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.

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

Office Supplies and Print Services Program
The MIA 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
MIA operates a web site that can drive new business your way: www.marble-institute.com 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 MIA member benefits, go to www.marble-institute.com or call the Membership Department at 440.250.9222.

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NOTES:

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MARBLE INSTITUTE OF AMERICA (MIA)

SAMPLE SPECIFICATION LANGUAGE FOR DESIGN PROFESSIONALS

Marble Institute of America (MIA)

For over 70 years the Marble Institute of America (MIA) has been the world's leading information resource and advocate for the natural stone industry.

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

  Sample Language for Fabricator/Installer Qualifications (Residential or Commercial Projects)
  Fabricator/Installer Qualifications: A Marble Institute of America (MIA) 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.

- 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; maintenance of exterior and interior stone installations; and a glossary of terms relating to dimension stone.

  Sample Language to Reference the MIA's DSDM
  For granite, limestone, marble and onyx, quartz-based, serpentine, slate, soapstone, and travertine, comply with recommendations in MIA's Dimension Stone Design Manual (DSDM), version 8 (©2016).

- **MIA Accreditation** for natural stone fabricators and commercial contractors recognizes those companies that meet the industry's highest standards for business activities, product knowledge, fabrication and installation. To earn MIA 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 Language for MIA Accredited Natural Stone Fabricators (Residential Projects):

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

Sample Language for MIA Accredited Commercial Contractors:

Installer Qualifications: A firm experienced in installing engineered dimension stone cladding systems. Company must be an MIA Accredited Commercial B Contractor (low rise) or an MIA Accredited Commercial A Contractor (high rise) of current good standing with the Marble Institute of America. Bidding company must supply their official MIA 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 MIA Dimension Stone Design Manual and compliant with applicable codes. Comprehensive shop drawings with attachment details shall accompany engineering analysis.

For more information:

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Oberlin, OH 44074
USA
PH: 440-250-9222
FAX: 440-774-9222
www.marble-institute.com

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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.

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

[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."

[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.

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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 thick.

3.2 The underlying mantle is about 1,620 miles thick and can be is envisioned as two parts: a weak **upper mantle** of about 190 to 440 miles 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 thick, and a molten metallic **outer core** about 1,420 miles 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.

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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 *ferr*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.

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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 (in mm): >256
Rock Name: Boulder Conglomerate
Stone Abbreviation: Cgl.

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

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

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

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

3.14.6 Particle Name: **Clay**
Size Range (in mm): <1/256
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.

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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 200°C to near-melting, ≈700-800°C, 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

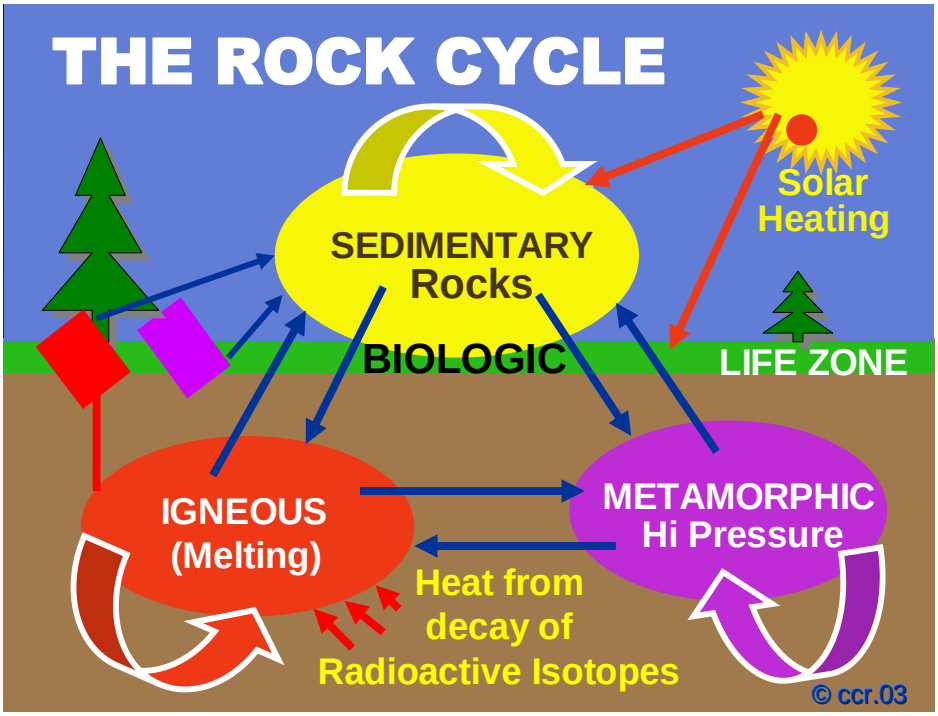
4.1 Basic processes and relationships inherent in the geological concept known as "the rock cycle" help to understand the variety and complexity of stone.

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.

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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.

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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 (Exterior)

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

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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

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

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

7.5 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.

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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.

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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", 16" x 16", 18" x 18", and other sizes, up to a maximum of 24" x 24". 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,

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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 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", 4" x 6", or 6" x 6".

7.3 Project samples should be 1' x 1' 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

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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.

MIA Bookstore Resources:

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

Two MIA-produced, consumer-focused brochures are available on the use and care of natural stone: "Beautify Your Home with Natural Stone (A Guide to Choosing Natural Stone and a Qualified Stone Contractor)," and "Care & Cleaning of Natural Stone Surfaces." Stone professionals can purchase both of these brochures from the MIA Bookstore.

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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 petrograpic 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" to 2" x 3"), 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)

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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 C119-11, showing that it was revised in 2011. An additional number in parentheses, e.g., ASTM C97-92(1994), indicates that the 1992 edition was formally reaffirmed without change in 1994. 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.

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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 ±2°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 ±2°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".

3.5 Limitations of Thin Stone Pavers. It is the position of the Marble Institute of America that stones less than 1¼", 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 3 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. However, sometimes the stone is not available in that thickness, especially flooring material, which may be only 3/4" or 3/8". 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" square and the "as cleft" thickness, which is typically ¼" to 3/8". 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. 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 3 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

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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 170. They should be cubes at least 2" to 3" 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 3 specimens that are 4"x 8"x 2¼" 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" apart. The 7" span allows the 8" long specimen to overhang the supports by ½" 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" 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" ends of the specimen. In the analogy, several decks would have to be stacked up to a height corresponding to the 8" 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.

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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" thick. Rubbing or sanding the cleft faces achieves the specified 1" 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".

While these test methods are useful, they have certain limitations. Since the specimen for ASTM C99 is always 2¼" thick (or 1" 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", the width is 4". If specimens for an exterior building veneer are 4" x 1¼" x 15", the test span should be 12.5. For a 3/8" floor tile, the specimens would be 4" x 3/8" x 4½" and the test span would be 3.75". 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" square and 1" thick. One 2" 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" 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" 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" thick. For a specimen ¾" thick, the 2,000 grams would be increased by the mass of the missing ¼" 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.

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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 initiate slipping divided by the normal force) per the ASTM C1028 method. This test method was withdrawn in 2014 and no replacement method was offered.

In the ceramic tile industry, slip resistance is not being evaluated by measuring the dynamic coefficient of friction (the force required to sustain slipping divided by the normal force) per the ANSI A137 method.

The Marble Institute of America has several studies using the ANSI A137 method on Natural Stones. Recorded results are encouraging, indicating that this test method may be equally reliable for use with natural stone products as it is with ceramic products. Additional studies are yet to be completed which will provide greater statistical confidence, after which a formal endorsement of the procedure will likely follow, however that endorsement was not yet available at the time of this writing. Such endorsement will be published as a Marble Institute of America Technical Bulletin, and the reader is advised to check the Marble Institute of America's technical publications library to see the most recent publications on the subject.

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.agi-usa.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

Construction Specifications Institute (CSI)
www.csinet.org

International Masonry Institute (IMI)
www.imiweb.org

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

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

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

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.

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

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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 Marble Institute of America (MIA):

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 MIA Bookstore. Go online at www.marble-institute.com.

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 the MIA, 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 MIA.

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" 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,

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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] [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 MIA, 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" between stone backs and adjacent structure. (Note: many bolted connections will require more space than this; 2" 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" 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.

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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" 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" 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". Apply pointing mortar in layers not exceeding 3/8" 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" 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.

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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" 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" 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" 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" 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" 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", 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" for exteriors and 1/8" 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.

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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".

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 MIA 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. MIA Members can provide these range samples.

8.0 PROPER USAGE TIPS

8.1 Recommendation for commercial floors:

8.1.1 Minimum ¾" thickness.

8.1.2 A honed finish.

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

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.

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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 MIA 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.)*

Property	**Range of Values**
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/ft³	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

* 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)

4.1 Abrasion resistance is a property of stone that should be tested per ASTM C241 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 (Ha) of 25 or more, as measured by ASTM C241 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

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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, dis-integrate slowly if exposed to an acid-bearing atmosphere, as in regions where hydro-carbons 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 http://www.marble-institute.com/radon/. None of the research found a single stone that would be a health risk to homeowners.

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

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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.

NOTES:

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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, 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 Marble Institute of America (MIA):

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 MIA Bookstore. Go online at www.marble-institute.com.

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 MIA, 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 MIA.

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" and shall represent approximately the finish, texture, and anticipated range of color to be supplied. One set of approved samples shall be

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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.

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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] [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 MIA, 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" 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" between stone backs and adjacent structure. (Note: many bolted connections will require more space than this; 2" 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

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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" 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" 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" 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 recommendations for setting from 40°F to 20°F (4°C to -6°C) shall be followed, except that no additives shall be used in the setting mortar, and below 20°F (-6°C), all work shall be done in heated enclosures.

5.2.10 Individually set thin tile (nominal 3/8" thick) on vertical surfaces exceeding 8' 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

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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 MIA recommends a maximum area of 400 square feet 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 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 superenriched 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 postdepositional; 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.

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–

[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.

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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 MIA 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". The

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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 MIA 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 MIA 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. MIA Members can provide these range samples.

8.0 PROPER USAGE TIPS

8.1 Recommendation for commercial floors:

8.1.1 Minimum ¾" thickness.

8.1.2 A honed finish.

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

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 MIA 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)	
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 x 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) (C241)	3.0-33.0
Recommended (min): 10	

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

[4] Test methods described in current ASTM standards.

[5] Also known as Young's Modulus.

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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)

4.1 Abrasion resistance is a property of stone that should be tested per ASTM C241 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 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.

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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:

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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 (Exterior)

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

1.2.3 Marble Institute of America (MIA):

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 MIA Bookstore. Go online at www.marble-institute.com.

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 MIA 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 MIA.

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" 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

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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

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shall be within the range of sample(s) approved by the Specifying Authority.

2.1.1.1 ASTM C503 [C97] [C99] [C170] [C241] [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 MIA 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, with two additional anchors for each additional 8 square feet 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' 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" between stone backs and adjacent structure. (Note: many bolted connections will require more space than this; 2" 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" 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.

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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" 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" to flatten the ridges and fill the valleys. Ensure a maximum mortar thickness of 3/32" 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" tile; not less than 80% contact on ¾" 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" thick) on vertical surfaces exceeding 15'-0" 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". Apply pointing mortar in layers not exceeding 3/8" 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" greater than the joint width.

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

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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 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

[1] Adapted from: Bates, R. L. and J. A. Jackson, eds., 1980, *Glossary of Geology*, 2nd Edition, American Geological Institute, 1980.
[2] Ibid.

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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 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

[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.

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 of the $CaCO_3$ molecule. Crystals may grow in isolated free spaces or voids called "vugs[7]" or in

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

[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.

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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].

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

[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.

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.

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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.

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.

[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.

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". 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" 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" thickness.

8.1.2 A honed finish.

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

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

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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 MIA 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 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

[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."

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.

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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/ft³ (C97) 140-185
Recommended (min):
162 (calcite),
175 (dolomite)

Thermal Conductivity "k"
Btu/in/hr/ft²/°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 (C241).....5.0-50.0
Recommended (min): 10

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* 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"-thick marble.

3.3 The use of an insulating material with marble substantially improves the fire rating, as shown below.

7/8" marble with 1" 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)

4.1 Abrasion resistance is a property of stone that should be tested per ASTM C241 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 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."

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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.

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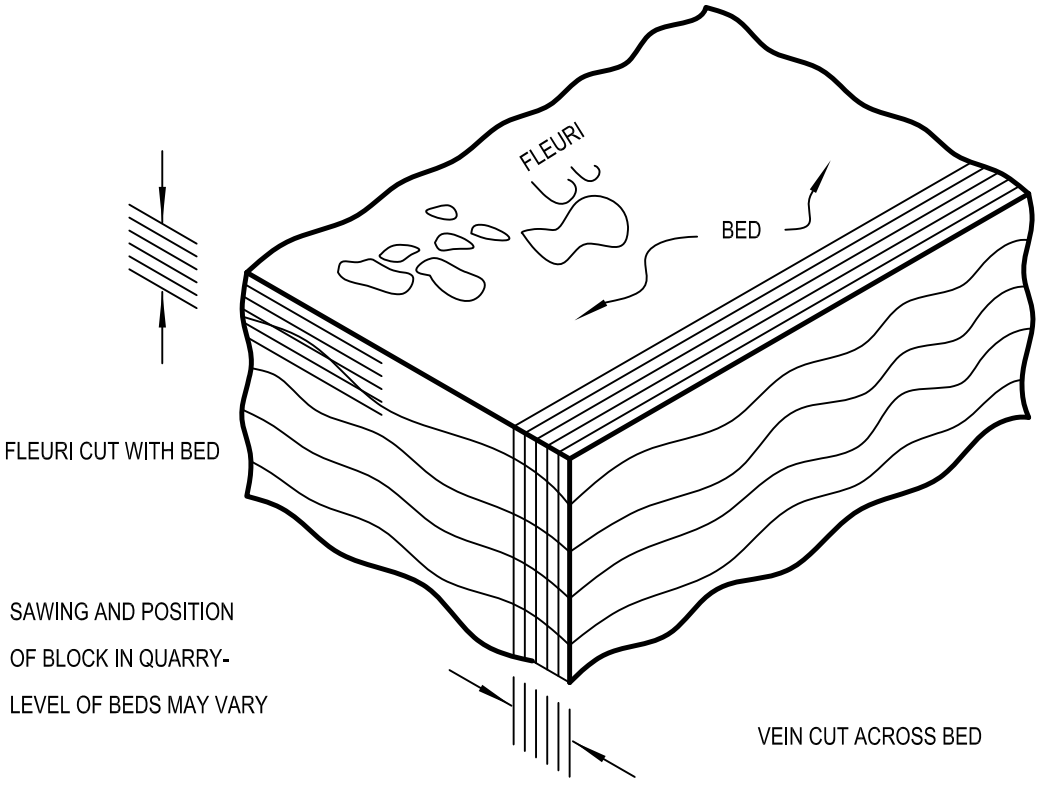
VENEER CUTTING

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 AND SAWING DIRECTIONS

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 7-D-1

SCALE: Not to Scale

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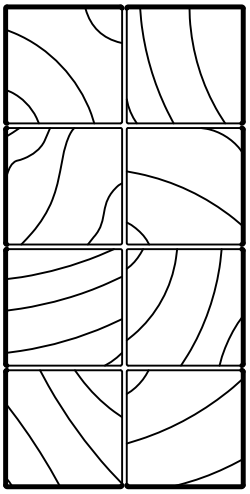
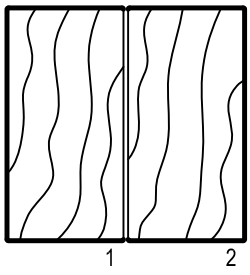
VENEER PATTERNS

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.



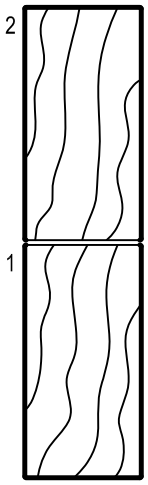
BLEND PATTERN

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.



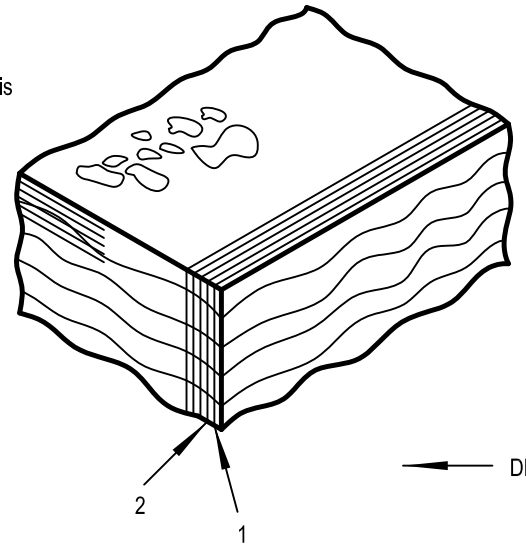
SIDE SLIP PATTERN

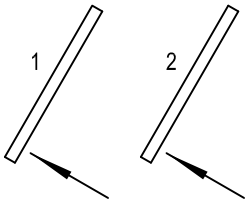
Panels are placed side by side to give a repetitive pattern and blended color in the horizontal.



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.





DENOTES SIDE TO BE FINISHED

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VENEER VEIN PATTERNS

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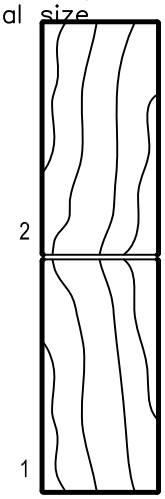
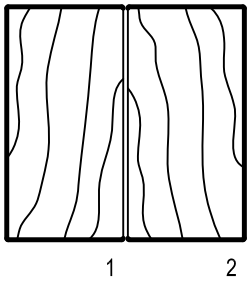
VENEER PATTERNS

Allow the illistrations 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.



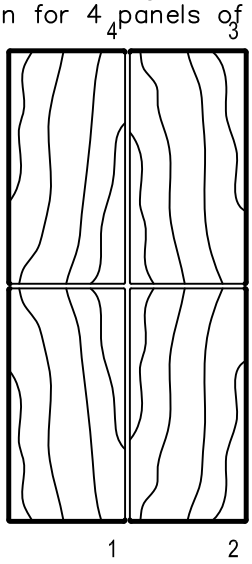
END MATCH PATTERN

The adjacent faces of panels 1 & 2 are finished.Panel 2 is inverted above panel 1.



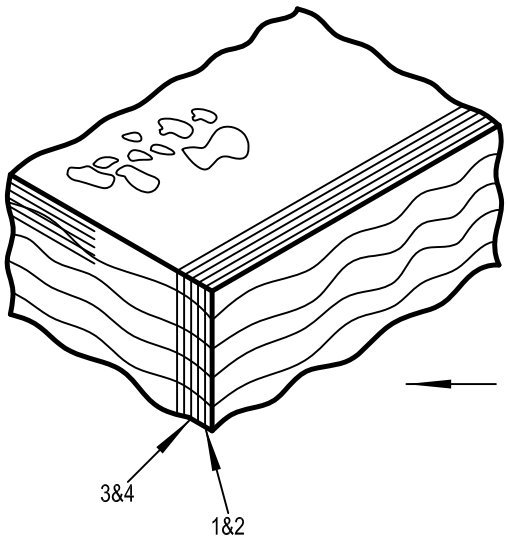
BOOK MATCH PATTERN

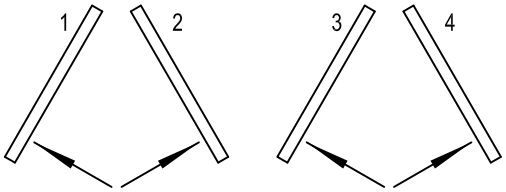
The adjacent faces of panels 1 & 2 are finished. Panel 2 is placed next to Panel 1 as the pages of a book are opened.



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.





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RIFT AND SAWING DIRECTIONS

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 7-D-3

SCALE: Not to Scale

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NOTES:

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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

1.2.3 Marble Institute of America (MIA):

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 MIA Bookstore. Go online at www.marble-institute.com.

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 MIA 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 MIA.

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" 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] [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*)

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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 MIA 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" 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" between stone backs and adjacent structure. (Note: many bolted connections will require more space than this; 2" 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" 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" 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.

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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" thick stone) a dry-set portland cement mortar is applied with a 3/8" or ½" 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" 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" thick) is used, nonstaining adhesives or dry-set mortars may be employed. Individually set thin tile (nominal 3/8" thick) on vertical surfaces exceeding 8' 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". Apply pointing mortar in layers not exceeding 3/8" 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" 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.

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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 ($SiO_2 \cdot NaH_2O$), 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.

[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 sea-shells 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" 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.

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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 conglo-merates 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".

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" 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.

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.

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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".

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 MIA 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)

4.1 Abrasion resistance is a property of stone that should be tested per ASTM C241 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) of 8 or more, as measured by ASTM C241 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 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

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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.

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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

1.2.3 Marble Institute of America (MIA):

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 MIA Bookstore–go online at www.marble-institute.com.

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 MIA 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 MIA.

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" 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

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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, bench marks, 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, though not in all situations. Where questions of suitability for use are encountered, the MIA recommends that reliance on past performance is the best guide for making decisions as to future performance.

[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."

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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] [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 (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 MIA 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.

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

[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.

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, with two additional anchors for each additional 8 square feet of 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' 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" between stone backs and adjacent structure. (Note: many bolted connections will require more space than this; 2" space may be more desirable. Large-scale details should illustrate and control these conditions.)

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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" 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 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 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 nonstaining 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" 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

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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" to flatten the ridges and fill the valleys. Ensure a maximum mortar thickness of 3/32" 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" tile; not less than 80% contact on ¾" 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" thick) on vertical surfaces exceeding 8' is not recommended. Where thin serpentine tile is installed, nonstaining 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". Apply pointing mortar in layers not exceeding 3/8" 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" 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 nonstaining 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

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$CaMg(CO_3)_2$. 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 beltlike 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.

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 Mohorovicić 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 serpertinite 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,

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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". When a serpentine thinner than ¾" is specified, the ratio between thickness and overall size and the use of reinforcing backup materials must be considered. Serpentine thicker than 2" 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" thickness.
2) A honed finish.
3) A minimum hardness value of 10 as measured by ASTM C241.

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

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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	

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* 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"-thick serpentine.

3.3 The use of an insulating material with serpentine substantially improves the fire rating, as shown in the following:

7/8" serpentine with 1" 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)

4.1 Abrasion resistance is a property of stone that should be tested per ASTM C241 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 abrasive hardness rating (H_a) 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 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

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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).

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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 Marble Institute of America (MIA):

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 MIA Bookstore. Go online at www.marble-institute.com.

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 MIA 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 MIA.

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.

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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] 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 (1) for each different slate/finish combination in the project.

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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 the MIA 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". Standard economical lengths are up to 6'-6" and widths up to 4'-0". Special larger sizes are available to meet design and job conditions on special request. No single piece is recommended to be over 9'-6" in length or 5'-0" 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" are recommended between standard size panels, and ¼" and 3/8" 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" between stone backs and adjacent structure. (Note: many bolted connections will require more space than this; 2" 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" 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" 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.

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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" wire (depending on the thickness of the stone) turned down 1" into a 3/8" round, 1½" deep hole in the edge of the slate. Each piece must be anchored individually for proper adjustment. Slabs over 12 square feet in surface area shall have at least two additional anchors every 6 square feet. 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" 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" located every 18" 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" or less ¼" 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") on vertical surfaces exceeding 15'-0" is not recommended.

5.3 Mortar Joints

5.3.1 Mortar joints shall be raked out to a depth of ½" to ¾". Apply pointing mortar in layers not exceeding 3/8" 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" 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

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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 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

[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.

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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.

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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". Slate tiles are available in a variety of thicknesses ranging from ¼" to 1". 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 MIA 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. MIA Members can provide these range samples.

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8.0 PROPER USAGE TIPS

8.1 Recommendation for commercial floors:

8.1.1 Minimum ¾" thickness.

8.1.2 A honed or cleft finish.

8.1.3 A minimum hardness value of 8 as measured by ASTM C241.

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 MIA 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

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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) (H_a)	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 (Ha) 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

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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:

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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 Marble Institute of America (MIA):

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 MIA Bookstore. Go online at www.marble-institute.com.

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 MIA 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 the MIA.

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"

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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 See the chart of applicable ASTM standards and tests in the Appendix.

2.1.3 Schedule: Soapstone shall be provided as follows:

2.1.4 For (*state location on building*) (*state name and color*) Soapstone with a (*type*) finish,

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supplied by (*name company or list several approved suppliers*).

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

2.1.6 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.

2.1.7 Finishes listed in the schedule shall conform with definitions by the MIA 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.

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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. 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.

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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

1.2.3 Marble Institute of America (MIA):

1.2.3.1 Membership, Products, and Services Directory

1.2.3.2 Dimension Stone Design Manual

Additional publications may be available from the MIA Bookstore. Go online at www.marble-institute.com.

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 the MIA 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" 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

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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. (The MIA 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 Marble Institute of America Dimension Stone Design Manual standards unless other criteria are mutually agreed upon in writing by the Travertine Contractor and the Specifying Authority.

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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] [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 (1) for each different travertine/finish combination in the project.

2.1.3 Finishes: Finishes listed in the schedule shall conform with definitions by MIA 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" of finished surface when using nonstaining 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" between stone backs and adjacent structure; however, many bolted connections will require more space – 2" 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" 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

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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 nonstaining 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 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 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" of finished floor. All bed and vertical joints shall be 3/8" 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" 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 40°F to 20°F (4°C to -6°C) shall be followed, except that no additives shall be used in the setting mortar, and below 20°F (-6°C), all work shall be done in heated enclosures.

5.2.11 Individually set thin tile (nominal 3/8") on vertical surfaces exceeding 8' is not recommended.

5.3 Mortar Joints

5.3.1 Mortar joints shall be raked out to a depth of ½" to ¾". Apply pointing mortar in layers not exceeding 3/8" 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" 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 nonstaining.

5.6.2 It is not the intent of this specification to make control or expansion-joint recommendations for a specific project. The

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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. 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 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 ($SrSO_4$).

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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". 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 MIA 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. The MIA 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

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recommended that selection be based on viewing sufficient samples to show the general range of color of the desired stone. MIA Members can provide these range samples.

8.0 PROPER USAGE TIPS

8.1 Recommendation for commercial floors:

8.1.1 Minimum ¾" thickness.

8.1.2 A honed finish.

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

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 MIA 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/ft³ (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.

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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)

4.1 Abrasion resistance is a property of stone that should be tested per ASTM C241 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) of 10 or more as measured by ASTM C241 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 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.

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INSTALLATION – GENERAL INFORMATION

1.0 INSTALLATION OF DIMENSION STONE

1.1 This chapter of the Marble Institute of America's Dimension Stone Design Manual includes general notes and references that apply to the installation of natural stone in both horizontal (walking surfaces, interior and exterior) and vertical (cladding, interior and exterior) applications. Chapter 14 references issues specific to the installation of horizontal surfaces, and chapter 15 references issues specific to the installation of vertical surfaces. This chapter should be used in conjunction with either chapter 14 or 15 to provide a complete discussion of the process if installing natural stone in a particular application.

2.0 STONE PRODUCT DEFINITIONS

2.1 Tile. A stone tile is a thin, flat piece of natural stone used as finishing material, with a thickness ranging from ¼" to $^{5}/_{8}$" (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.

2.2 Cut-to Size. Cut-to-size stone products, also referred to as "slab stock" stone products, are custom fabricated pieces of natural stone with any dimension exceeding the limits defined in the tile definition above. Fabrication of these products normally occurs in a shop setting, where each piece is custom fabricated to fit, but partial fabrication can also occur in the field at the time of installation.

2.3 Tolerances. 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.

2.4 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 which labor group is assigned the field installation of a given product.

3.0 RELATED MATERIALS

3.1 Setting Bed Mortars

3.1.1 Portland Cement Mortar (Thick Bed)

3.1.1.1 Portland cement mortar is a mixture of portland cement and sand, roughly in proportions of 1:3 for floors, and of portland cement, sand, and lime in proportions of 1:5:½ to 1:7:1 for walls.

3.1.1.2 Installation Methods. Portland cement mortar is suitable for most surfaces and ordinary types of installation. The thick bed, 3/8" to 1½" on walls and nominally 1¼" on floors, facilitates accurate slopes or planes in the finished work. There are two equivalent methods recognized for installing stone tile with a portland cement mortar bed on walls, ceilings, and floors:

3.1.1.2.1 The method (ANSI A108.1A) that requires that the stone be set on a mortar bed that is still plastic.

3.1.1.2.2 The method (ANSI A108.1B) that requires the stone to be thin set on a cured mortar bed with dry set or latex portland cement mortar or a two-part, 100% solids epoxy.

3.1.1.3 Suitable Backings. Portland cement mortars can be reinforced with metal lath or mesh, backed with membranes, and applied on metal lath over open studding on walls or on rough floors. They are structurally strong, not affected by prolonged contact with water, and can be used to plumb and square surfaces installed by others. Suitable backings, when properly prepared, are brick or concrete masonry unit, concrete, wood or steel stud frame, rough wood floors, plywood floors, foam insulation board, gypsum board, and gypsum plaster. The one coat method may be used over masonry, plaster, or other solid backing that provides firm anchorage for metal lath.

3.1.1.4 Installation and Material Specifications. Complete installation and material specifications are contained in ANSI A108.1 for installation when bed is still plastic, and for cured float bed and thin set applications.

3.1.2 Thin-Set Mortar [Thin Bed (ANSI A118.1)]

3.1.2.1 Thin-set mortar is a mixture of portland cement with sand and additives providing water retention, and is used as a bond coat for setting stone.

3.1.2.2 Installation Methods. Thin-set mortar is suitable for use over a variety of surfaces. The stone should be properly tamped in place into the mortar, which will be one layer as thin as 3/32" after tamping. Thin set mortar has excellent water and impact resistance, can be cleaned with water, is nonflammable and good for exterior work.

3.1.2.3 Thin-set mortar is available as a factory-sanded mortar to which only water need be added. Cured thin set mortar is not affected by prolonged contact with water, but does not form a water barrier. It is not intended to be used in trueing or leveling the substrate surfaces as tile is being installed.

3.1.2.4 Suitable backings. When properly prepared and in sound structural condition, suitable backings include plumb and true masonry, concrete, gypsum board, cementitious backer units, terrazzo, cured portland cement mortar beds, brick, ceramic tile, and dimension stone. Existing control joints including divider strips shall be maintained. Polished, glossy, honed, or smooth backup surfaces shall be roughened by sanding or scarifying. See ANSI A108.01 General Requirements: Subsurfaces and Preparations by Other Trades.

3.1.2.5 Installation and Material Specifications. Complete installation and material specifications are contained in ANSI A108.5 and A118.1.

3.1.3 Latex-Portland Cement Mortar [Thin Bed (ANSI A118.4)]

3.1.3.1 Latex-Portland cement mortar is a mixture of portland cement, sand, and special latex additives which is used as a bond coat for setting stone tile.

3.1.3.2 Installation Methods. The uses of latex-portland cement mortar are similar to those of thin-set mortar. It is less rigid than portland cement mortar.

3.1.3.3 When latex-portland cement mortar is used to install stone in a wet area that may not thoroughly dry out in use (e.g., swimming pools and gang showers, etc.), it is recommended that the complete installation be allowed to dry out thoroughly (cure) before exposure to water. Consult the thin-set manufacturer for curing instructions. Latexes vary considerably, and the directions of the latex Manufacturer must be followed explicitly.

3.1.3.4 Suitable backings (See 3.1.2.4 above).

3.1.3.5 Installation and Material Specifications. Complete installation

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specifications and material specifications are contained in ANSI A108.5 and ANSI A118.4.

3.1.4 Epoxy Mortar (ANSI A118.3)

3.1.4.1 This is a thin bed mortar system employing epoxy resin and epoxy hardener portions. A two- part, 100% solid epoxy is to be used as the setting bed for green colored marbles, serpentine stones susceptible to warping and for any fiberglass mesh-backed tiles.

3.1.4.2 Suitable Backings. Acceptable substrates, when properly prepared and structurally sound, include concrete, APA rated Exposure 1 underlayment grade plywood*, steel plate, and ceramic tile. Application is made in one thin layer. Pot life, adhesion, water cleanability before cure, and chemical resistance vary with manufacturer.

3.1.4.3 Installation and Material Specifications. Complete installation and material specifications are contained in ANSI A108.6 and ANSI A118.3.

3.1.5 Limestone Setting Mortar. Cement used with limestone shall be white portland cement, ASTM C150, or white masonry cement, 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 normal cement has been used in the backup material, and if an effective water barrier has not been provided between the stone and the backup, the use of nonstaining cement may not prevent all discoloration. Discoloration will 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."

3.1.6 Setting Bed. White portland cement with low alkali content is required for all light colored stone varieties.

3.2 Grouts Between Stones

3.2.1 Commercial Portland Cement Grout ("Unsanded Grout")

3.2.1.1 Commercial portland cement grout is a mixture of portland cement and other ingredients, producing a water-resistant, dense, uniformly colored material. There are two types: white and gray. Damp curing is advantageous for both wall and floor types.

3.2.2 Sand-Portland Cement Grout ("Sanded Grout")

3.2.2.1 Sand-portland cement grout is an on the job mixture of one of the following proportions: one part portland cement to one part clean, fine-graded sand (ASTM C144) used for joints up to 1/8" wide; 1:2 for joints up to ½" wide; and 1:3 for joints over ½" wide. Up to 1/5 part lime may be added. Damp curing is necessary. Sand-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.

3.2.3 Polymer Modified Portland Cement Grout (ANSI A118.7)

3.2.3.1 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

* APA- The Engineered Wood Association, Voluntary Production Standard PS 1-07 Structural Plywood.

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. It is less absorptive than regular cement grout.

3.2.4 Colored Grouts

3.2.4.1 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.

3.3 Sand. Sand should comply with ASTM C144.

3.4 Water. Mixing water must be potable quality.

3.5 Stone Sealants, Backing Rods, and Caulking

3.5.1 Building sealants are normally covered as a separate section in project specifications, and in most trade areas the installation of sealants is not in the trade jurisdiction of Marble Mechanics and Stonemasons. Grouting is almost always in the stone specification.

3.5.2 Silicone Sealants. 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.

3.5.3 Severe service areas (patios, decks, traffic surfaces) should be caulked with materials having sufficient abrasion resistance. Consult Sealant Manufacturer's technical recommendations for sealants in these areas.

3.5.4 Oil based organic sealants should not be used in conjunction with natural stone products because they may stain the stone.

3.5.5 Sealing the Face of the Stone. Nothing in this section is intended to imply that actual sealing of the faces of the stones is a recommended practice. If any sealer coating is specified for any natural stone material, advice should be sought in detail from qualified Stone Suppliers or Installers (See Ch 3, pg. 3-5, section 5.10).

3.5.6 Joint Filler. An important feature in the determination of the joint sealant is the selection of the joint filler. The joint filler, or backing rod, performs three functions:

3.5.6.1 Controls both the depth and shape of the sealant.

3.5.6.2 Provides support for the caulking sealant when it is being compressed during tooling.

3.5.6.3 Acts as a bond breaker for the sealant to prevent three sided adhesion. (Three-sided adhesion can result in failure of the sealant.)

3.5.7 Waterproof sealant is applied in joints that have backing rods inserted. The backing rods can be porous (open cell), or nonporous (closed cell), and are typically made of polyethylene or polystyrene rope.

3.5.8 Consult the Sealant, Waterproofing, and Restoration Institute guidelines for further information on proper joint sealant design, selection, and installation.

3.6 Expansion Joints

3.6.1 Design and Location. 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

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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.

3.6.2 Final Design. It is not the intent of this manual to make control and expansion joint recommendations for a specific project. The Architect must specify control and expansion joints and show location and details on drawings.

3.6.3 Sealants. Where so specified, joints shall be pointed with the sealant(s) referred to in this section, 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.

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

3.6.5 Expansion joint sealants include silicone, urethane, and polysulfide. Generally, urethane sealants are recommended for horizontal stone surfaces because of their resistance to abrasion and penetration.

3.6.6 Silicone sealants may be used in expansion joints on both exterior and interior vertical stone surfaces. Some one part, mildew-resistant silicone sealants are formulated with fungicide for sealing interior joints in showers and around tubs, sinks, and plumbing fixtures.

3.6.7 Sealants should comply with ASTM C920.

3.7 Substrate Limitations

3.7.1 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.

3.7.1.1 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.

3.7.2 Self Leveling Underlayments. Gypsum-based and self-leveling underlayments are not recommended for use with stone paving, except in conjunction with an approved water-proofing/crack isolation membrane (See ANSI A118.10-118.12). If using this method, extreme caution in following the Manufacturer's recommended procedure is required.

3.7.2.1 Installation of stone paving directly over gypsum based underlayment is not recommended.

3.8 Deflection of Surfaces

3.8.1 General Contractor Responsibility. It is the responsibility of the General Contractor to provide a rigid, code-compliant structure that is adequate to accommodate the stone and its anchorage including all associated loads and forces.

3.8.2 Cast-in-Place Concrete Floors. Design substrate for total load deflection not exceeding L/360, as measured between control or expansion joints.

3.8.3 Frame Construction. The subfloor areas over which stone tile is to be applied must be designed to have a deflection not exceeding L/720 of the span. In calculating load, the weight of the stone and setting bed must be considered.

3.8.3.1 Strongbacks, cross-bridging or other reinforcement shall be used to limit

differential deflection between adjacent framing members.

3.8.4 Maximum variation of a concrete slab or subfloor shall not exceed 1/8" in 10' from the required plane when thin set systems are applied.

3.8.5 Allowance should be made for live load and impact, as well as all dead load, including weight of stone and setting bed.

3.8.5.1 Mortar Bed Weight. For estimating purposes, mortar bed weight can be approximated as 0.75 lb per square foot per each 1/16" of thickness.

3.8.5.2 Stone Weight. For estimating purposes, stone weight can be approximated as 1 lb per square foot per each 1/16" of thickness.

4.0 SAMPLES

4.1 The Dimension Stone Contractor shall furnish samples of the various dimension stones to be used. Samples shall indicate the extremes of color, veining, and marking the stone supplied to the project will have. Samples must be approved or rejected in their entirety, without stipulation.

4.2 Pending the scope of the installation and the variability of the stone product, a full-sized mockup may be required to adequately demonstrate the range of the material's color and character.

4.3 Inspection of supplied material to evaluate compliance with approved samples shall be done at a viewing distance of not less than 6'-0" with natural lighting.

5.0 CARVING

5.1 All carving called for shall be performed by skilled workmen in strict accordance with approved full-size details or models. Architectural drawings will show approximate depth and relief of carving. Carving shall be left as it comes from the tool, unless otherwise specified.

6.0 FIELD REPAIR

6.1 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 executed satisfactorily by qualified mechanics.

6.2 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.

7.0 STONE TILE INSTALLATION REFERENCES.

The Marble Institute of America 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 Marble Institute of America publications. Contact the TCNA (www.tcnatile.com) or the Marble Institute of America's Book Store to obtain a copy of the handbook.

8.0 TRIPS AND TRAPS OCCURRING IN THE INSTALLATION OF NATURAL STONE

8.1 Stone Tiles with Fiberglass Mesh Backing. Producers frequently apply a fiber

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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.

8.2 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.) TCA Methods F116 and F142 should be used with an adhesive that is not water-based.

8.3 Travertine Voids. 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 (particularly 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.

8.4 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 be employed to verify compatibility.

8.5 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.

8.6 Down Washed Lighting. The use of down washed lighting, 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.

8.7 Reflection. 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.

8.8 Polishing Wheel Marks. Polishing wheel marks or other scratches caused during fabrication are unacceptable on honed or polished stone.

9.0 NOTES REGARDING INSTALLATION CHAPTERS

9.1 Stone Detail Symbol. The details in this manual have been drawn to represent generic stone rather than a particular type of stone, and a symbol was used that makes the stone easily identifiable.

9.2 Guidelines. While every effort has been made to produce accurate guidelines, they should be used only with the independent approval of technically qualified persons.

NOTES:

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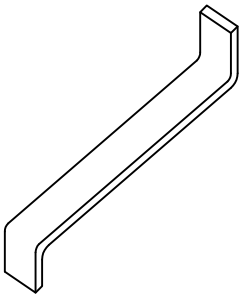

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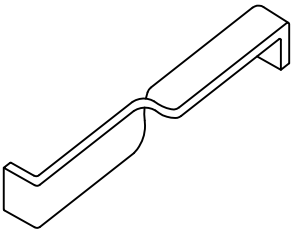

TWISTED STRAP
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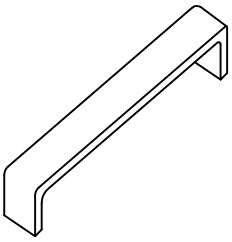

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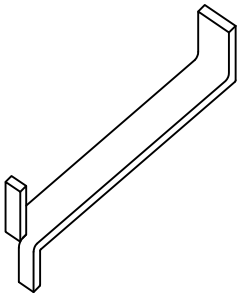

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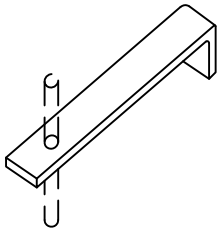
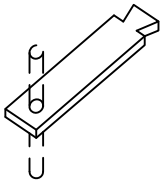


"L" STRAP
(HOLE FOR DOWEL)



DOVETAIL STRAP
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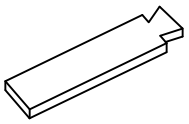

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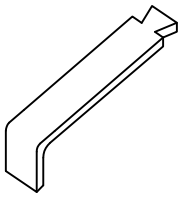

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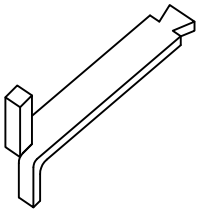

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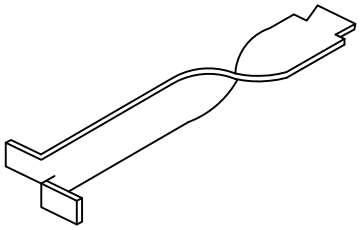

DOVETAIL TWISTED
(TWO WAY STRAP)

NOTE:
ALL ANCHORS AND ACCESSORIES
TO BE CORROSION RESISTANT METALS

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REV	DATE
0	Aug 2006
1	Oct 2006
2	Dec 2009

TYPICAL ANCHORS AND ACCESSORIES

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 13-D-1

SCALE: Not to Scale

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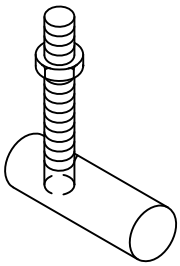
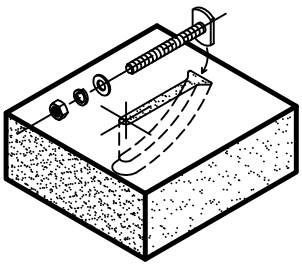
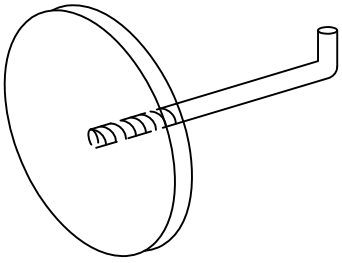


PLUG ANCHOR



T-31 BACK ANCHOR



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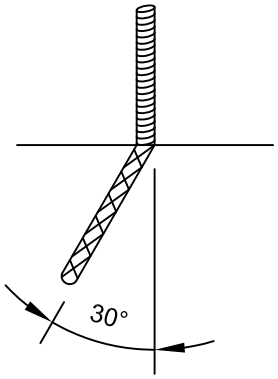
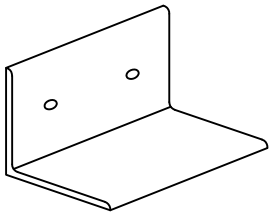
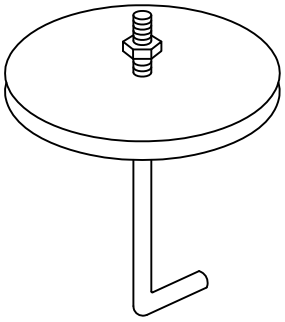


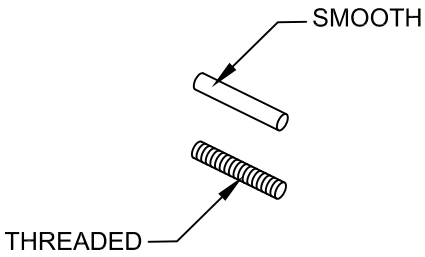
BENT ROD



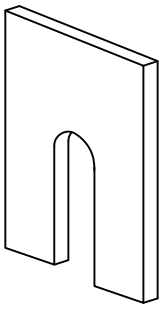
RELIEVING ANGLE-CLIP



SOFFIT HANGER



DOWELS



SHIM
(PLASTIC OR
STAINLESS STEEL)

NOTES: ALL ANCHORS AND ACCESSORIES TO BE CORROSION RESISTANT METALS.

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TYPICAL ANCHORS AND ACCESSORIES

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 13-D-2

SCALE: Not to Scale

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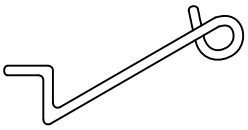
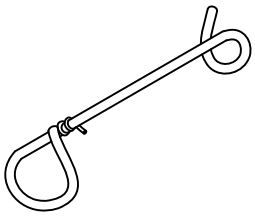
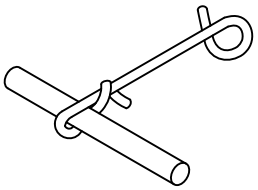


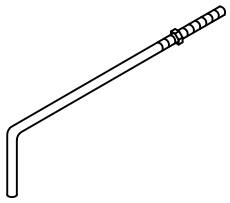
WIRE TIEBACK



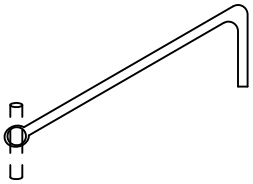
WIRE LACE
ANCHOR



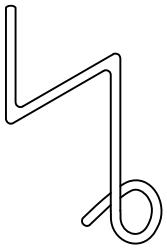
WIRE TIEBACK
(WITH DOWEL)



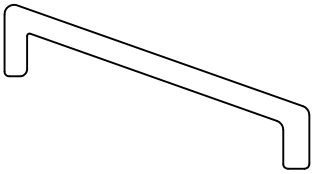
"L" BAR OR
HOOKED BOLT



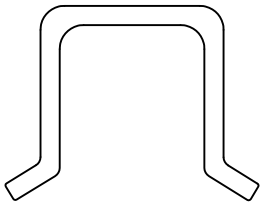
EYE ROD AND DOWEL



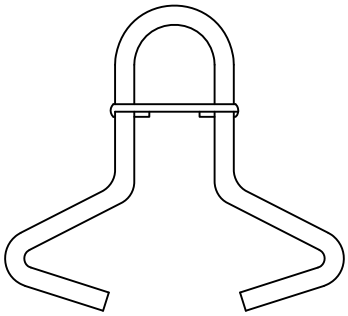
WIRE "GOOSE NECK"
ANCHOR



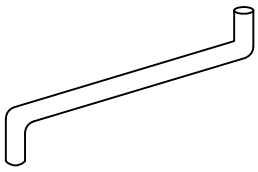
"U" CLAMP BAR



"HAIRPIN" PRECAST
ANCHOR



SPRING CLIP
(WITH COLLAR)



"Z" BAR

NOTE:
ALL ANCHORS AND ACCESSORIES
TO BE CORROSION RESISTANT METALS

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TYPICAL ANCHORS AND ACCESSORIES

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 13-D-3

SCALE: Not to Scale

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NOTES:

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HORIZONTAL SURFACES

1.0 INTRODUCTION

1.1 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.

1.2 For additional information, refer to Chapter 13, INSTALLATION - GENERAL INFORMATION.

2.0 DESIGN CRITERIA

2.1 Class of usage establishes the abrasion resistance a stone requires to withstand the foot traffic requirements of the project. This is determined according to the ASTM C241/ C 1353 test for abrasion resistance as measured by abrasive hardness (H_a). There are three classes of usage for stone flooring:

2.1.1 Light Traffic class is reserved for residential use where there is relatively little traffic and/or shoes are not always worn. Stone must have a minimum H_a of 6.0.

2.1.2 Moderate Traffic class is reserved for residential entranceways and small commercial installations. Foot traffic is less than 50 persons/minute. Stones must have a minimum H_a of 7.0

2.1.3 Heavy Traffic class is reserved for commercial installations (banks, shopping malls, train or bus stations, etc). Foot traffic is over 50 persons/minute. Minimum H_a is 10.0 for general areas, increasing to 12.0 for stairways, elevator halls, and other concentration areas. Exterior paving should always have a minimum H_a of 12.0.

2.1.4 It must be noted that 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 abrasion indices ≤ 20.0 are not suitable for most moderate and any heavy-traffic areas. Thermal finish is recommended for exterior paving.

2.1.5 Stone with high abrasion resistance (≥20.0) 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.

2.1.6 Limitations. If several varieties of stone are used together, care should be taken to ensure that the abrasive hardness (H_a) of the stones is 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 stone shall be ≤ 5.0. This can be ignored when using stones with abrasion resistances ≥20.0, since the resultant wear will be very slight.

2.2 Physical Property Values. Final design should always be based on specific property values of the stone to be used. These values may be obtained from the Stone Supplier. When reliable physical property data is not available from the supplier, re-testing of the stone should be considered.

2.3 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.

2.3.1 Reasons for hollow sounds include:

2.3.1.1 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.

2.3.1.2 Hollow sounds may be acoustical effects rather than bonding problems.

2.3.1.3 Air may be entrapped in either the setting bed or slab, causing one part of the floor to sound differently than another.

2.3.1.4 Separation or crack-isolation membranes installed between a slab and the setting bed may alter the sound report.

2.3.1.5 The elevation or composition of the subsurface may be irregular, causing one part of the floor to sound differently than another.

2.4 Width of Joints between Stones. Joints between stones should be of sufficient width to ensure that the grout being used can be placed at the bottom face of the stone and properly compacted within the joint.

2.4.1 Typical joint widths are:

2.4.1.1 Exterior Stone Pavement Installation: Minimum ¼", preferably 3/8". Joints of ½" or larger are frequently required for large unit size installation.

2.4.1.2 Interior Stone Flooring Installation: Minimum 1/16", preferably 1/8". Joints of ¼" or larger are frequently required for large unit size installation.

2.4.1.3 Joints of ½" to 1" are frequently required for installing stones with split, or "snapped" edges.

2.4.1.4 Stone units with "cleft" or other non-planar surface finishes generally require larger joints to minimize perceived lippage. Joint widths of ¾" or 1" are not uncommon in these cases.

2.4.1.5 Joints of stone with an arris or chamfer will appear wider than its actual dimension when filled.

2.4.2 IN NO CASE SHOULD NATURAL STONE BE INSTALLED WITH TIGHT JOINTS

2.4.3 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 3/8" in width, and continue through the stone assembly, all the way down to the substrate or backing (membranes may remain continuous). For joint depths greater than 3/8", backer rod is required. It is recommended that the horizontal surface go under the vertical surface.

2.4.4 Movement Joints are also required in fields of paving. Reference ANSI A108.01 section 3.7 and ANSI A108.02 section 4.4 for guidance on movement joint location.

2.4.5 Movement Joints: In addition to field and abutment to vertical surface requirements for movement joints in stone work, any expansion or construction joints in the substrate will need to carry completely through the stone installation assembly.

2.4.6 Wash and dry backs and edges of all pavers prior to installation.

3.0 MINIMUM THICKNESS

3.1 Suggested minimum thicknesses for stone walking surfaces:

3.2 Exterior Stone Pavers, Pedestrian Traffic: 1¼".

3.3 Exterior Stone Pavers, Vehicular Traffic: Is best determined by engineering analysis, but is generally 3" or thicker.

3.4 Interior Residential Stone Flooring: 3/8".

3.5 Interior Commercial Flooring, light duty: 3/8".

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3.6 Interior Commercial Flooring, Heavy Duty/High Traffic: ¾", or 1¼" pending stone variety selection.

3.7 Note: Large stone unit sizes, specific loading/traffic requirements may dictate the use of greater thicknesses than those listed above.

4.0 LIPPAGE

Tolerances for allowable lippage can be found in Chapter 22 on Tolerances.

4.1 Allowable lippage is an installation tolerance, and is additive to the inherent warpage of the stone unit.

4.2 This lippage will 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" may be required.

4.3 This degree of accuracy may not be achievable with extremely large format stone pavers, in which case larger than typical joint widths are recommended to minimize perceived lippage.

5.0 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 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 manufacturer's recommendations.

6.0 MEMBRANES

The use of membranes to improve system performance is common in the design of stone walking surface installations.

6.1 Always comply with the membrane manufacturer's written instructions regarding the applicability and installation of the membrane product.

6.2 Common types of membranes and their intended contribution to the system performance are discussed below:

6.2.1 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. Cleavage membranes can be either sheet applied or liquid applied.

6.2.2 Crack Isolation Membranes. Crack Isolation membranes are used to isolate the stone from minor in-pane cracking of the substrate surface in thin-set applications. Crack Isolation membranes can be sheet applied, trowel applied, or liquid applied and must meet ANSI A118.12.

6.2.3 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 the thin-set stone installation system.

6.2.4 Waterproof Membranes. Waterproof membranes are used to prevent the migration of liquid water. These membranes can be sheet applied, sheet metal, or liquid applied. In many cases these membranes are installed by other trades and must meet ANSI A118.10.

7.0 TECHNICAL DATA

7.1 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:

7.1.1 Granite: ASTM C615, Standard Specification for Granite Dimension Stone

7.1.2 Limestone: ASTM C568, Standard Specification for Limestone Dimension Stone

7.1.3 Marble: ASTM C503, Standard Specification for Marble Dimension Stone

7.1.3.1 Soundness Classification of "A" or "B" is recommended; although some marbles with lesser soundness can be considered if waxing, sticking, filling, cementing, and reinforcing are properly done.

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

7.1.5 Serpentine: ASTM C1526, Standard Specification for Serpentine Dimension Stone

7.1.6 Slate: ASTM C629, Standard Specification for Slate Dimension Stone

7.1.7 Soapstone: No ASTM Standard exists at this time

7.1.8 Travertine: ASTM C1527, Standard Specification for Travertine Dimension Stone

8.0 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.

During construction, the General Contractor shall protect all stone from staining and damage.

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EXTERIOR PAVING SYSTEMS

1.0 PRODUCT DESCRIPTION

1.1 Basic Use. Exterior paving for plazas, promenades, and similar applications.

1.2 Fabrication. Stone paving units are precut and prefinished to dimensions specified on shop drawings, and are delivered to the job site ready to install.

1.3 Abrasion Resistance. See Section in Introduction.

1.4 Finishes. Abrasive, natural cleft, thermal, and rough sawn finishes are recommended for exterior paving.

1.5 Colors. Any of the commercially available varieties are suitable.

1.6 Sizes. Size and thickness should be based on:

1.6.1 Flexural Strength (Ref: ASTM C880) of the stone

1.6.2 The unsupported span or anticipated deformation of the bedding system.

1.6.3 The anticipated load.

1.6.4 Standard thicknesses of 1¼", $1^5/_8$", and 2" or greater may be required.

1.7 Movement Joints. All stone paving systems shall include adequate movement joints. Refer to ANSI 108.1 and TCNA EJ 171 for movement joint location and design.

1.8 Traffic after Installation. 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.

2.0 INSTALLATION

2.1 Mortar Bed Bonded to Concrete Subsurface

2.1.1 Preparatory Work. Concrete slabs to receive bonded mortar beds, shall fulfill the following requirements:

2.1.2 Slope as required shall occur in the slab so as to maintain an even depth or thickness of the mortar bed.

2.1.3 Concrete Slab shall have a textured surface similar to a fine broom finish and shall be free of curing compounds or any other foreign materials that would inhibit an adequate bond of the mortar bed to the slab.

2.1.4 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.

2.1.5 Method. Stone paving should be installed in a full mortar bed consisting of one part portland cement and from four to five parts sand. Minimum thickness of a mortar bed is 1¼". The recommended thickness is 2". A bond coat of portland cement paste or other approved material (slurry) is recommended.

2.1.6 Joints. The joints may be pointed with suitable mortar or grout, or left entirely open to receive a resilient filler strip and approved sealant.

2.1.7 Reinforcing. Reinforcing of the mortar bed is recommended for beds of 2" depth or greater and shall be specified by the design professional. See TCNA F121 and NOTE for exterior uses.

2.2 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:

2.2.1 Cracks in the slab that may transfer through a bonded system.

2.2.2 Contamination of the slab that may be impractical to remove.

2.2.3 Capillary moisture issues exist.

2.2.4 Where cold or control joints in slab do not align with stone grid modules.

2.2.5 Where an unbondable membrane exists.

2.2.6 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 as to maintain an even thickness of the bed. Movement joint requirements will also remain the same; however, the membrane may remain continuous.

2.2.7 The mortar bed must be reinforced in any unbonded installation system as specified by the design professional.

2.3 Pedestal Supported Systems

2.3.1 Preparatory Work. Adequate slope for surface drainage must be provided in rough concrete slab. Before being installed, all stone must be clean and free of foreign matter of any kind.

2.3.2 Method. Stone slabs (pavers) shall be set on bricks, plastic pods, or mortar spots of one part portland cement and from three to five parts sand, at or near the corners with the joints left open for drainage (see illustration at the close of this section).

2.3.3 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. Paver thickness, span, flexural strength, and appropriate safety factors must be considered in the design.

2.3.4 Open Joints. The joints in this system are left open, allowing water to flow below the stone units to be collected by the drainage system.

2.3.5 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 servicing of the drainage system below.

2.4 Sand Bed Method

2.4.1 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.

2.4.2 Method. Place bedding course of sharp, normal weight limestone screening or concrete sand to a depth of approximately 1½" leveled to grade. Compact bedding course parallel to finish grade and tamp.

2.4.3 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 wood 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" thick, 12" wide, and 6' long, and tamp with an approved tamper. 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.

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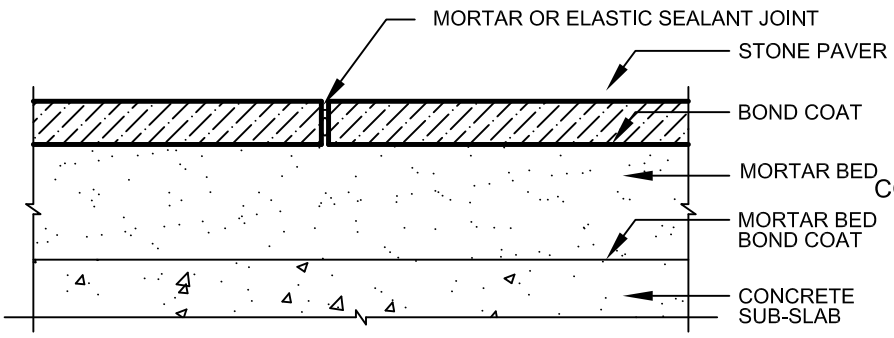
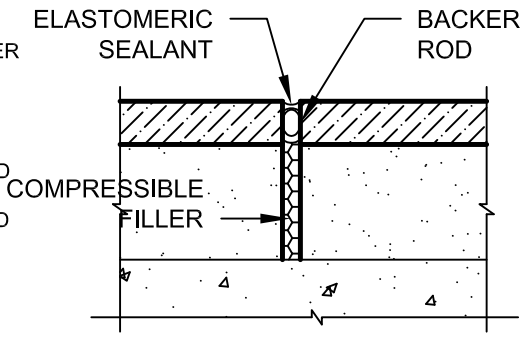
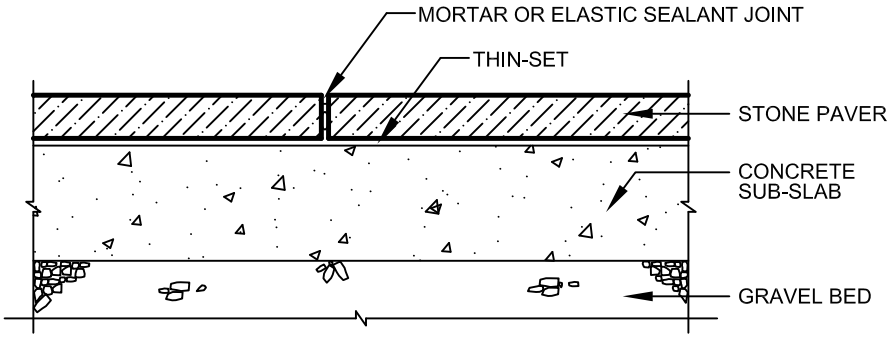


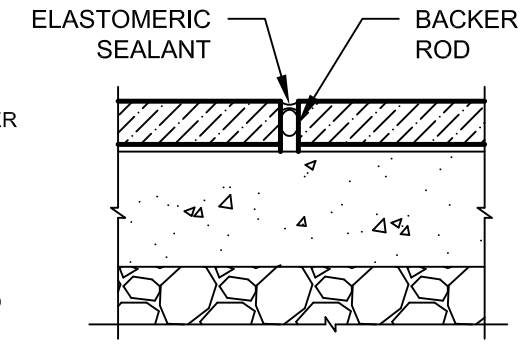
1 MORTAR BED WITH BOND COAT



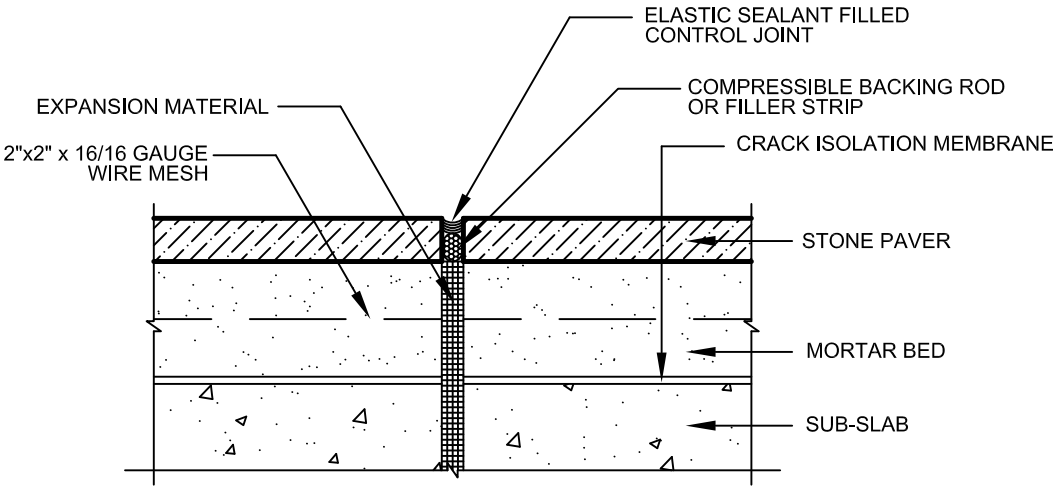
1A MOVEMENT JOINT



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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EXTERIOR STONE PAVING

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 14-D-1

SCALE: 3" = 1'-0"

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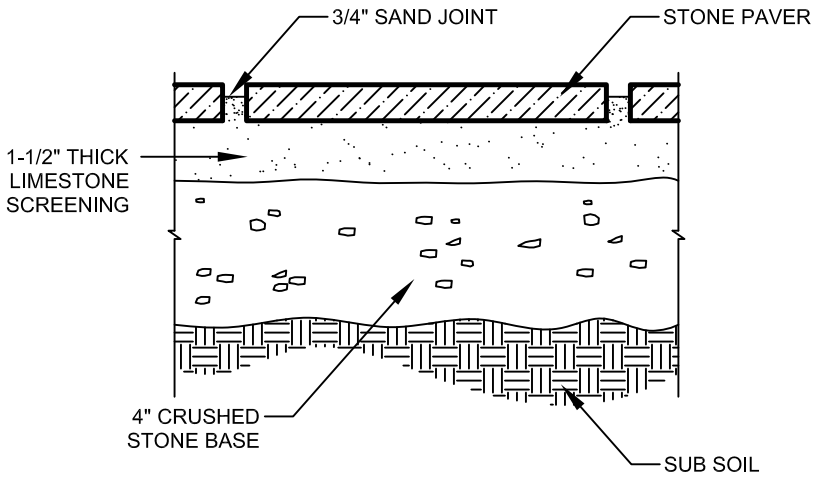
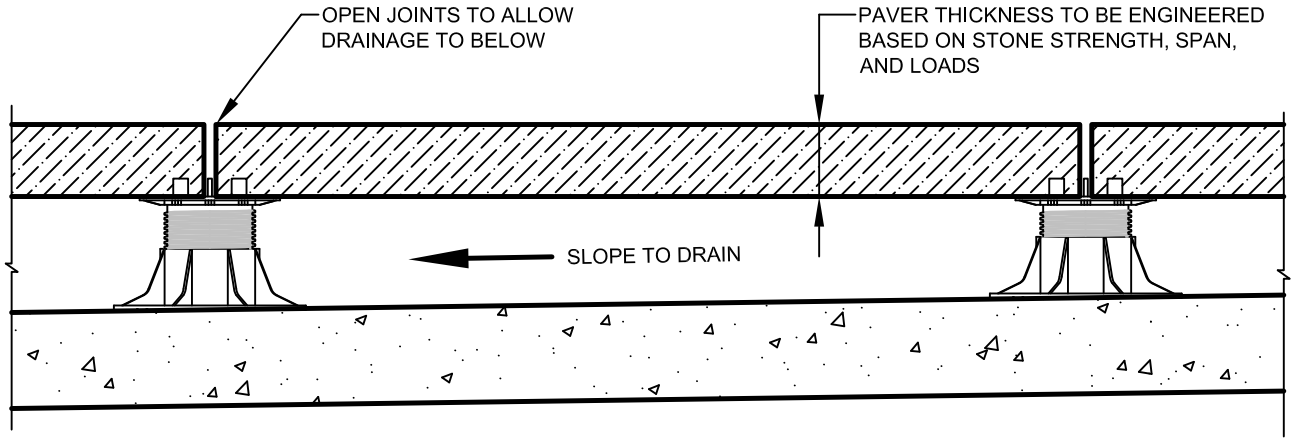


1 STONE PAVERS SET IN SAND BED

Scale: 3" = 1'-0"



2 PEDESTAL SUPPORTED STONE PAVERS

Scale: 1½" = 1'-0"

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EXTERIOR STONE PAVING

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 14-D-2

SCALE: As Noted

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INTERIOR STONE FLOORING SYSTEMS

1.0 INTRODUCTION

1.1 Installation Methods. Interior stone flooring 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 Data Sheet Installation section and illustrations of installation examples at the close of this section).

1.2 Abrasion Resistance. See Introduction Section. (Note: abrasion resistance does not measure values for coefficient of friction or slip resistance.)

2.0 RELATED COMPONENTS

2.1 TCNA Details. Because natural stone tiles can be installed in certain thin-bed setting systems in the same manner as ceramic tiles, the current "Handbook for Ceramic Tile Installation" by the Tile Council of North America may be referred to for details. A list of details from this manual endorsed by the MIA is included in Chapter 13 of this manual.

2.2 Stone Abuts Softer Floor Material. Where stone abuts softer flooring materials, a stone threshold or metal edge protection strip may be used. This will help prevent edge chipping caused by impact.

2.3 Grout. Sanded or unsanded grout, or nonstaining sealant, can be used as joint filler. If sanded grout is used, mask the face of the stone tile before filling the joints to avoid scratching of the stone surface.

2.4 Stones Sensitive to Moisture and Alkalinity. Stone suppliers shall identify stones that are adversely affected by moisture and alkalinity.

2.5 Setting Bed. White Portland cement with low alkali content is recommended for light colored stone.

2.6 Bond Mortar. White bond mortar is recommended for light colored stone.

2.7 Hollow Sound. Refer to the section in introduction portion of this chapter.

2.8 Traffic after Installation. After the stone flooring 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 flooring surfaces for at least two weeks after the floor has been grouted.

2.9 Sealing. Reference Maintenance and Restoration Section of the DSDM for MIA position on sealers.

2.10 For additional information, refer to Chapter 13, INSTALLATION - GENERAL INFORMATION.

2.11 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.

3.0 PRODUCT DESCRIPTION

3.1 Basic Use. As interior flooring for commercial, institutional, and residential use.

3.2 Abrasive Hardness. Reference Introduction Section

3.3 Fabrication. Stone flooring units are precut and prefinished to dimensions specified on shop drawings, and delivered to the job site

ready to install. Alternatively, stone flooring units may be field cut or field modified at the installation site.

3.4 Finishes. Polished, honed, abrasive, thermal, sanded, and natural cleft.

3.5 Colors. Most of the commercially available varieties are suitable.

4.0 INSTALLATION METHODS

Interior stone flooring is installed by one of the following methods.

4.1 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]).

4.1.1 Concrete to receive bonded mortar beds or direct bond of stone shall fulfill the following requirements:

4.1.1.1 Slope if required, shall occur in the concrete substrate so as to maintain an even depth or thickness of the mortar bed and/or bond mortar.

4.1.1.2 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 an adequate bond of the mortar bed or bond mortar to the concrete.

4.1.1.3 Undersides and edges of concrete slabs on grade shall have a suitable vapor barrier so as to prevent moisture intrusion into concrete.

4.1.1.4 Concrete that requires 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 is completed.

4.1.2 Limits of moisture vapor transmission shall be established by the stone supplier. Testing and certification of compliance is the responsibility of the specifying authority.

4.1.3 Wash and dry backs and edges of pavers or tiles prior to installation.

4.1.4 A mortar bed consisting of one part portland cement to five parts sand is laid over the concrete subfloor to a nominal thickness of 1¼". Stone buttered uniformly with a cement paste bond coat are 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).

4.2 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:

4.2.1 Cracks in the slab that may transfer through a bonded system.

4.2.2 Contamination of the slab that may be impractical to remove.

4.2.3 Capillary moisture issues exist.

4.2.4 Where cold or control joints in slab do not align with stone grid modules.

4.2.5 Where an unbondable membrane exists.

4.2.6 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. 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

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the same; however, the membrane may remain continuous.

4.3 Mortar Bed Separated From Wood Subfloor. This method is used where subfloor is subject to movement and deflection.

4.3.1 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 four to five parts sand 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. (See Detail D-3 at the close of this section).

4.4 Thin Bed Over Plywood Subfloor

4.4.1 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 1/8" in 10'-0", and a deflection not exceeding L/720. 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 in^2 and no voids within 2" of tile corners on 3/8" tile. Back butter the stone tiles to ensure 80% contact with no voids exceeding 4 in^2 and no voids within 2" of tile corners on ¾" or thicker material. All corners and edges of stone tiles must be fully supported and contact shall always be 95% in water-susceptible conditions. Joints are later grouted with a portland cement based grout or other approved material.

4.5 Thin-Bed Portland Cement Mortar Over Concrete Substrate

4.5.1 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". Mortar bed is laid using a notched trowel over subfloor to a thickness of not greater than 3/32". 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 to ensure 95% contact with no voids exceeding 2 in^2 and no voids within 2" of tile corners on 3/8" tile. Back butter the stone tiles to ensure 80% contact with no voids exceeding 4 in^2 and no voids within 2" of tile corners on ¾" or thicker material. All corners and edges of stone tiles must always be fully supported and contact shall always be 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).

4.6 Thin-Bed Mortar Over Cementitious Backer Units

4.6.1 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", and 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 95% contact with no voids exceeding 2 in² and no voids within 2" of tile corners on 3/8" tile. Back butter the stone tiles to ensure 80% contact with no voids exceeding 4 in² and no voids within 2" of tile corners on ¾" or thicker material. All corners and edges of stone tiles must be fully supported and contact shall always be 95% in water-susceptible conditions. Joints are later grouted with a portland cement based grout or other approved material.

5.0 HEATED FLOOR SYSTEMS

5.1 In frame construction, the plywood portion of the substrate must be a minimum of 1½" exterior glue plywood. Leave a gap between the plywood sheets for expansion. Install a cleavage membrane over the plywood.

5.2 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" over the top of heating pipes, with a minimum bed thickness of 2½". 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. Follow applicable Data Sheet Installation methods listed previously, but first install a crack-suppression or uncloupling membrane according to Manufacturer's recommendation.

6.0 PLYWOOD SUBFLOORS

5.3 Refer to APA form No. E30 for plywood installation methods.

5.3.1 Plywood subfloors, including tongue-and-groove plywood, must be installed with a gap between the sheets to allow for expansion. Stagger all seams. 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.

5.3.2 Plywood shall be APA underlayment, C-C plugged or plugged crossband grade.

5.3.3 Inner surfaces must be clean. Remove all sawdust and dirt before applying adhesive.

5.3.4 Use a construction adhesive, applying a 1/8" bead at 2" intervals. Apply adhesive in accordance with manufacturer's written directions.

5.3.5 Allow adhesive to cure per manufacturer's recommendations before beginning stone installation.

5.3.6 Place screws 6" on center in both directions.

5.3.7 Align strength axis of both subfloor and underlayment layers.

5.3.8 Always apply a double layer subfloor/underlayment, regardless of joist spacing.

5.3.9 Always use a crack suppression membrane in frame construction.

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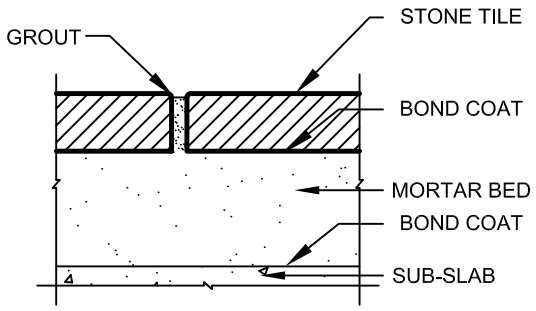
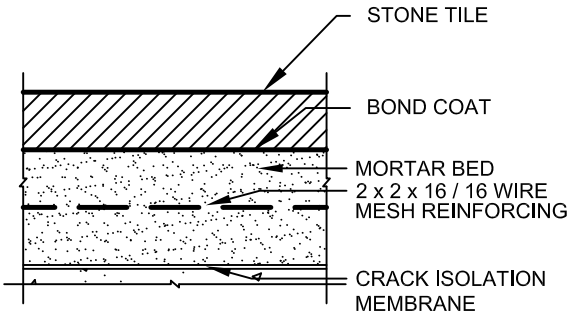
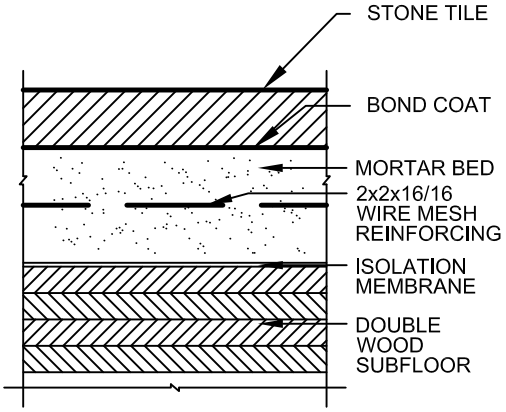


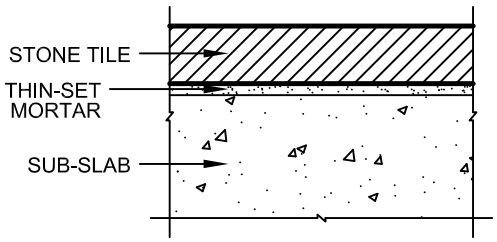
1 STONE TILE SET IN MORTAR BED



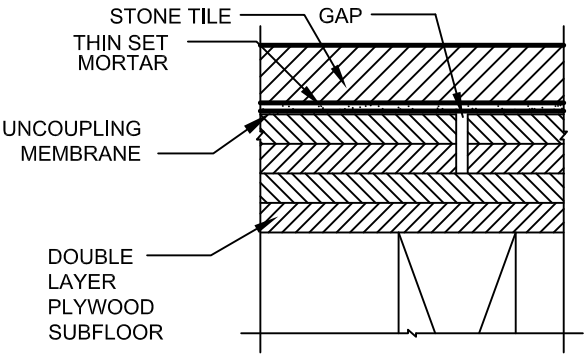
2 STONE TILE SET IN REINFORCED MORTAR BED



3 STONE TILE SET IN REINFORCED MORTAR BED OVER WOOD FRAME



4 STONE TILE SET IN THIN-SET BED OVER CONCRETE SLAB



5 STONE TILE SET IN THIN-SET BED WITH UNCOUPLING MEMBRANE OVER WOOD FRAME

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INTERIOR STONE FLOORING

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 14-D-3

SCALE: 3" = 1'-0"

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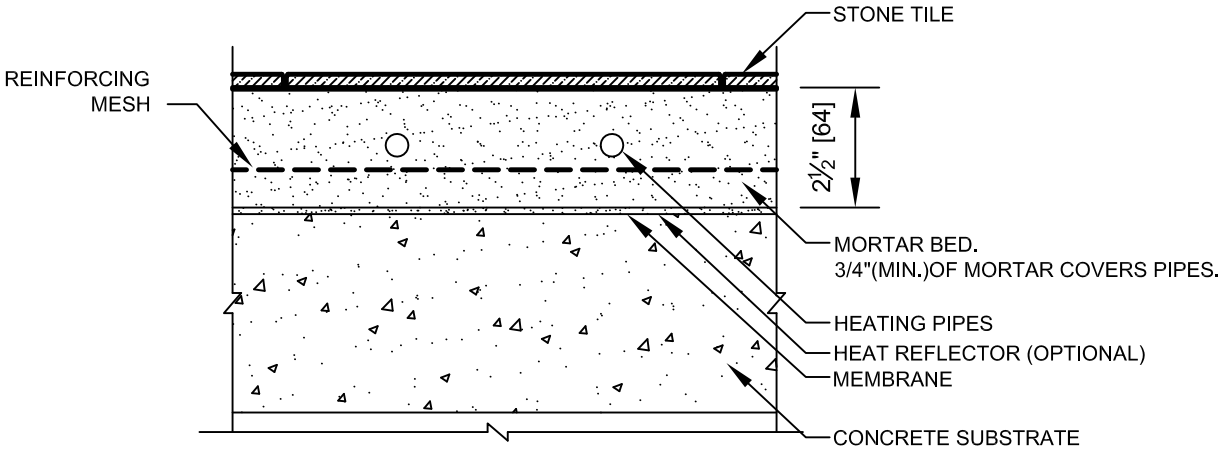
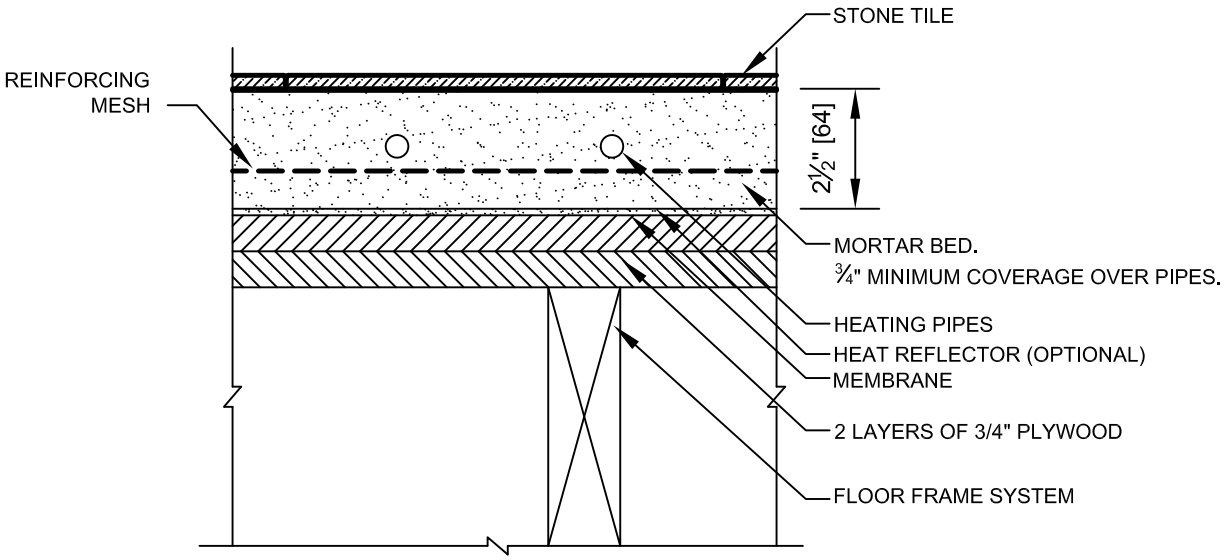


1 STONE TILE OVER HYDRONIC RADIANT HEAT SYSTEM WITH CONCRETE SUBSTRATE



2 STONE TILE OVER HYDRONIC RADIANT HEAT SYSTEM WITH WOOD FRAME SUBSTRATE

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INTERIOR STONE PAVING RADIANT HEAT DETAILS

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 14-D-4

SCALE: 3" = 1'-0"

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HORIZONTAL SURFACES – STONE THRESHOLDS

1.0 INTRODUCTION

1.1 Installation Methods. Stone thresholds 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 Data Sheet Installation section and illustrations of installation examples at the close of this section).

2.0 DESIGN CRITERIA

2.1 Thresholds. By acting as a transitional piece between two different finished floor levels, thresholds permit the use of the conventional, thick-bed mortar method in rooms where it would not otherwise be possible. They also can be used with thin-set methods.

2.2 Abrasive Hardness. Care should be taken to ensure the abrasive hardness (H_a) of the varieties selected is a minimum of 12.0 as measured by ASTM C241. These values may be obtained from the Stone Supplier.

2.3 Stone Abuts Softer Floor Material. Where stone abuts softer flooring materials, stone thresholds or metal edge protection profiles may be used. This will help prevent chipping caused by impact.

2.4 Traffic after Installation. After the stone thresholds have been installed, the General Contractor must keep all traffic off the thresholds for at least 48 hours. No heavy traffic should be permitted on newly installed stone flooring surfaces for at least two weeks.

2.5 White portland cement is recommended as a setting bed for light-colored granite and marble. White portland cement with a low alkali content is recommended for limestone.

2.6 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.

2.7 For additional information, refer to Chapter 13, INSTALLATION - GENERAL INFORMATION.

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.

3.0 PRODUCT DESCRIPTION

3.1 Basic Use. Floor structural element that lies below a door or other entranceway.

3.2 Limitations. Only varieties having a minimum abrasive hardness (H_a) of 12.0, as measured by ASTM C241, are recommended.

3.3 Fabrication. Stone thresholds are precut and prefinished to dimensions specified on shop drawings, and delivered to the job site ready to install.

3.4 Finishes. Polished and honed.

3.5 Colors. Most of the commercially available varieties are suitable.

3.6 Sizes. Thicknesses of ½", ¾", and 1¼", or as specified.

4.0 TECHNICAL DATA

4.1 Each stone variety used for thresholds should conform to the applicable ASTM standard specification and the physical requirements contained therein. The specification for each stone type follows:

4.1.1 Granite: ASTM C615, Standard Specification for Granite Dimension Stone

4.1.2 Limestone: ASTM C568, Standard Specification for Limestone Dimension Stone

4.1.3 Marble: ASTM C503, Standard Specification for Marble Dimension Stone

4.1.4 Quartz-based Stone: ASTM C616, Standard Specification for Quartz-based Dimension Stone

4.1.5 Slate: ASTM C629, Standard Specification for Slate Dimension Stone

4.1.6 Serpentine: ASTM C1526, Standard Specification for Serpentine Dimension Stone

4.1.7 Soapstone: No ASTM Standard exists at this time

4.1.8 Travertine: ASTM C1527, Standard Specification for Travertine Dimension Stone

5.0 INSTALLATION

5.1 Methods. Stone thresholds may be installed using a cement mortar bed, epoxy mortar, or any of the thin-set mortar methods. (See detail illustrations at the close of this section).

5.2 100% coverage of mortar bed material between threshold and subfloor is recommended.

5.3 General Precaution. During construction, the General Contractor shall protect all stone from staining or damage.

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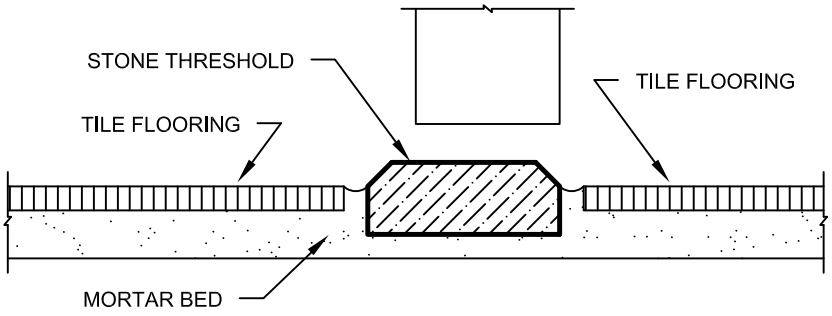
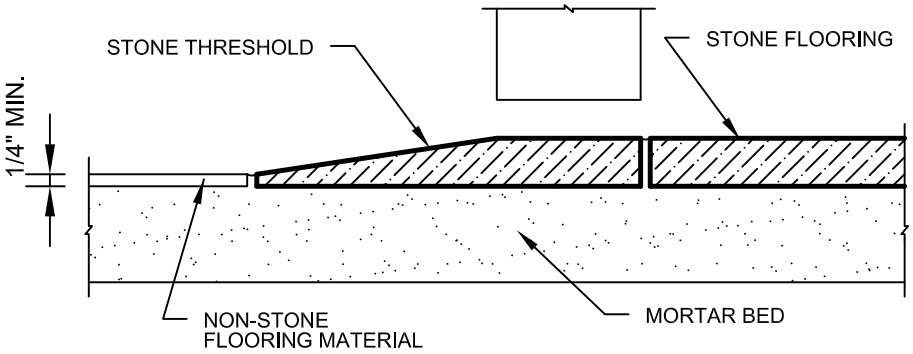
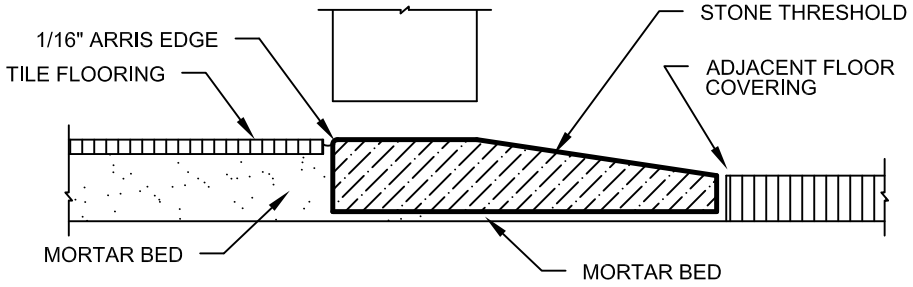


1 MEDIUM BED MORTAR METHOD



2 FULL MORTAR BED METHOD



3 THIN-SET METHOD

NOTE: USE 100% COVERAGE OF BOND COAT MATERIAL BETWEEN THRESHOLD AND SUB-SLAB.

NOTE: Minimum Abrasive Hardness Of Threshold Material Should Be 12.0 (ASTM C241).

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STONE THRESHOLDS

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 14-D-5

SCALE: 6" = 1'-0"

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NOTES:

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HORIZONTAL SURFACES – STONE STAIR TREADS

1.0 INTRODUCTION

1.1 Installation Methods. Stone stair treads can be installed by several methods, each dependent upon the design detail. Consideration should be given to the various features of each method in making a selection for a specific installation. (See Data Sheet Installation section and illustrations of installation examples at the close of this section).

2.0 DESIGN CRITERIA

2.1 Final design should always be based on physical properties of the stone to be used. If the open-tread detail is planned utilizing the stone tread as a structural member spanning the stringers, the thickness should be developed by an Engineer based on the strength properties furnished by the Stone Supplier.

2.2 Slip Resistance. Slip resistant strips or filled grooves are recommended in heavy-traffic areas. These can be specified as shop fabricated or field installed per applicable code or building requirements.

2.3 Deflection. The backup for stone steps must be of limited (<L/720) deflection for installation of thin (1¼" or less) treads. If there is greater deflection, the thickness of the tread is determined by calculating the load and ensuring that the flexural strength (ASTM C880) of the stone is sufficient to resist the load, including a safety factor. In any event, the minimum recommended thickness is 1¼" for treads and ¾" for risers.

2.4 Traffic after Installation. After the stone treads have been installed, the General Contractor must keep all traffic off the treads for at least 48 hours. No heavy traffic should be permitted on newly installed treads for at least two weeks.

2.5 Thin stone (½" and under) 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" plywood installed in opposite directions with 1/8" gaps between sheets. These types of applications will not withstand high impact or wheel loads. No overhang is permitted when stones of this thickness are used.

2.6 White portland cement is recommended as a setting bed for light-colored granite and marble. White portland cement with a low alkali content is recommended for limestone.

2.7 For additional information, refer to Chapter 13, INSTALLATION - GENERAL INFORMATION.

2.8 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, local building codes should be consulted for compliance.

3.0 PRODUCT DESCRIPTION

3.1 Basic Use. Horizontal top part of a step in a staircase.

3.2 Limitations. Only varieties having a minimum abrasive hardness (H_a) of 12.0 or more, as measured by ASTM C241, are recommended.

3.3 Finishes. Honed, polished, abrasive, thermal, and natural cleft for interior uses; rough, textured, abrasive, thermal, honed, and natural cleft for exterior uses.

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3.4 Colors. Most of the commercially available varieties.

3.5 Sizes. Tread thicknesses of ¾", 1¼", and 1½" for interior uses. Thicknesses of 1½", 2" and cubic (greater than 2") for exterior. Risers may be ¾" or 1¼" thick.

4.0 TECHNICAL DATA

4.1 Each stone variety used for stone stair treads should conform to the applicable ASTM standard specification and the physical requirements contained therein. The specification for each stone type follows:

4.1.1 Granite: ASTM C615, Standard Specification for Granite Dimension Stone

4.1.2 Limestone: ASTM C568, Standard Specification for Limestone Dimension Stone

4.1.3 Marble: ASTM C503, Standard Specification for Marble Dimension Stone (Exterior)

4.1.4 Quartz-based Stone: ASTM C616, Standard Specification for Quartz-based Dimension Stone

4.1.5 Slate: ASTM C629, Standard Specification for Slate Dimension Stone

4.1.6 Serpentine: ASTM C1526, Standard Specification for Serpentine Dimension Stone

4.1.7 Soapstone: No ASTM Standard exists at this time

4.1.8 Travertine: ASTM C1527, Standard Specification for Travertine Dimension Stone

5.0 INSTALLATION

5.1 Methods. Stone stair treads may be installed in a cement mortar bed, or in a thin-set cement mortar bed, over a subtread, or supported by stringers. (See detail illustrations at the close of this section).

5.1.1 100% coverage of mortar bed material between tread and subtread is desirable.

5.1.2 Risers ¾" or thicker must be anchored with wire or stainless steel strap anchors. If risers thinner than ¾" are used, they may be installed using the thin-bed portland cement mortar method.

5.2 General Precaution. During construction, the General Contractor shall protect all stone from staining or damage.

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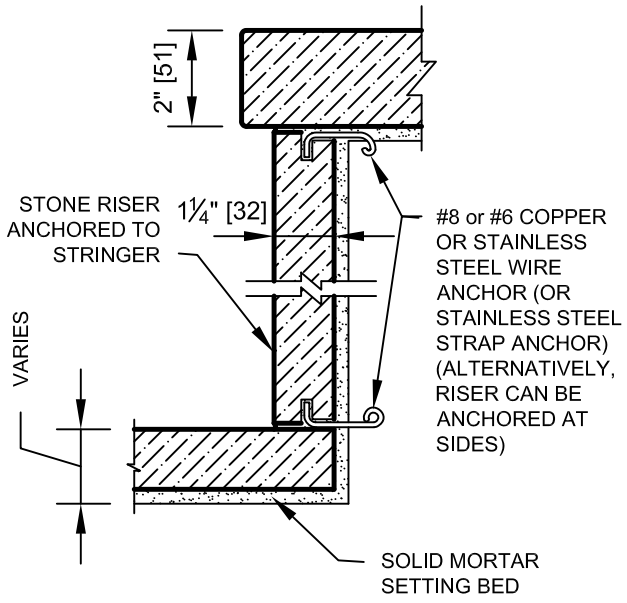
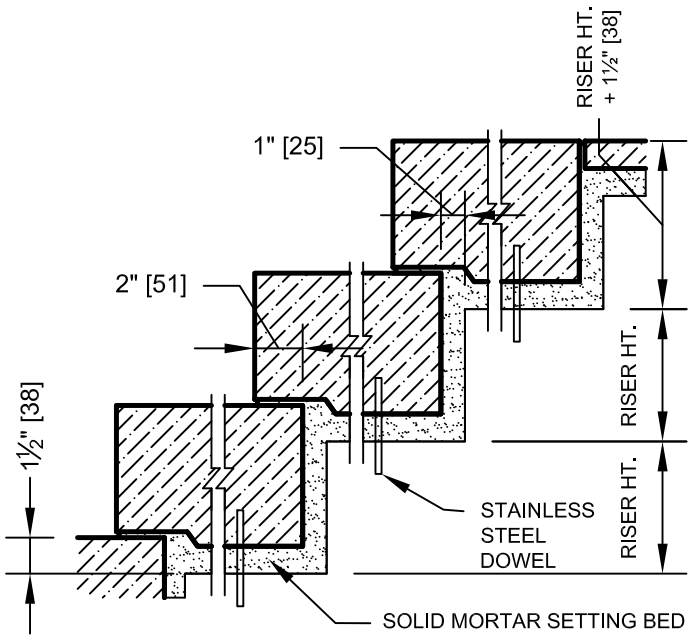


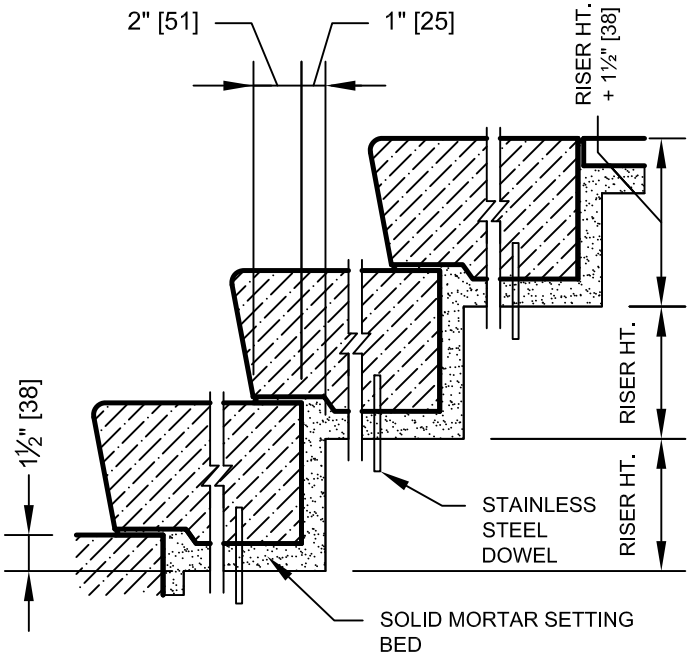
1 VENEERED STEP DETAIL

SCALE: 3" = 1'-0" (1:4)



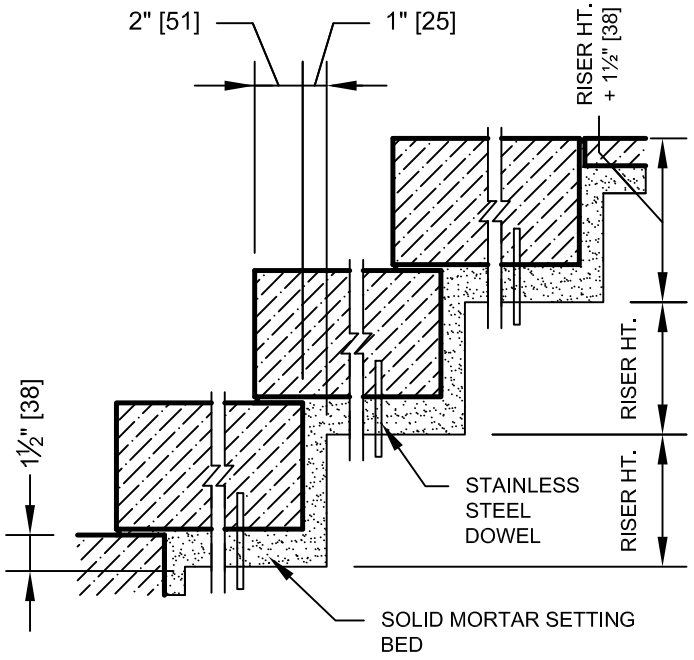
2 CUBIC STEP DETAIL

SCALE: 1½" = 1'-0" (1:8)



3 CUBIC STEP DETAIL

SCALE: 1½" = 1'-0" (1:8)



4 CUBIC STEP DETAIL

SCALE: 1½" = 1'-0" (1:8)

NOTES: *1. A ROUGH OR TEXTURED FINISH IS RECOMMENDED FOR EXTERIOR USAGE.*
2. MINIMUM ABRASION RESISTANCE OF 12.0 (TESTED PER ASTM C 241) IS RECOMMENDED FOR STONE TREADS.

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STONE STAIR TREAD DETAILS

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 14-D-6

SCALE: As Noted

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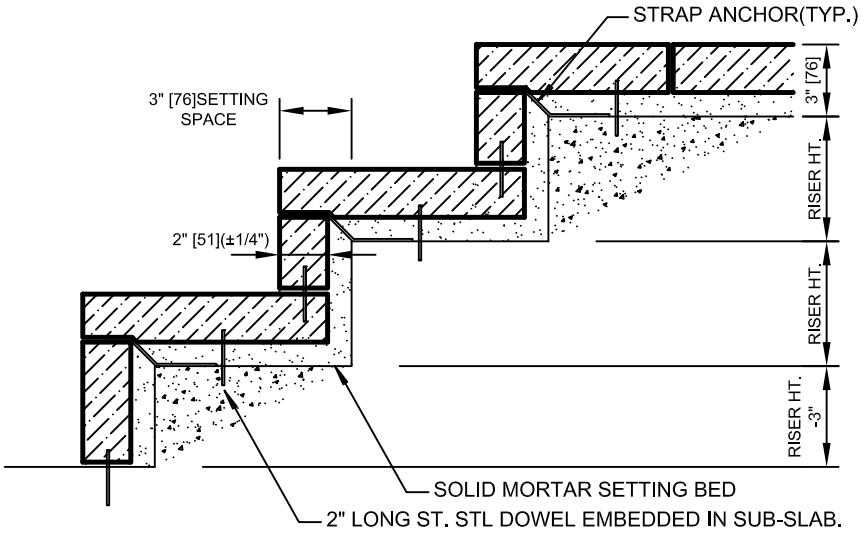
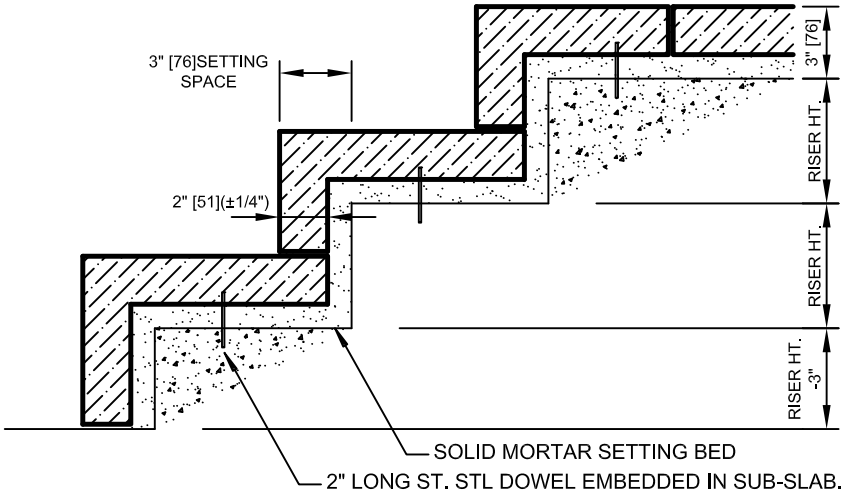


5 VENEERED STEP DETAIL



6 HOOKED STEP DETAIL

NOTE: 1. A ROUGH OR TEXTURED FINISH IS RECOMMENDED FOR EXTERIOR USAGE.
2. MINIMUM ABRASIVE HARDNESS OF 12.0 IS RECOMMENDED FOR STONE TREADS(ASTM C241).
3. FABRICATION LABOR REQUIREMENTS COMMONLY MAKE DETAIL 6 A HIGHER COST ALTERNATIVE.

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STONE STAIR TREADS

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DRWG NO: 14-D-7

SCALE: 1½" = 1'-0"

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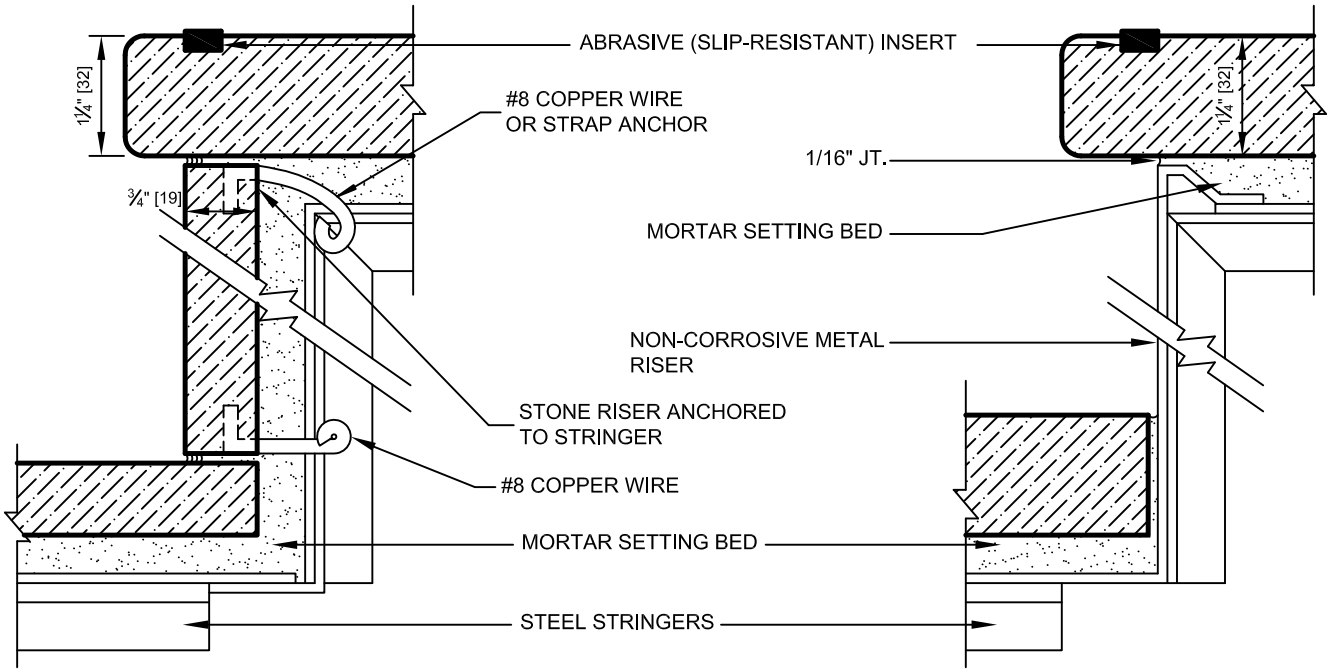
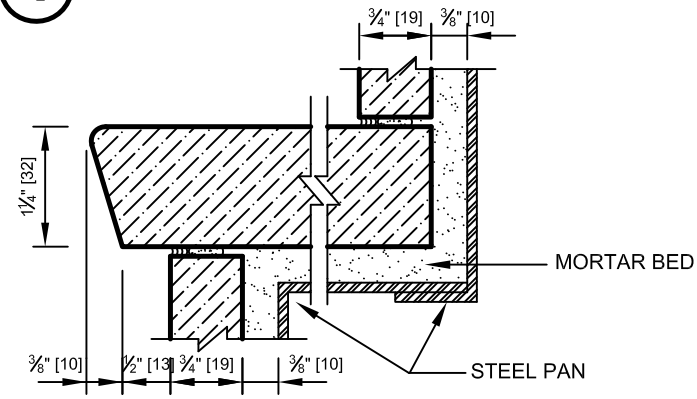
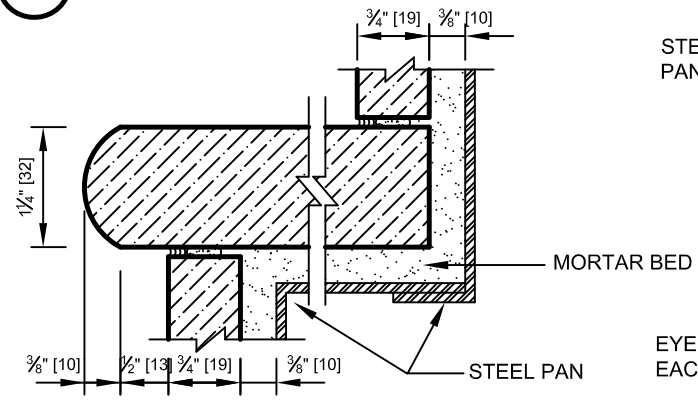


1 STEP DETAIL ON METAL PAN

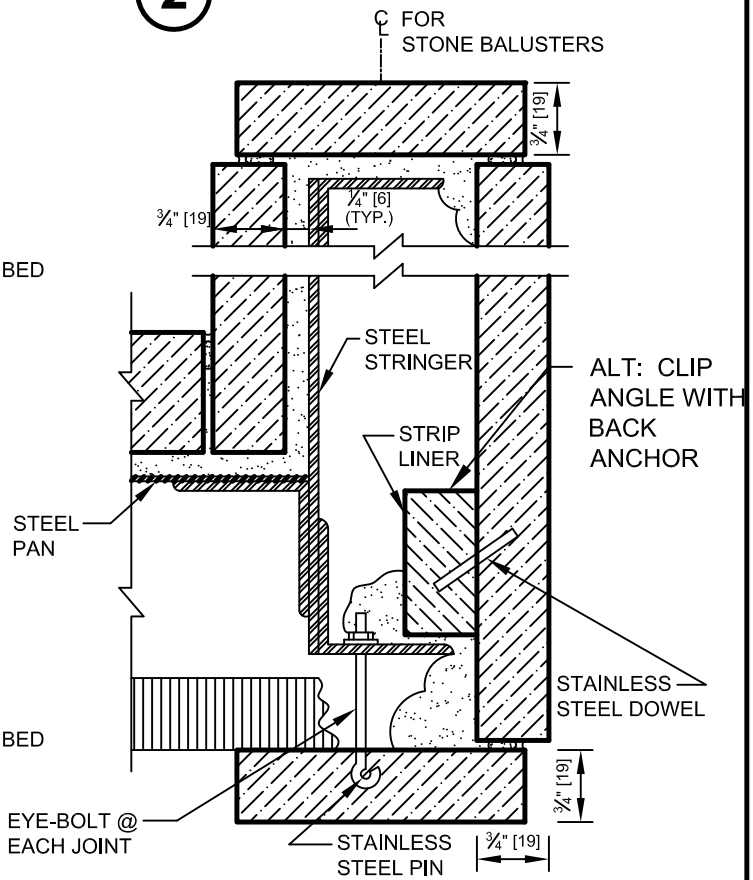
2 STEP DETAIL ON METAL PAN



3 STEP DETAIL ON METAL PAN



4 STEP DETAIL ON METAL PAN



5 STEP DETAIL ON METAL PAN

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STONE STAIR TREADS/TYPICAL DETAILS /INTERIOR TREADS

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 14-D-8

SCALE: 6" = 1'-0"

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NOTES:

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VERTICAL SURFACES - INSTALLATION NOTES

1.0 VERTICAL SURFACES 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:

1.1 Independently Supported Veneer

1.1.1 Each stone panel is independently supported (relieved and restrained) by mechanical anchorage attached to the back up wall substrate (building structure, masonry backup, stud framing assembly, miscellaneous steel and etc.).

1.1.2 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 back up 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 compressive and tensile capacities adequate to meet the performance requirements for the project. A minimum joint width of 3/8" 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.

1.2 "Stacked" Veneer With Relieving Supports

1.2.1 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.

1.2.2 Each stone panel is restrained by mechanical anchorage attached to the back up wall substrate (building structure, masonry backup, stud framing assembly, miscellaneous steel, and 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 back up wall substrate through the stone anchorage. Relieving supports (i.e., 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'). 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.

1.2.3 Consideration of weeps and flashing is recommended when continuous relief angles are utilized.

1.3 Adhered Installation

1.3.1 Thin Stone. Adhered installation is to be used for thin stone only (¼" to ½" thickness) of heights not exceeding 15'-0" (4.5 m).

1.3.2 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

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square foot (73 kg/m^2) unless approved by the local governing officials and the engineer of record.

1.3.3 Thin-Set Mortar [Thin Bed (ANSI A118.1)]. See Chapter 13, section 3.1.2.

1.3.4 Latex-Portland Cement Mortar [Thin Bed (ANSI A118.4)]. See Chapter 13, section 3.1.3.

1.3.5 Epoxy Mortar (ANSI A118.3). See Chapter 13, section 3.1.4.

1.3.6 Limestone Setting Mortar. See Chapter 13, section 3.1.5.

1.3.7 Setting Bed. White portland cement with low alkali content is required for all light colored stone varieties.

1.3.8 Petroleum-based organic adhesives should be avoided because they may stain the stone.

1.3.9 Recommended substrate materials are masonry and cementitious backer board.

1.3.10 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.

1.3.11 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.

1.3.12 Substrates to receive adhered veneer using thin-set adhesive methods shall be held to a tolerance of 1/8" variation in 10'-0".

1.4 Other systems include a variety of prefabricated and proprietary systems commonly known as:

1.4.1 "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.

1.4.2 "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.

1.4.3 Integrated Stone Curtain Wall. Stone veneer installed in glazing channels of glazed curtain wall members, in similar manner to metal spandrel panels or stone veneer installed in structurally glazed curtain walls, in a similar manner to glass.

1.4.4 Panelized dimension stone cladding, which may include independently supported veneer, "stacked" veneer with relieving supports, adhered veneer, or a combination of these methods. This is also known as a truss system.

1.5 Consideration should be given to the various features of each system in making a selection for a specific installation. See detailed illustrations of examples at the close of this section.

1.6 Venting of Exterior Stone Veneers

1.6.1 Existing Methods. The existing methods of installing exterior thin stone veneer

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have evolved through the years. For the most part, the standards were developed when the joints were filled with portland cement mortar and the building interiors were not temperature- and humidity-controlled.

1.6.2 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 interior 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. The back face of the stone should not be sealed.

1.6.3 Veneer Cavities. Solid grouting of stone veneer cavities that would permit passage of moisture through the wall from exterior to interior, and interior to exterior, is inadvisable. Windblown rain would be forced through the wall, and water vapor would move from exterior to interior and reverse, forced by the temperature and humidity differentials from outside to inside.

1.7 Relieving Supports

1.7.1.1 Relieving angles should be provided over all openings and at each story height (or maximum vertical spacing of 20'). Angles should have ¼" weep holes every 2'. When stone liners are used, they are fastened by stainless steel dowels and epoxy to the back of the finished stone facing and are supported on these angles. Refer to local codes for variance.

2.0 RELATED COMPONENTS

2.1 Mechanical Anchors, Exterior and Interior

2.1.1 Anchor Size. Anchor sizing is dependent upon materials, codes, and physical conditions of the structure. Anchors should be engineered separately for each.

2.1.2 Anchor Placement. Under typical conditions, standard practice provides for a minimum of 4 anchors per piece of stone up to 12 sq ft of surface area, and 2 anchors for each additional 8 sq ft. Weight, size, shape, and type of stone may dictate deviations from the foregoing. 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.

2.1.3 Anchor Types. Anchors shall be of non-staining, corrosion resistant metals. Stainless steel, aluminum, bronze, and brass wire and straps, and copper wire are preferred for their corrosion resistance. (See illustrations of typical anchors and accessories at the close of this chapter). In exterior cladding systems, stainless steel (series 304) is the most common. Copper is commonly limited to interior applications.

2.1.3.1 Copper Wire Tie Anchorage is a historically effective method of anchoring stone panels, but is to be used within the following limitations:

2.1.3.1.1 Wire anchors are not generally recommended for installations exceeding 15'-0" vertically.

2.1.3.1.2 Stainless steel wire is recommended in lieu of copper wire for exterior or wet area interior applications. "Spot" material used in conjunction with wire anchors in exterior or wet areas shall be of a portland cement based compound. Setting plaster, moulding plaster, or other gypsum based products are not adequate products for this purpose.

2.1.3.1.3 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 embitterment 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.

2.1.4 Thin Stone. Natural stone in thicknesses of less than ¾" (20 mm) are not usually capable of receiving mechanical anchors and can only be used with adhesive attachment.

2.1.5 Technical Information. Every construction condition requires engineering based on specific factors for each project–panel weight, wind and seismic loads, backup material, stone compressive and flexural properties, etc. The most stringent building code always takes precedence. Contact the engineer or manufacturer of each anchoring system for its particular technical information and engineering formulas.

2.1.5.1 Grout. When using adhesion installation methods, grout joints shall be a minimum of ¼" wide. Apply grout to full depth of stone. Avoid use of "designer grouts" on exterior or in wet areas, as these grouts tend to be soft and very absorbent.

2.1.5.1.1 Limestone and Light-Colored Stones. Wherever limestone, or white and light-colored marble or granite are to be installed, it is important to use only white portland cement, white thin-set mortar, or white-colored adhesive to adhere the stone to the backup, or for setting anchors. It is normal for the setting spots to darken the stone at the face. The dark coloring should disappear as the setting material cures and excess moisture is ventilated from the cavity. (This process has been known to take up to 8 months). Prior to installing any stone the Setter is not experienced with, the setting material should always be applied to a test scrap stone and allowed to cure thoroughly to make sure that the stone will not be permanently stained.

2.2 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.

2.2.1 Where permanent setting pads are required, 90 durometer neoprene or high-impact plastic is recommended.

2.2.2 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.

2.3 Sealant: Silicone-based building sealants that remain flexible with a modulus capable of accommodating anticipated inter-panel movements are recommended for vertical work. Verify the sealant is non-staining to the specified stone material.

2.4 Metal Studs. Metal studs placed behind stone wall installations to hold the wall should be 16 gauge or heavier.

2.4.1 Lateral channels are frequently required to facilitate attachment locations and also to distribute loads over multiple studs.

2.4.2 Where studs exceed 8'-0" in height, it may be necessary to relieve the weight at a maximum of 8'-0" intervals.

2.4.3 Walls and partitions constructed of metal studs should be designed to maximum deflection of L/720 for conditions utilizing thick-set or thin-set mortar installation methods.

2.5 Joint Size. Typical joint widths are:

2.5.1 Exterior Stone Cladding: Minimum ¼", preferably 3/8". Joints of ½" or larger are frequently required for large unit size installation.

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2.5.2 Interior Stone Cladding: Minimum 1/16", preferably 1/8". Joints of ¼" or larger are frequently required for large unit size installation.

2.5.3 IN NO CASE SHALL TIGHT or "HAND-BUTTED" JOINTERY BE USED.

2.6 Lippage. Tolerances for allowable lippage can be found in Chapter 22 on Tolerances.

2.6.1 Allowable lippage is an installation tolerance, and is additive to the inherent warpage of the stone unit.

2.6.2 This lippage 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" may be required.

2.6.3 This lippage may not be achievable in extremely large format stone pavers, in which case larger than typical joint widths are recommended to minimize perceived lippage.

2.7 Exposed stone edges must be gauged to the precise thickness specified.

2.8 Physical Property Values. Final design should always be based on specific physical property values obtained by ASTM test methods for the stone and attachment method systems to be used.

NOTES:

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EXTERIOR STONE VENEER

1.0 INTRODUCTION

1.1 Installation Methods. There are several methods by which exterior stone cladding can be installed. Consideration should be given to the various features of each method in making a selection for a particular installation. See detailed illustrations of examples at the close of this section.

1.2 For additional information, refer to Chapter 13 Installation – General Information.

1.3 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.

1.4 General Precautions. During construction, the General Contractor shall protect all stone from staining and damage.

2.0 RELATED COMPONENTS

2.1 Anchorage Hardware: All anchors in contact with exterior stone are to be non-corroding.

2.2 Joint Fillers. When using adhesion installation methods, grout joints shall be a minimum of ¼" wide. Apply grout to full depth of stone. Silicone-based building sealants that remain flexible with a modulus capable of accommodating anticipated inter-panel movements are recommended for vertical work. Verify the sealant is non-staining to the specified stone material.

2.3 Gypsum Plaster. The use of gypsum plaster (molding plaster) setting spots for exterior stone is not acceptable practice.

2.4 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.

2.4.1 Where permanent setting pads are required, 90 durometer neoprene or high-impact plastic is recommended.

2.5 Insulation. Because heat is easily transmitted through stone when stone is part of a system assembly, insulation should be provided by other Contractors. Insulation should never be placed directly against the stone.

2.6 Control and 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.

3.0 HYSTERESIS

3.1 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 their 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.

DATA SHEET

4.0 EXTERIOR STONE VENEER - PRODUCT DESCRIPTION

4.1 Basic Use. Exterior cladding or facing for structural elements.

4.1.1 Thickness Limitations for Mechanically Attached Systems. As a general rule, stone panel thickness should be a minimum of 1¼". However, 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.

4.1.2 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.

4.1.3 Finishes. Most commercially available stone thicknesses are suitable for exterior veneer. Some stones, notably marbles, may not retain a polished finish in exterior environments.

4.1.4 Colors. Most of the commercially available varieties are suitable.

4.1.5 Panel Sizes. Panel sizes are subject to the size and soundness of the block yielded by the quarry. Generally, panel dimensions of greater than 5'-0" (1.5 m) 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.

5.0 TECHNICAL DATA

5.1 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:

5.1.1 Granite: ASTM C615, Standard Specification for Granite Dimension Stone

5.1.2 Limestone: ASTM C568, Standard Specification for Limestone Dimension Stone

5.1.3 Marble: ASTM C503, Standard Specification for Marble Dimension Stone (Soundness Classifications A and B only)

5.1.4 Quartz-based Stone: ASTM C616, Standard Specification for Quartz-based Dimension Stone

5.1.5 Serpentine: ASTM C1526, Standard Specification for Serpentine Dimension Stone

5.1.6 Slate: ASTM C629, Standard Specification for Slate Dimension Stone

5.1.7 Soapstone: No ASTM Standard exists at this time.

5.1.8 Travertine: ASTM C1527, Standard Specification for Travertine Dimension Stone

6.0 ENGINEERING

6.1 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.

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7.0 GENERAL PRECAUTION:

7.1 During construction, the General Contractor shall protect all stone from staining and damage.

7.2 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 certified testing agencies specializing in natural stone testing.

NOTES:

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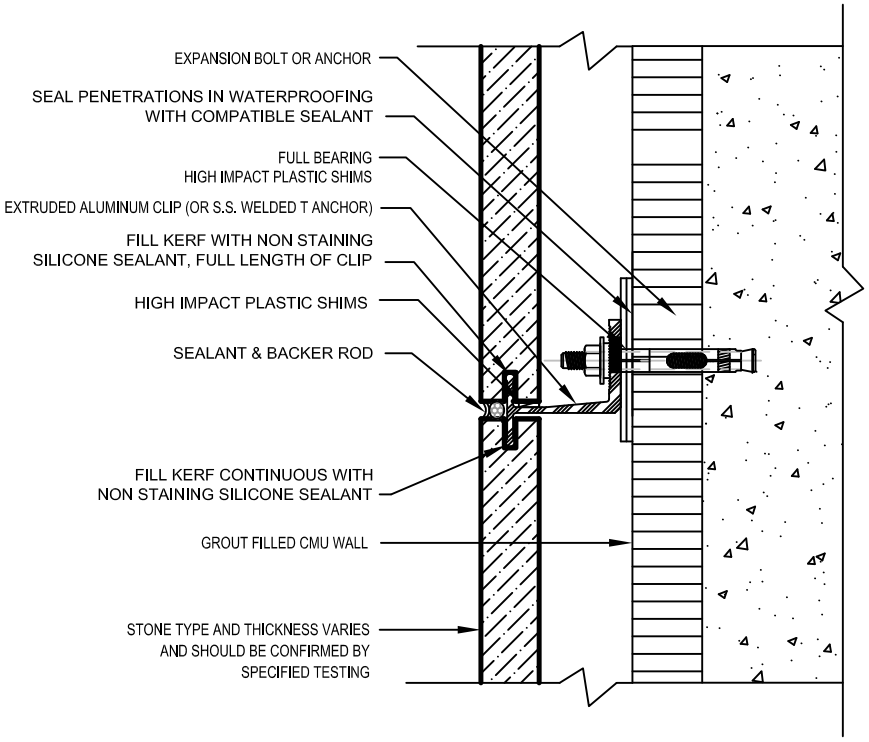
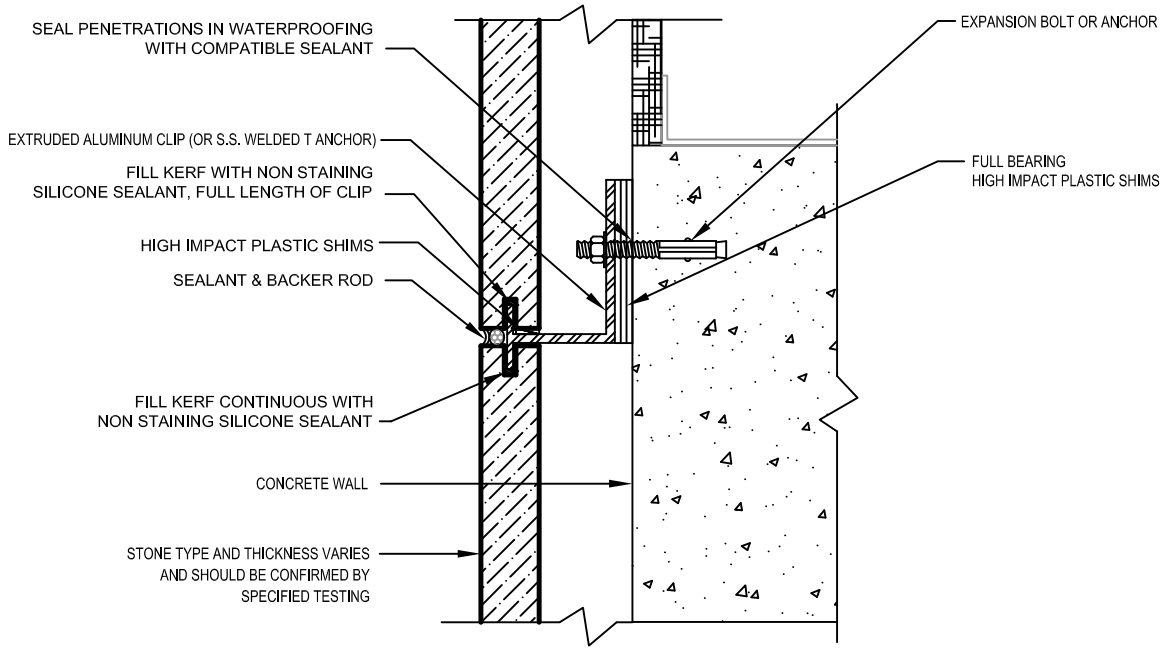


1 EXTRUDED ALUMINUM OR WELDED STAINLESS STEEL "T" ON CMU BACKUP



2 EXTRUDED ALUMINUM OR WELDED ST. STEEL "T" ON CONCRETE BACKUP

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EXTERIOR STONE ATTACHMENT DETAILS

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 15-D-1

SCALE: 3" = 1'-0"

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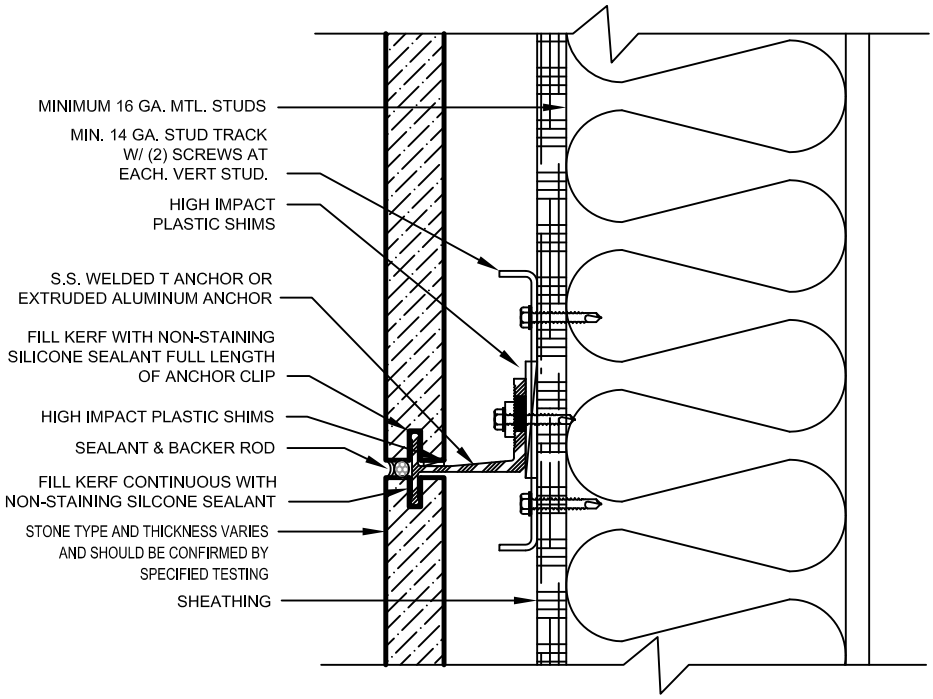

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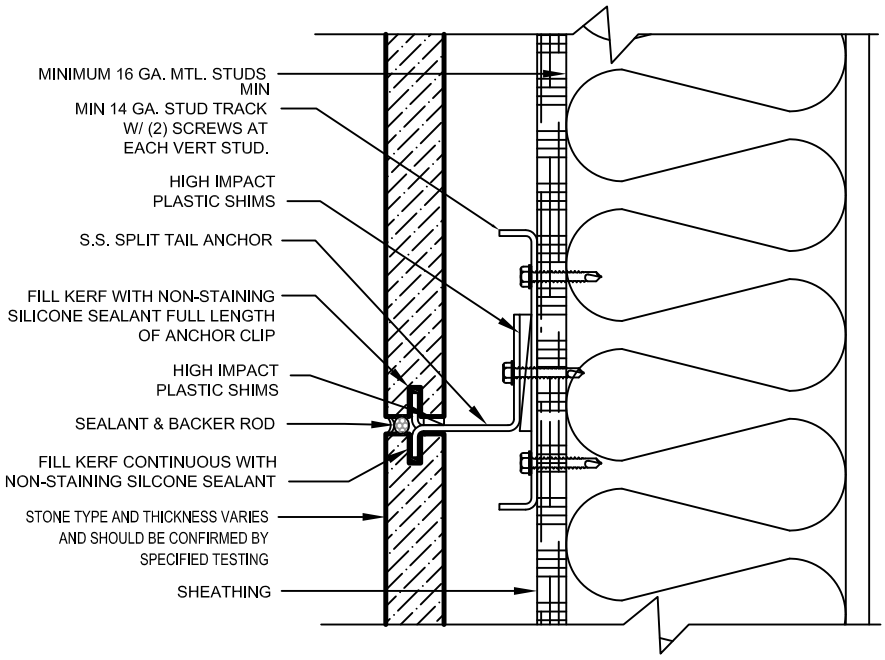

2 STAINLESS STEEL SPLIT-TAIL ANCHOR ON METAL STUD BACKUP

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EXTERIOR STONE ATTACHMENT DETAILS

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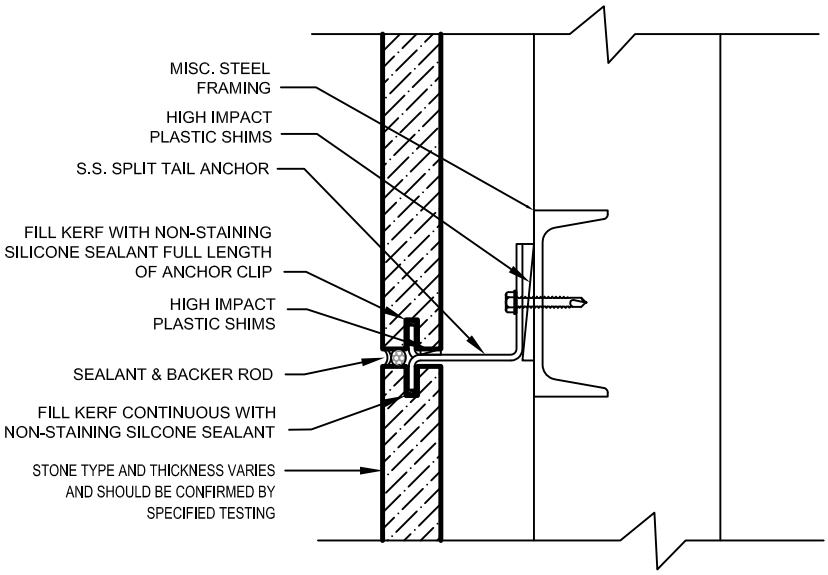

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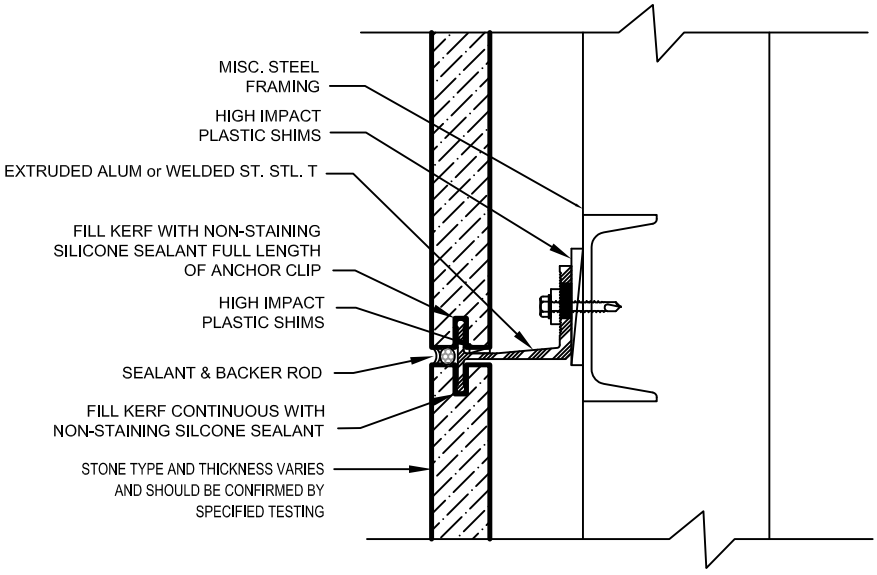

2 EXTRUDED ALUMINUM OR WELDED ST. STEEL "T" ON MISC. METAL BACKUP

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EXTERIOR STONE ATTACHMENT DETAILS

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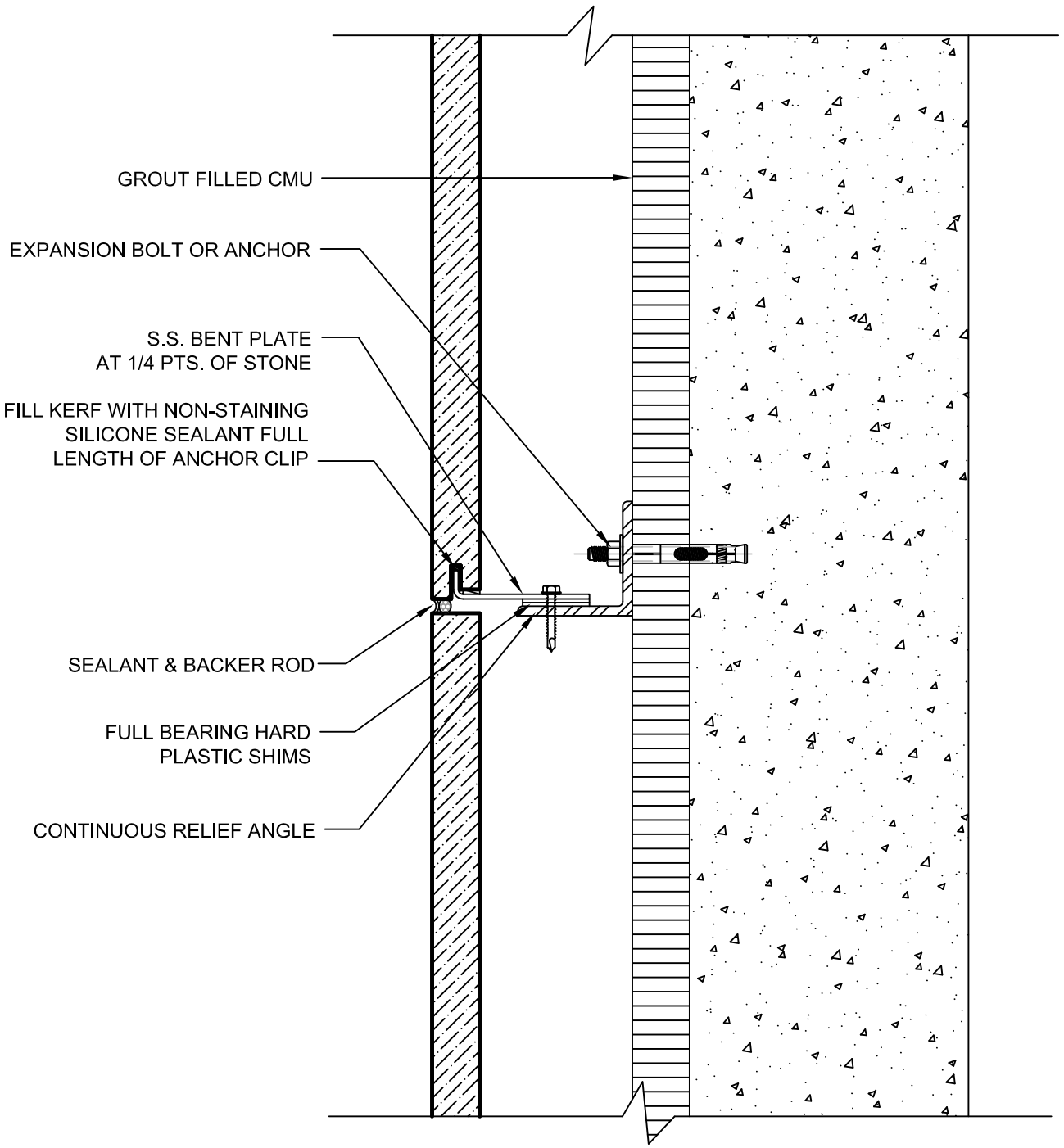

1 RELIEF ANGLE CONNECTION ON CMU/CONCRETE BACKUP

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EXTERIOR STONE ATTACHMENT DETAILS

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SCALE: 3" = 1'-0"

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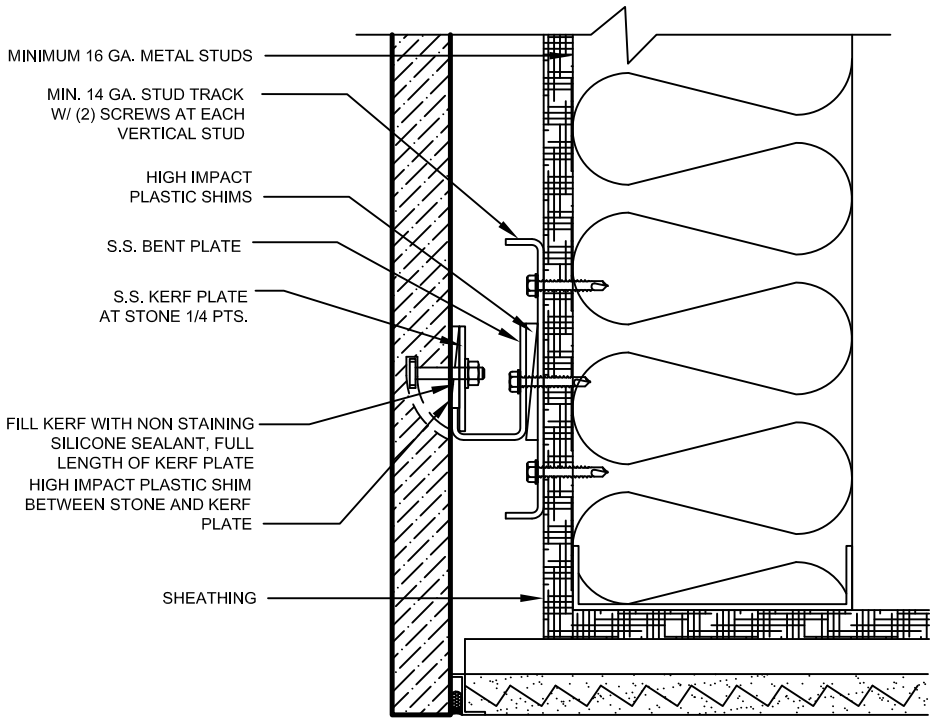
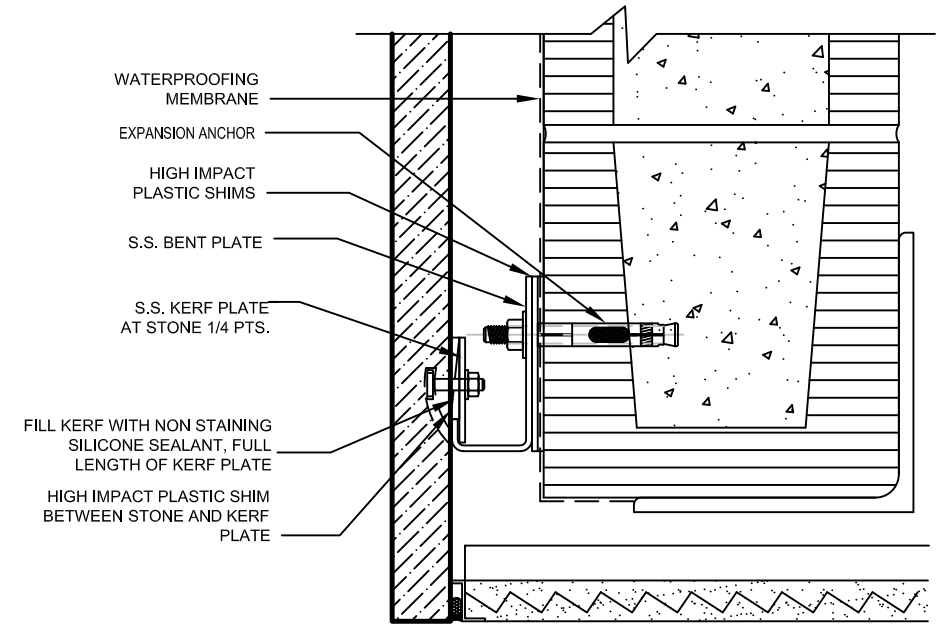


1 BACK ANCHOR & ST. STL. CLIP FOR "BLIND" CONNECTION ON METAL STUDS



2 BACK ANCHOR & ST. STL. CLIP FOR "BLIND" CONNECTION ON CMU/COMCRETE

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EXTERIOR STONE ATTACHMENT DETAILS

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SCALE: 3" = 1'-0"

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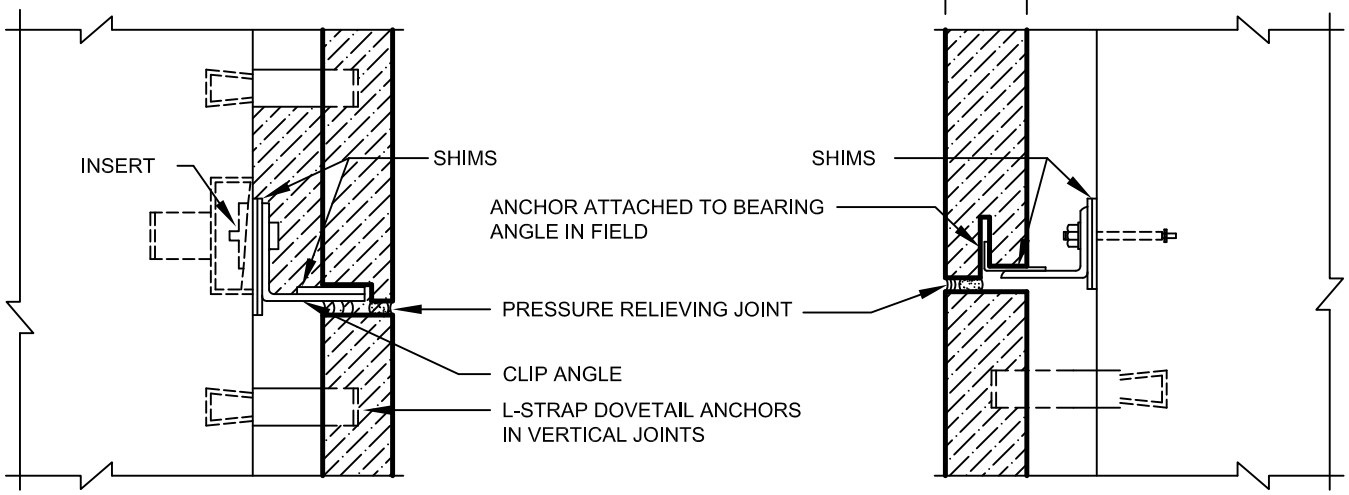

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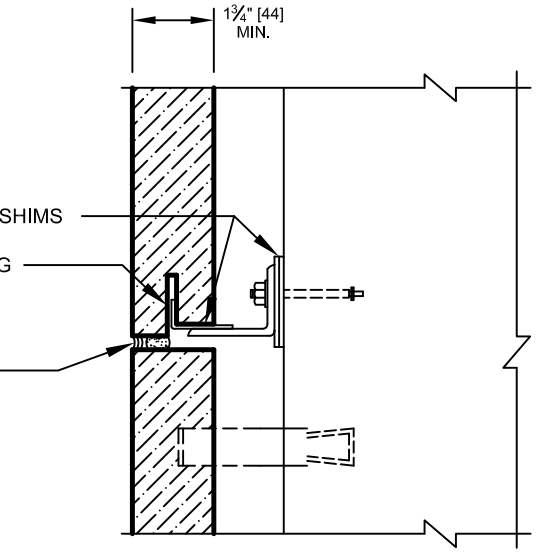

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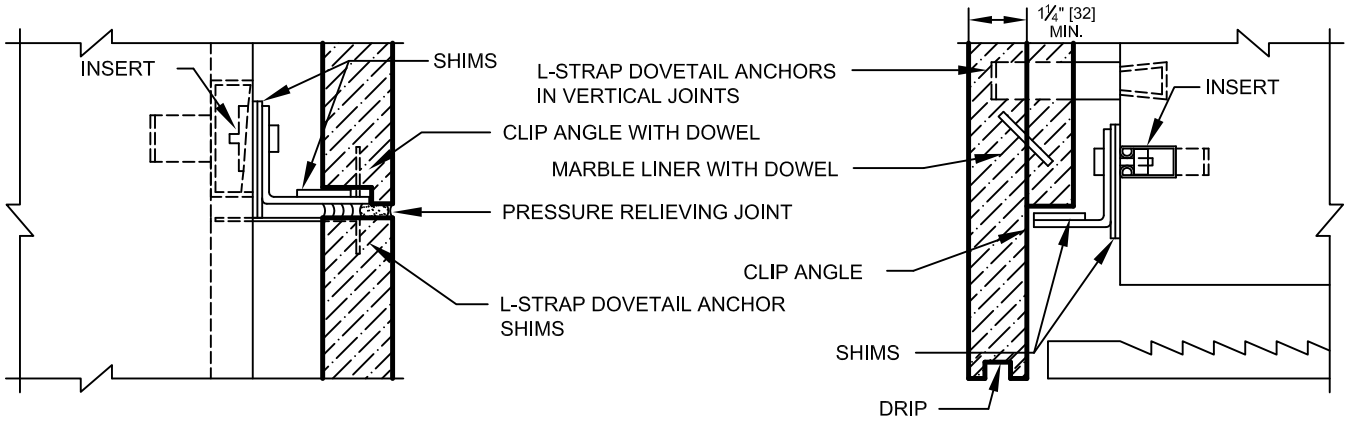

3 DETAIL

4 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 RELIEF DETAILS WITH REBATED BEARING

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 15-D-6

SCALE: 3" = 1'-0"

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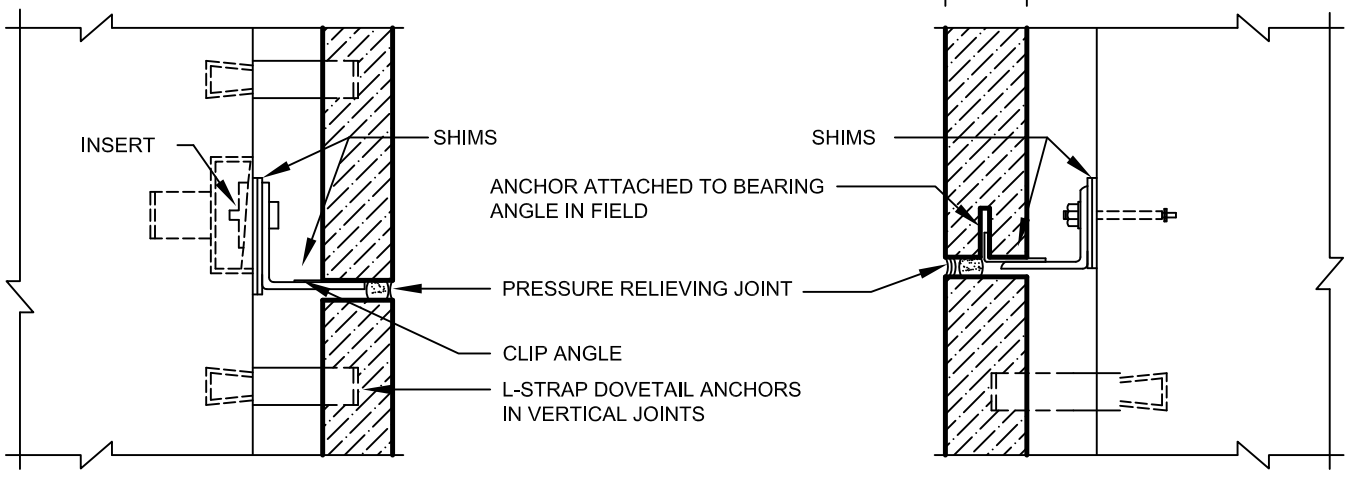
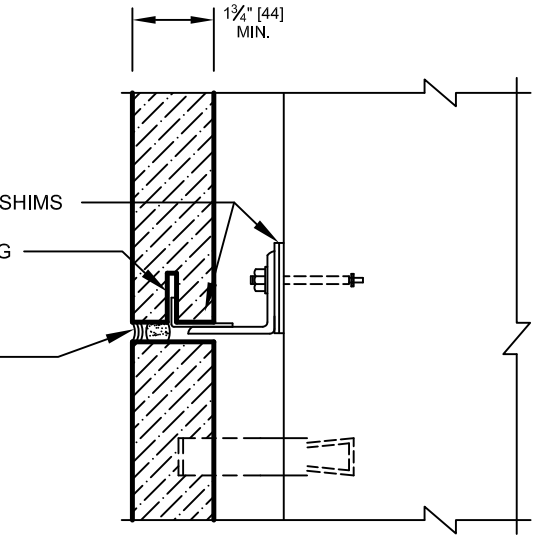
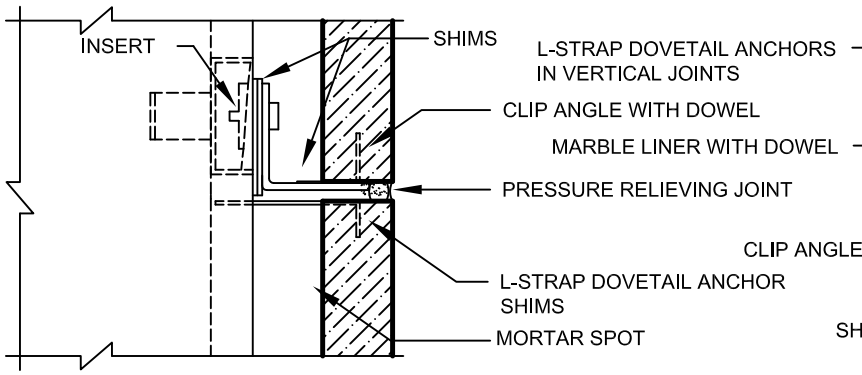


1 DETAIL



2 DETAIL



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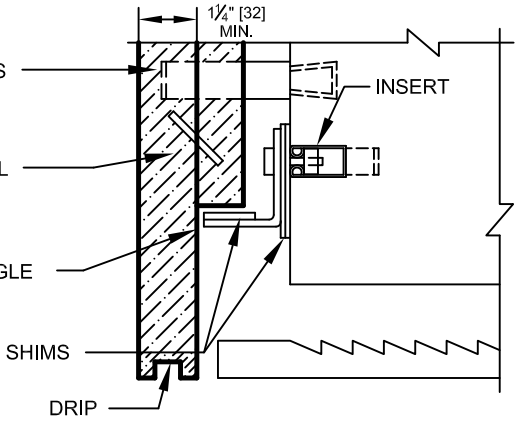

4 DETAIL

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 RELIEF DETAILS WITH NON– REBATED BEARING

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 15-D-7

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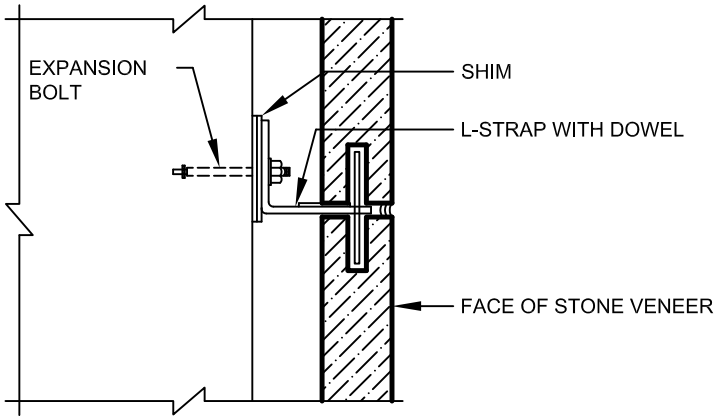
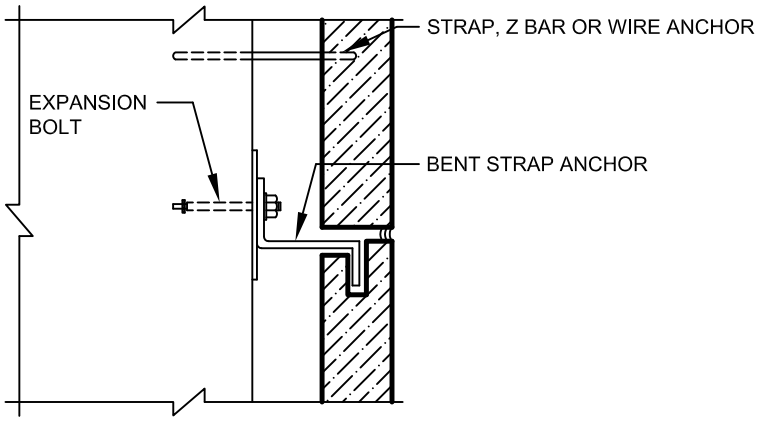


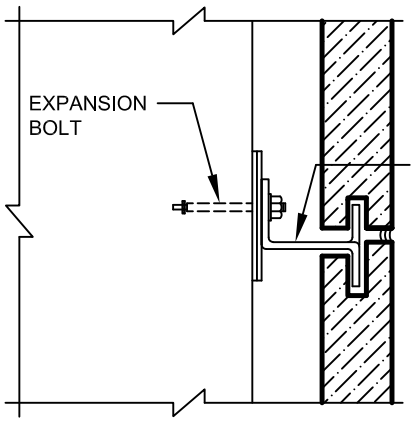
1 DETAIL

NOTES:

1. *ALL METALS IN DIRECT CONTACT WITH STONE MUST BE STAINLESS STEEL.*
3. *RECOMMENDED MINIMUM THICKNESS OF STONE VENEER FOR ANCHORAGE SHOWN IN DETAILS 7,8,9 & 12 VARIES.*



2 DETAIL



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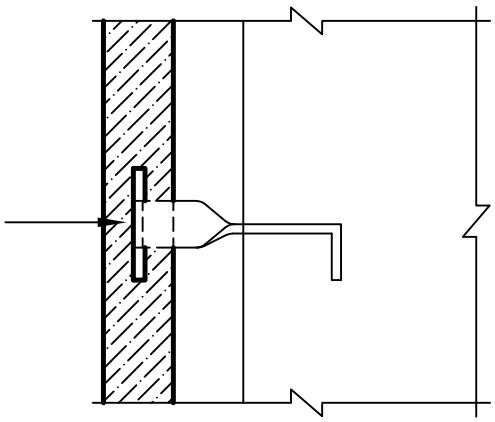

4 DETAIL

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EXTERIOR STONE VENEER RESTRAINT ANCHORAGE DETAILS

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 15-D-8

SCALE: 3" = 1'-0"

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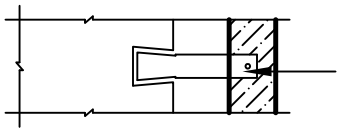
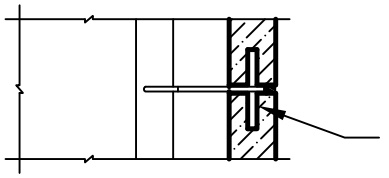
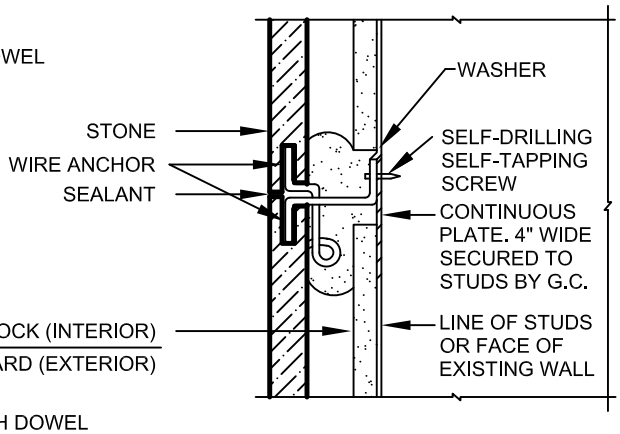


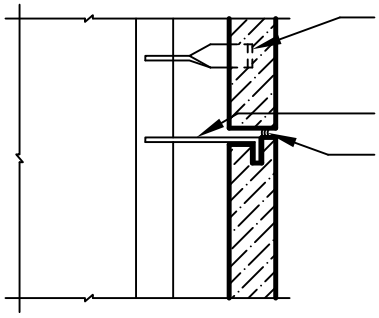
PLAN OF DETAIL 12



DETAIL 12



DETAIL 14



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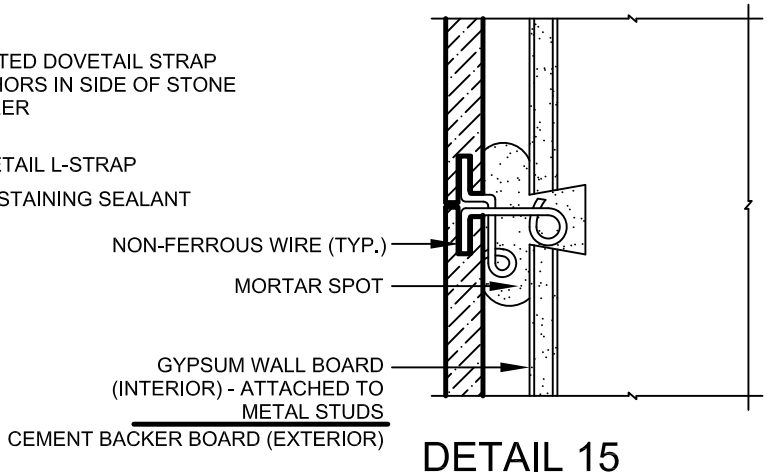
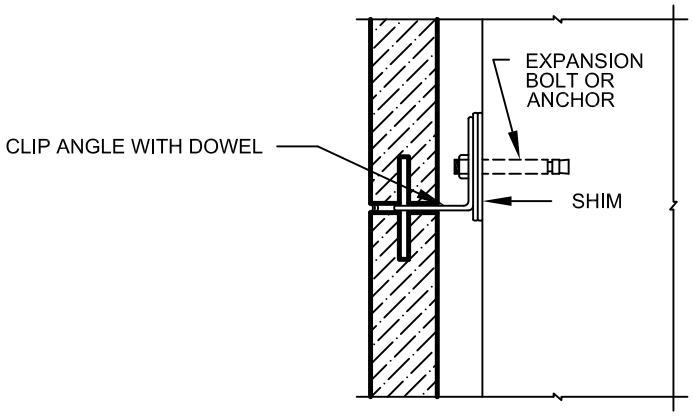


DETAIL 15

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.



DETAIL 16

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EXTERIOR STONE VENEER RESTRAINT ANCHORAGE DETAILS

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 15-D-9

SCALE: 3" = 1'-0"

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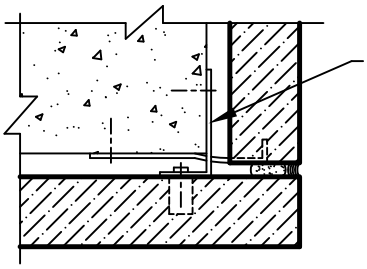
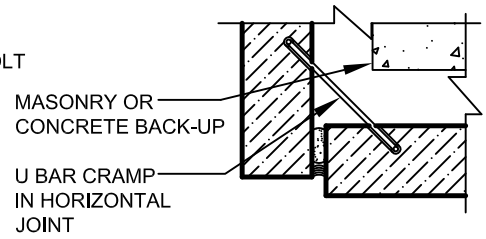
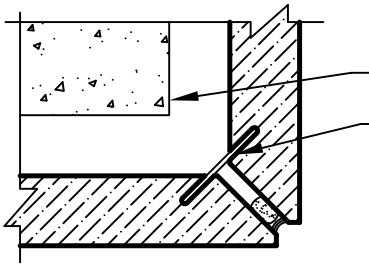


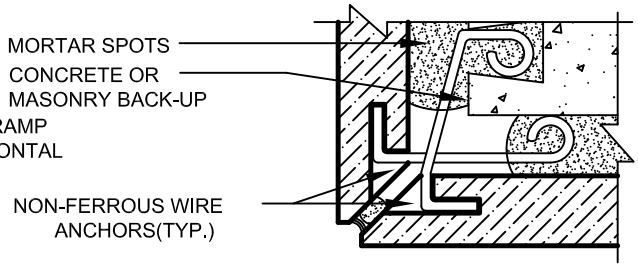
1 BUTT JOINT



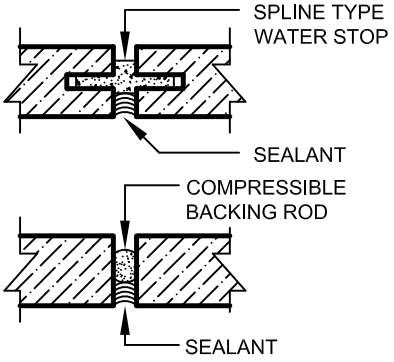
2 OFFSET BUTT JOINT



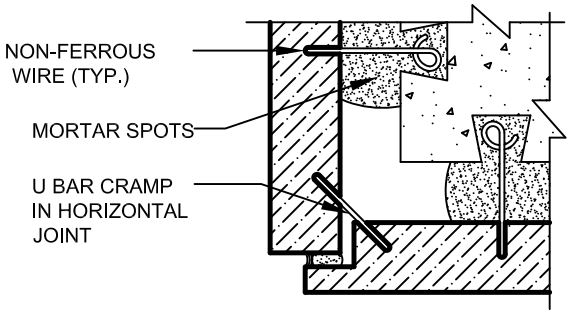
3 QUIRK MITER JOINT



4 QUIRK MITER JOINT



5 TYPICAL EXPANSION JOINTS



6 RABBETED JOINT

NOTE: ALL METAL IN DIRECT CONTACT WITH THE STONE MUST BE STAINLESS STEEL.

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EXTERIOR STONE VENEER /TYPICAL CORNERS, EXPANSION JOINTS,REGLETS

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 15-D-10

SCALE: 6" = 1'-0"

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INTERIOR STONE WALL CLADDING

1.0 INTRODUCTION

1.1 Installation Methods. There are several methods by which interior stone cladding can be installed. Consideration should be given to the various features of each method in making a selection for a particular installation. See detailed illustrations of examples at the close of this section.

1.2 For additional information, refer to Chapter 13 Installation – General Information.

1.3 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.

1.4 General Precautions. During construction, the General Contractor shall protect all stone from staining and damage.

2.0 DESIGN CRITERIA

2.1 Stone Size and Thickness. Most dimension stones, as defined by ASTM C119, are suitable for interior cladding. Stone panel size and thickness are closely interrelated with the type of stone being installed and its particular engineering qualities. Generally, consideration for greater stone thickness should be made for larger-sized stones (over 12 sq ft) set at higher elevations, and more fragile stones, with the exception of natural stone veneer panels with integrated reinforced backers, which have a limited availability of up to 5' x 10'.

2.2 Installation. Stone wall facing panels may be installed either by conventionally set method using nonstaining anchors, dowels, pins, cramps, wire, and mortar spots; nonstaining adhesive in securing thin tile units to interior vertical surfaces; or by one of the several mechanical methods.

2.3 Physical Property Values. Final design should always be based on specific physical property values of the stone. These values are available from the Stone Supplier.

3.0 MECHANICAL SYSTEMS

3.1 Performance Criteria. The Specifying Authority must determine the performance criteria of the mechanical system to be employed.

3.2 Engineering. A knowledgeable and experienced Installer must be engaged to engineer and fabricate a system that will satisfy the functional and aesthetic requirements of the project.

3.3 Anchorage systems must be securely attached and located as shown on the approved shop drawings and shall be plumb and in true plane.

3.4 Assembly/Installation Systems. A number of proprietary assembly and installation systems are available.

3.5 Panel Installation. Stone panels must be installed to the mechanical system in the prescribed manner, with vertical lines plumb and horizontal lines level.

3.6 Conditions. 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: 1/8" in 10'-0" with no more than 1/32" between individual stones.)

3.7 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.

3.8 Metal Studs. Must be 16 gauge or thicker. Stone anchors may attach directly to the studs, or a horizontal track component may be used to carry the load of the anchor to several studs. May use plywood, cementitious backer board, or gypsum board as a non-loadbearing sheathing.

3.9 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 to several studs. May use plywood, cementitious backer board, or gypsum board as a non-loadbearing sheathing.

3.10 Mechanical Systems. Each mechanical system is different. Follow Manufacturer's recommendations.

3.11 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.

4.0 STONE PANELS

4.1 General. Stone panels that cover a wall (wall die) or a lower portion of a wall (wainscot) are supplied in several standard as well as custom thicknesses depending on the stone, its location on the wall, and its use in the project. Normally, stone thickness of ¾" is sufficient. In some instances of very large or fragile stones, thickness of 1¼" or greater may be necessary.

4.2 Base. The base may be in coplanar position with the wainscot or die or be offset so that a portion or all of the top edge of the base stone remains prominent. It may be profiled or otherwise decorated to achieve architectural effect. The base must be separated from the floor with a "soft" joint appropriately sized to accommodate anticipated building movements and prevent damage to either the horizontal or vertical surface.

4.3 Installation. Stone panels may be solid set or standard set (with a cavity) to the substrate. Normally, standard set is the more economical method, and is most commonly employed. The solid-set method is seldom used, except for installing wainscot or in certain wet or special circumstance area conditions. In the standard-set method, space allowed between the substrate and the back face of the stone may be as little as 1". Wider spaces over 2" should have strap anchors instead of twisted-wire anchors.

4.4 Weight Relief. Stone panels should have their weight relieved when spanning openings over windows or doors, at all floor lines, at any expansion joints in the substrate, or at 12' to 15' intervals in height.

5.0 STONE TILE

5.1 Color Differential. Stone tiles are subject to manufacturing processes different than other dimension stones and natural stone veneer panels. There is greater latitude in the acceptability of shaded stones, and Installers should obtain approval of the stone layout prior to installation.

5.2 Installation. Stone tile may be installed in almost any location for which stone panels are considered. The exception is for elevations higher than 15'-0", which require anchors. Thin stone tiles are not suitable for use with anchors. Stone tile may be installed in a full mortar bed, in a thin-set mortar bed, or with an approved adhesive.

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5.3 Back Buttering. 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.

5.4 Size. 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.

5.5 Substrates. Suitable substrates for stone tile are masonry, cementitious backer board, and gypsum board. Do not use gypsum-based products in wet areas.

5.6 Fire Rating. Two (2) layers of gypsum board are required in elevator shaft walls and where a fire rating is required.

6.0 LIGHTWEIGHT NATURAL STONE VENEER PANELS

6.1 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.

NOTES:

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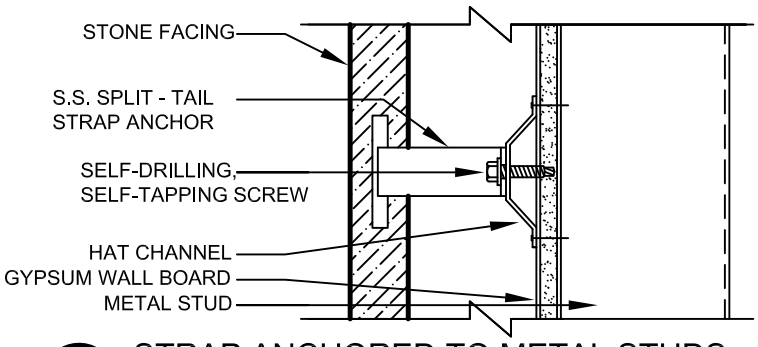
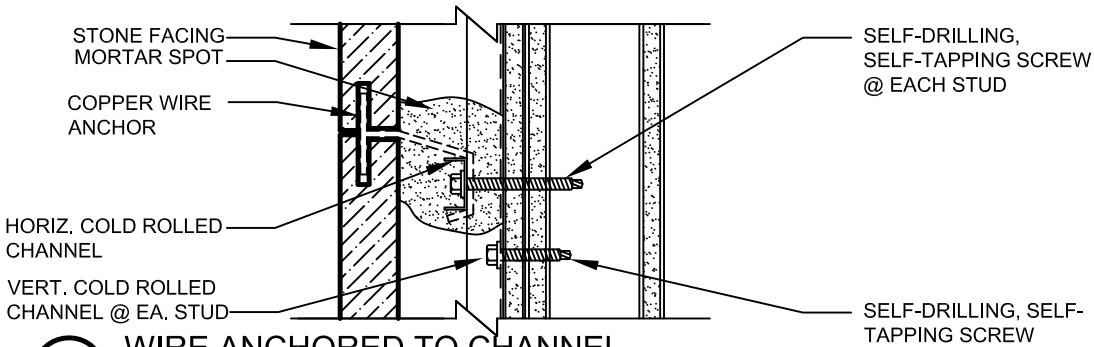
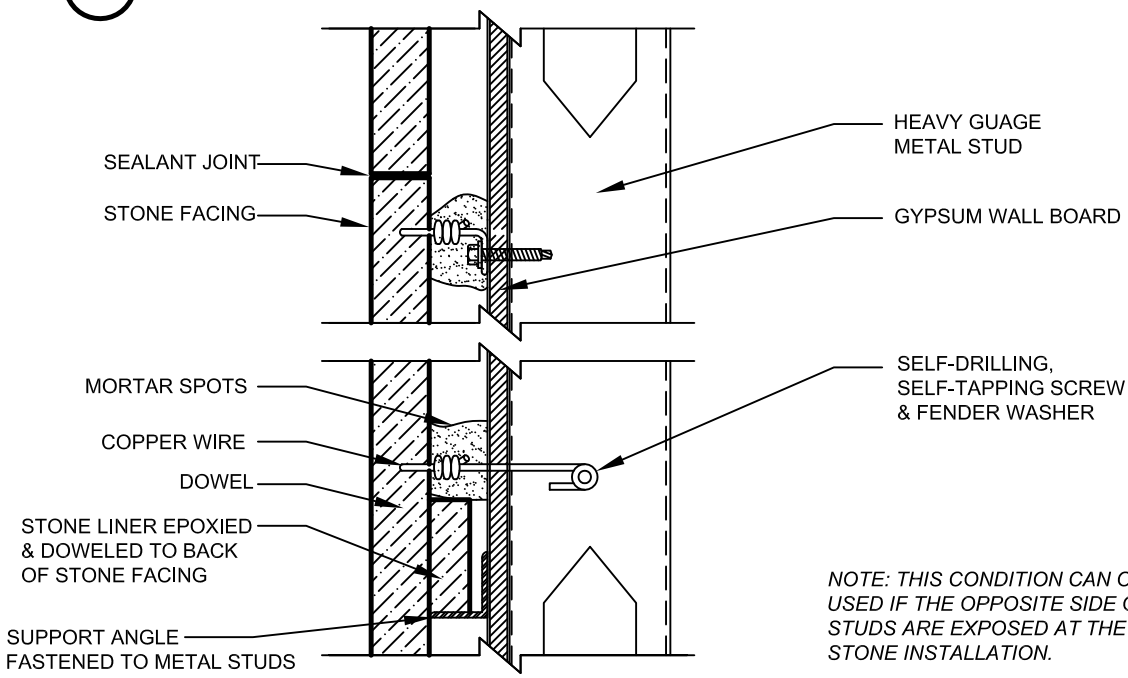


1 STRAP ANCHORED TO METAL STUDS



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 WALL CLADDING WALL FACING DETAILS

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 15-D-11

SCALE: 3" = 1'-0"

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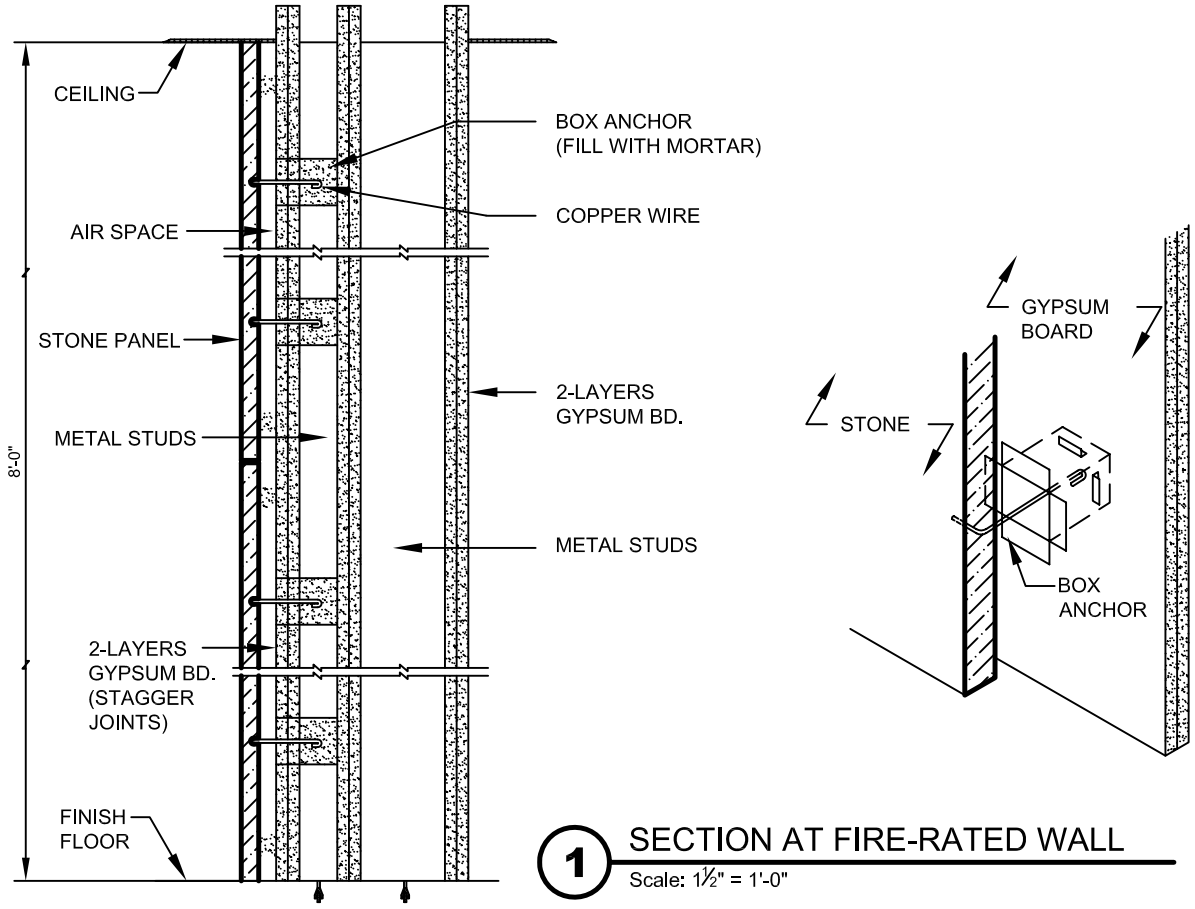
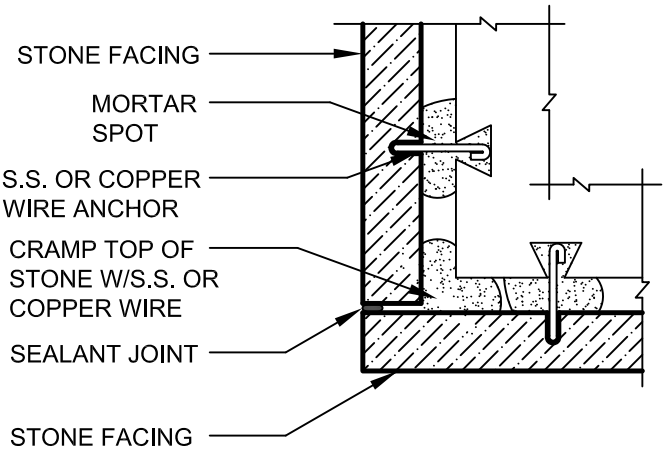


1 SECTION AT FIRE-RATED WALL
Scale: 1½" = 1'-0"



2 CORNER DETAIL
Scale: 3" = 1'-0"

NOTE: 1½" SETTING SPACE REQUIRED WHEN MARBLE LINERS ARE NOT EMPLOYED.

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INTERIOR STONE WALL CLADDING WALL FACING DETAILS

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 15-D-12

SCALE: AS NOTED

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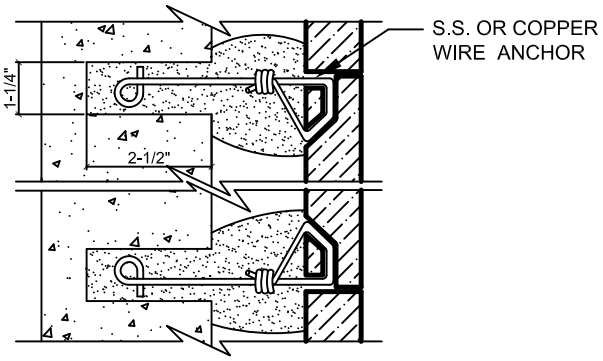
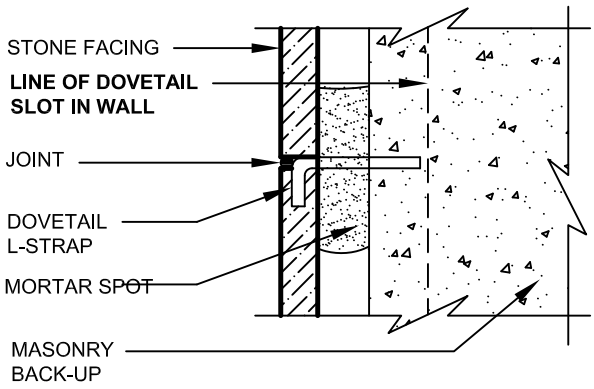
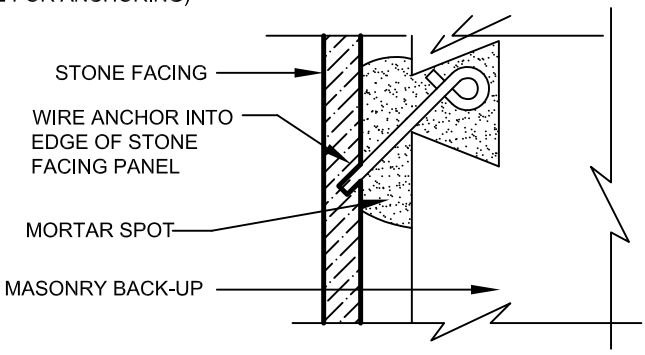


1 WIRE LACE ANCHOR

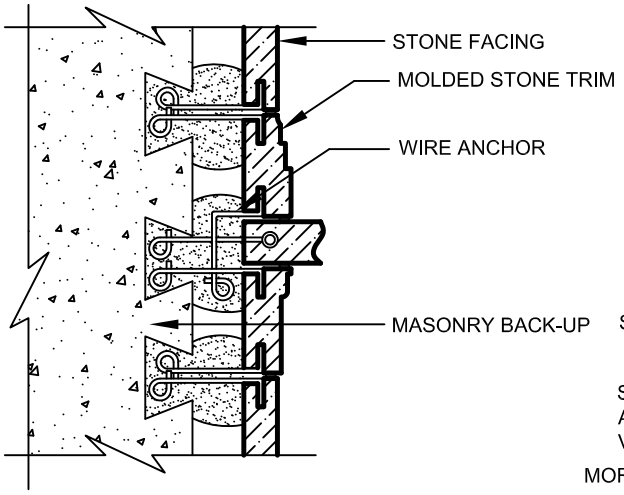
(TO BE USED ONLY WHERE EDGE CONDITION IS NOT AVAILABLE FOR ANCHORING)



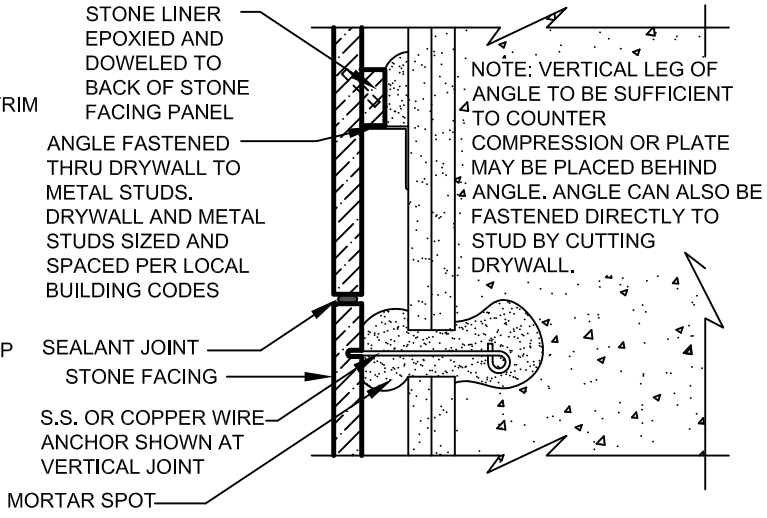
2 DOVETAIL ANCHOR IN MASONRY



3 WIRE ANCHOR IN MASONRY



4 WIRE ANCHORED MOULDED TRIM



5 WIRE ANCHORED TO METAL STUDS

NOTE: 1-1/2 INCH SETTING SPACE REQUIRED WHEN MARBLE LINERS ARE NOT EMPLOYED.

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INTERIOR STONE WALL CLADDING
WALL FACING DETAILS
MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 15-D-13

SCALE: 3" = 1'-0"

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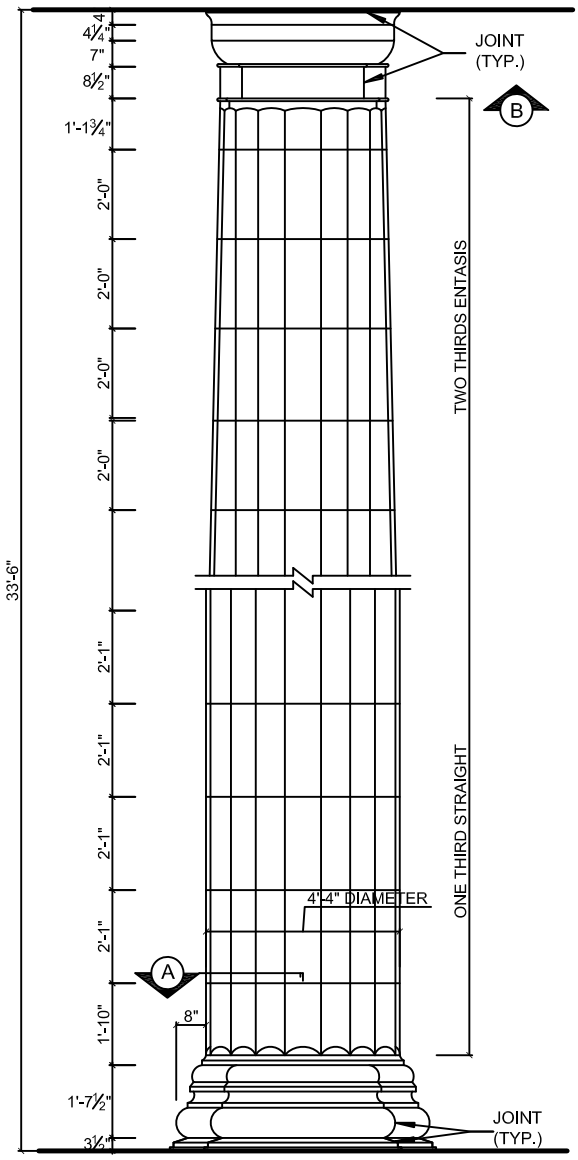
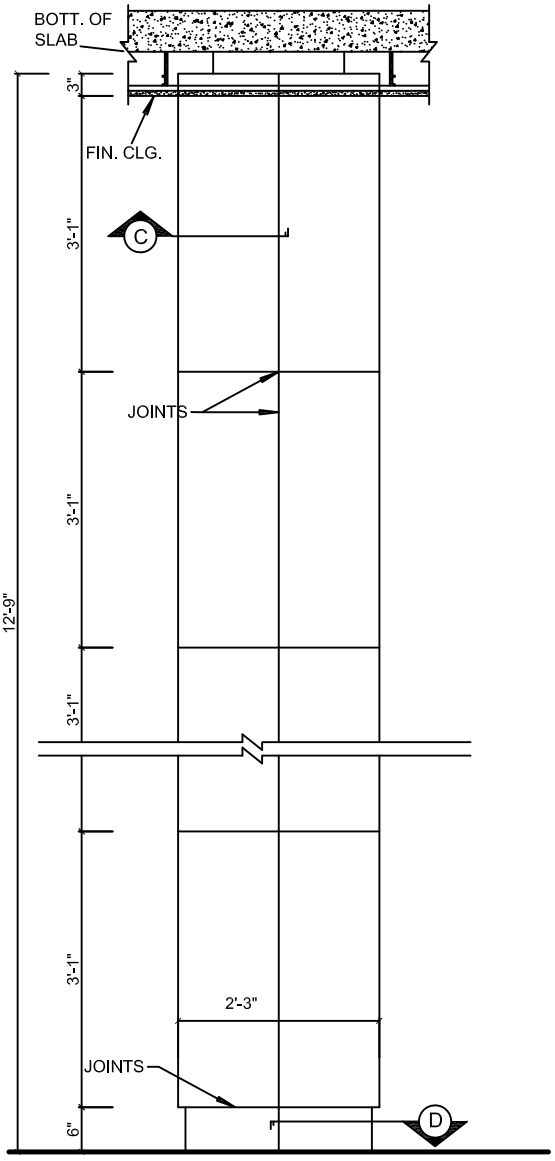


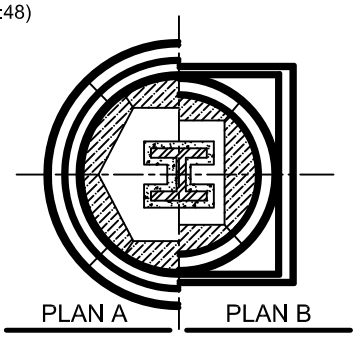
ELEVATION

1/4"=1'-0" (1:48)



ELEVATION

1/2"=1'-0" (1:24)

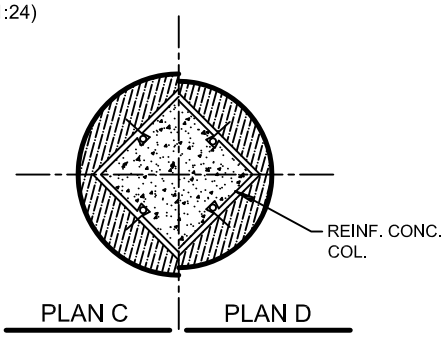


PLAN A

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)

KEY TO MATERIALS: STONE CONCRETE STEEL

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INTERIOR STONE WALL CLADDING FREE–STANDING COLUMN DETAILS

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 15-D-14

SCALE: As Noted

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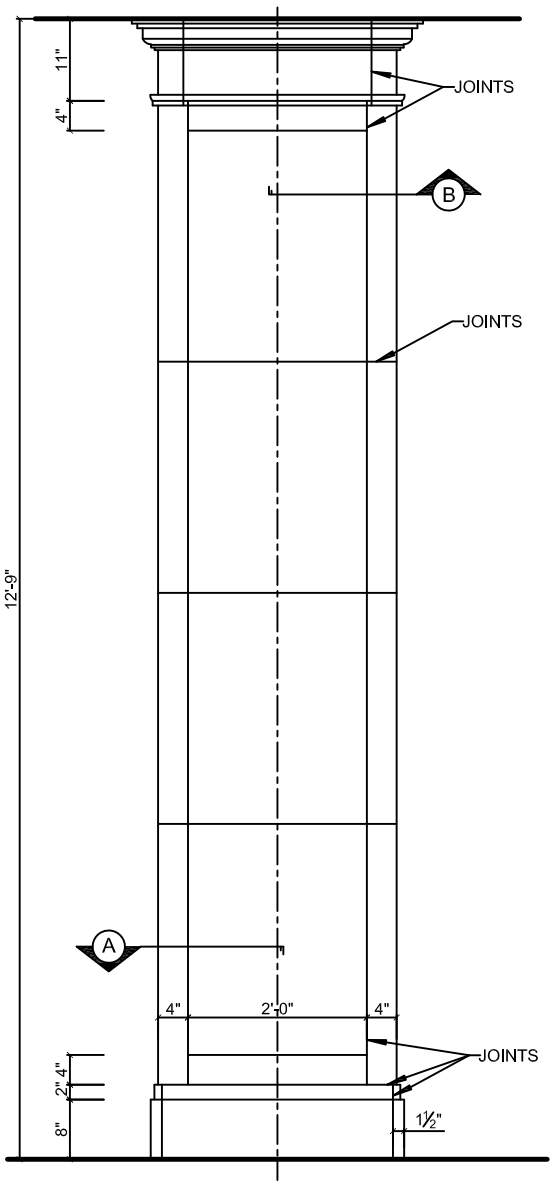
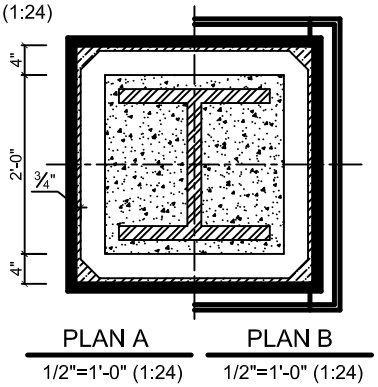
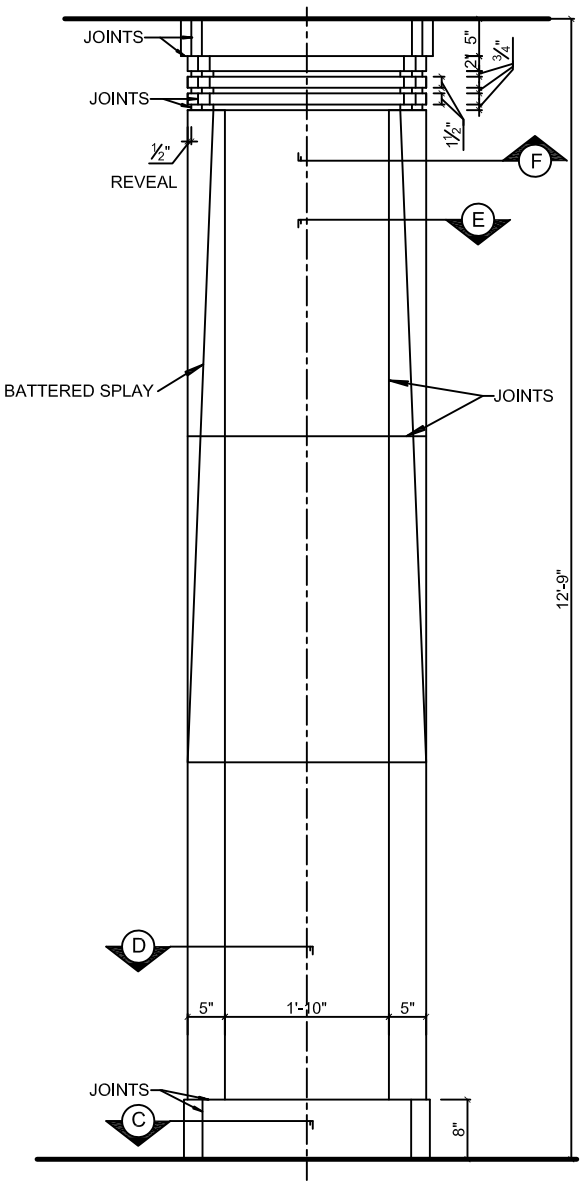


ELEVATION
1/2"=1'-0" (1:24)



PLAN A
1/2"=1'-0" (1:24)

PLAN B
1/2"=1'-0" (1:24)



ELEVATION
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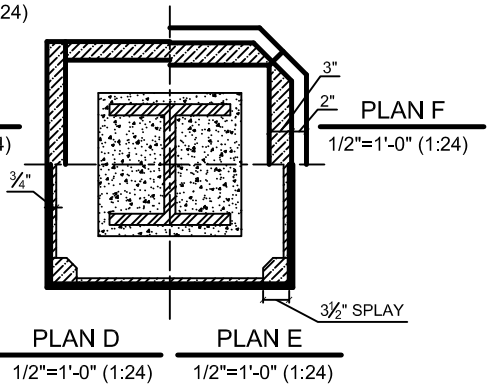

PLAN C
1/2"=1'-0" (1:24)

PLAN F
1/2"=1'-0" (1:24)

PLAN D
1/2"=1'-0" (1:24)

PLAN E
1/2"=1'-0" (1:24)

KEY TO MATERIALS: STONE CONCRETE STEEL

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INTERIOR STONE WALL CLADDING FREE–STANDING COLUMN DETAILS

MIA DIMENSION STONE DESIGN MANUAL VIII

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SCALE: As Noted

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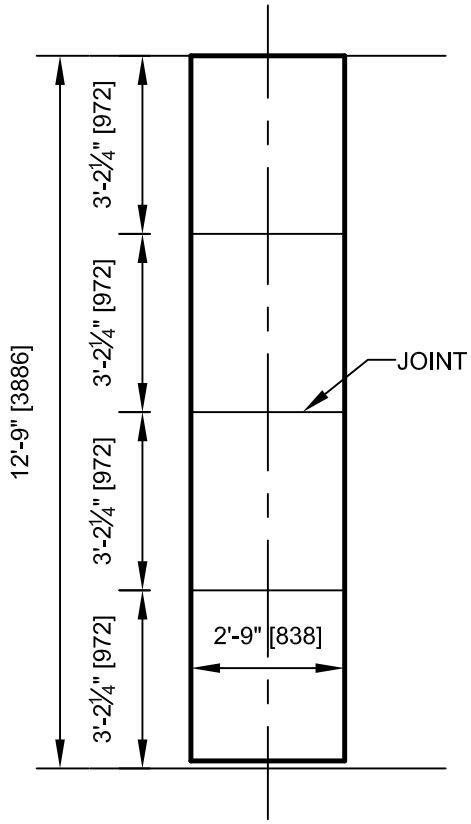

SQUARE COLUMN
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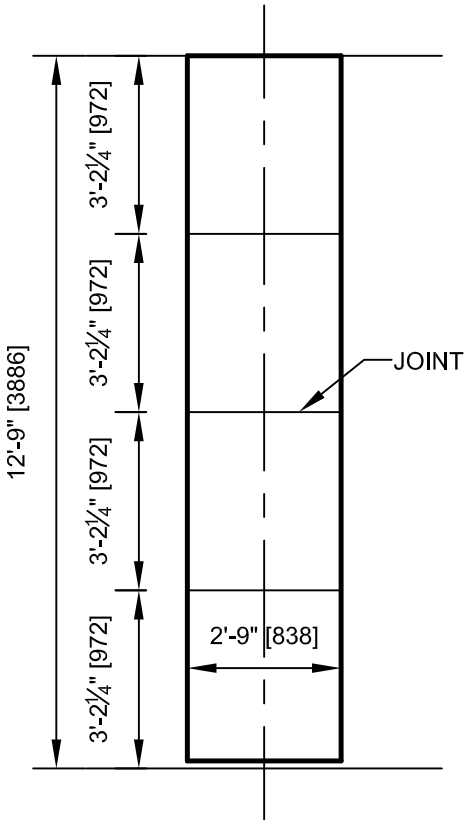
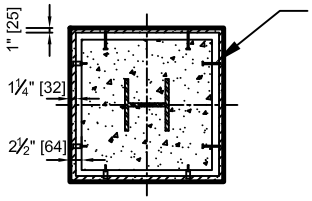
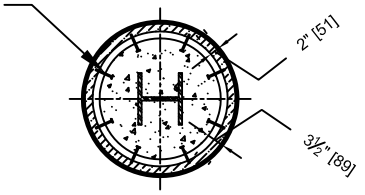


ROUND COLUMN-FOUR SECTIONS
ELEVATION 1/2"=1'-0" (1:24)



PLAN
1/2"=1'-0" (1:24)



PLAN
1/2"=1'-0" (1:24)

KEY TO MATERIALS: STONE CONCRETE STEEL

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INTERIOR STONE WALL CLADDING FREE–STANDING COLUMN DETAILS

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 15-D-16

SCALE: ½" = 1'-0"

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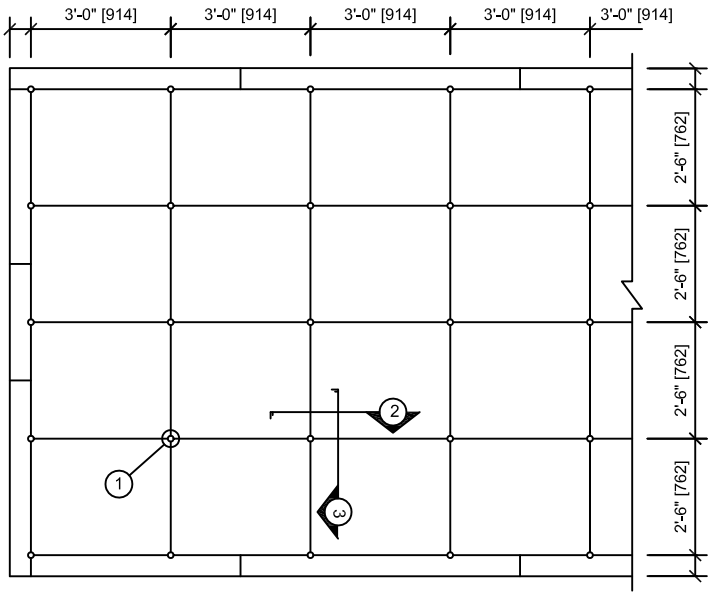
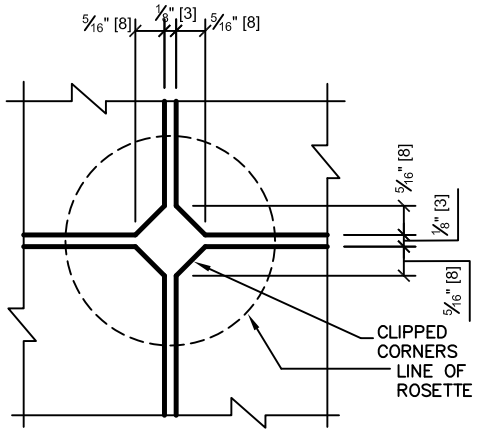


NOTE: DIMENSIONS ARE TO CENTER OF 1/8" JOINTS. TOP, BOTTOM AND SIDE TRIM PIECE WIDTH VARIES.

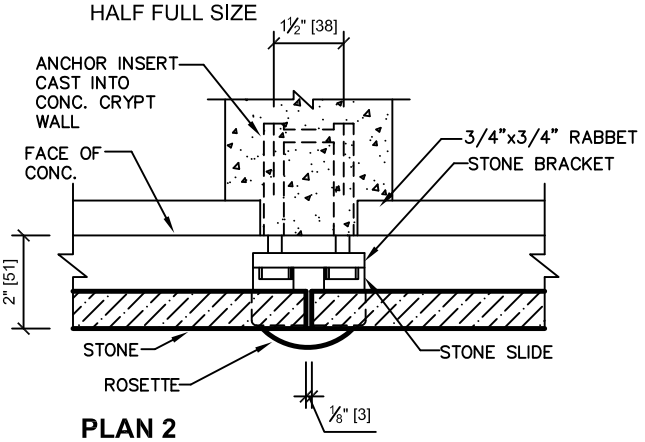
ELEVATION

1/4"=1'-0"(1:48)



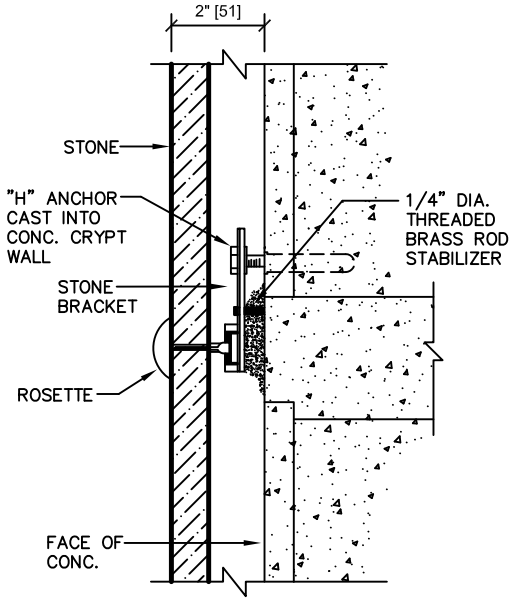
DETAIL 1

HALF FULL SIZE



PLAN 2

3"=1'-0"(1:4)



SECTION 3

3"=1'-0"(1:4)

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Interior Stone Wall Cladding Crypt with Bracket and Rosette Detail

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 15-D-17

SCALE: As Noted

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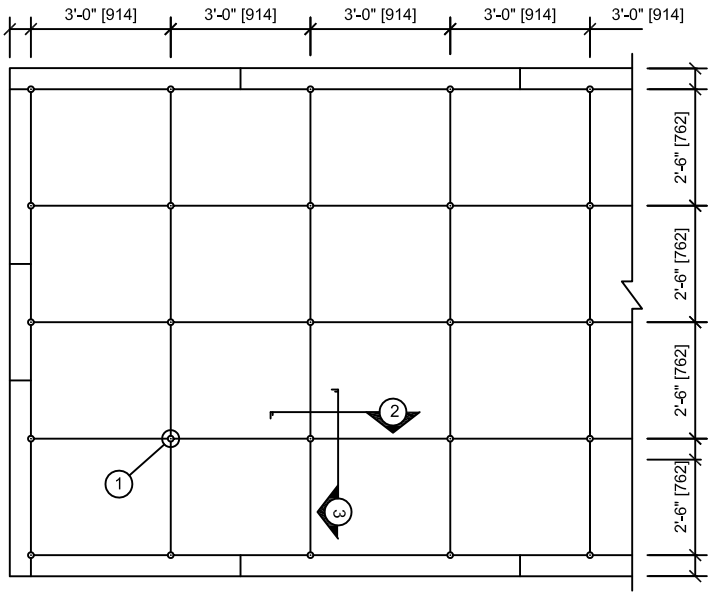
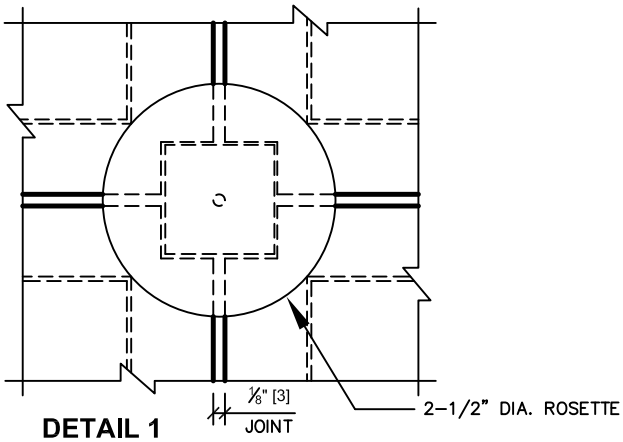


NOTE: DIMENSIONS ARE TO CENTER OF 1/8" JOINTS. TOP, BOTTOM AND SIDE TRIM PIECE WIDTH VARIES.

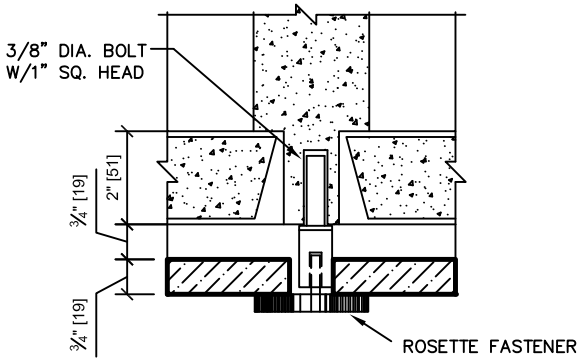
ELEVATION

1/4"=1'-0"(1:48)



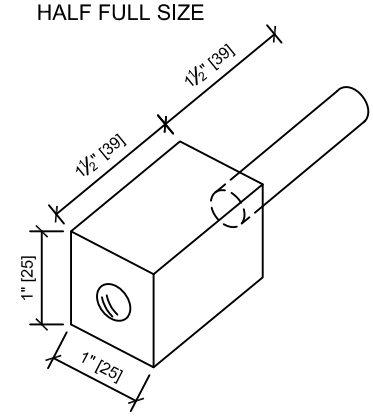
DETAIL 1

HALF FULL SIZE



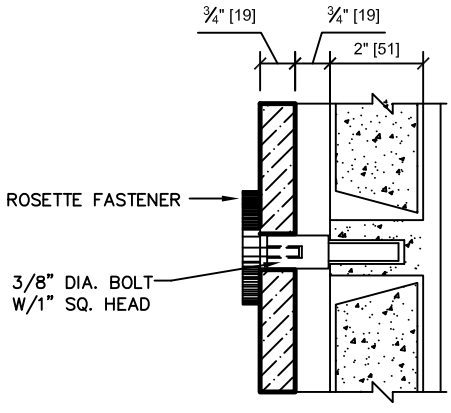
PLAN 2

3"=1'-0"(1:4)



3/8" DIA. BOLT W/1" SQ. HEAD

HALF FULL SIZE



SECTION 3

3"=1'-0"(1:4)

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Interior Stone Wall Cladding Crypt with Bolt and Rosette Fasteners

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 15-D-18

SCALE: As Noted

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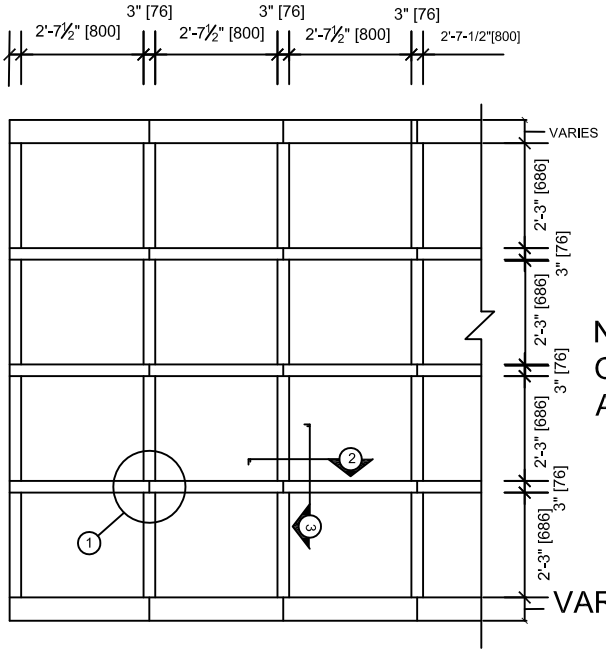
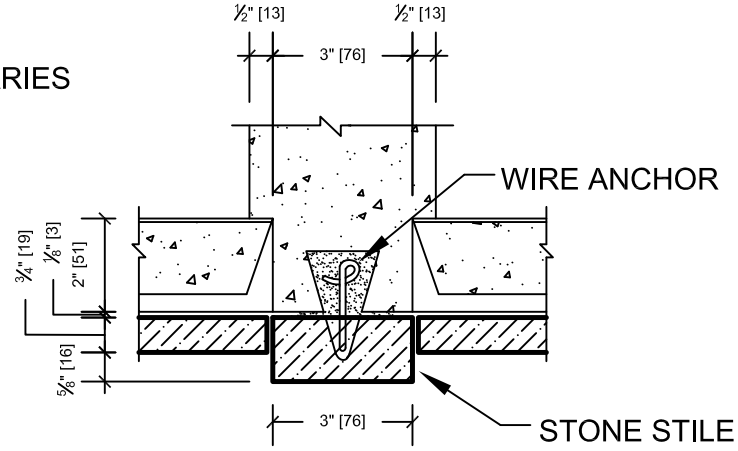


NOTE: DIMENSIONS ARE TO EDGE OF STILE OR RAIL. TOP, BOTTOM AND SIDE TRIM PIECE WIDTH VARIES.

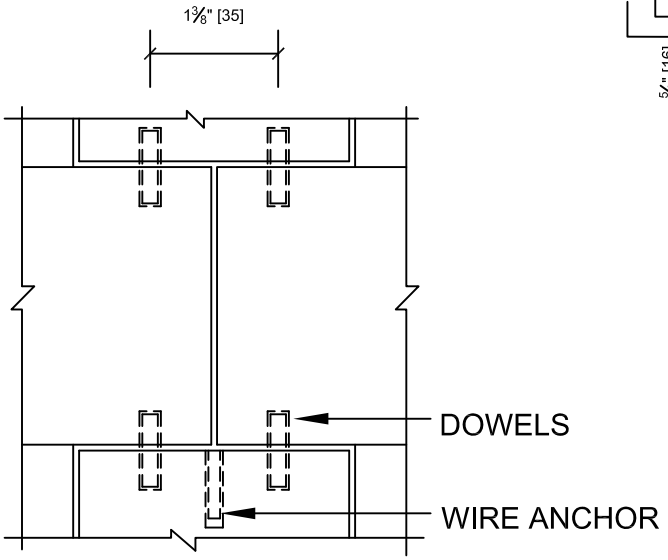
ELEVATION

1/4"=1'-0"(1:48)



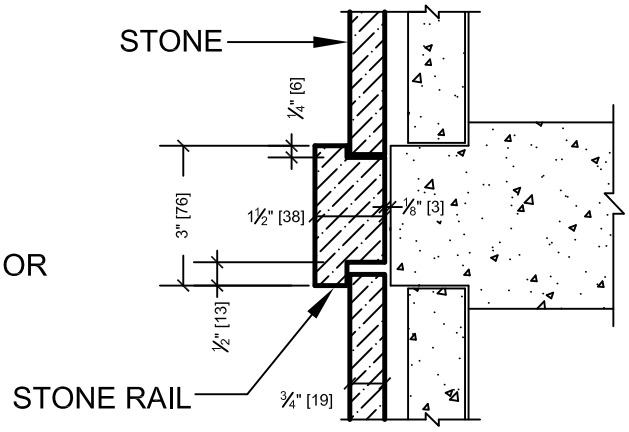
PLAN 2

3"=1'-0"(1:4)



DETAIL 1

HALF FULL SIZE



SECTION 3

3"=1'-0"(1:4)

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Interior Stone Wall Cladding Crypt with Stile and Rail Detail

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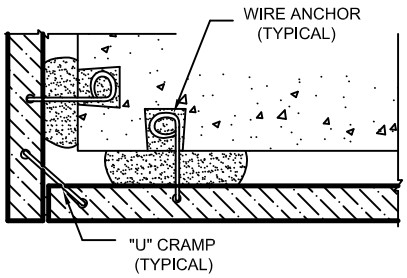
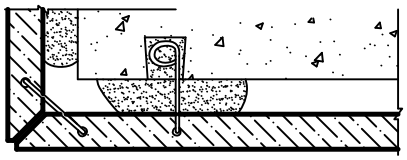
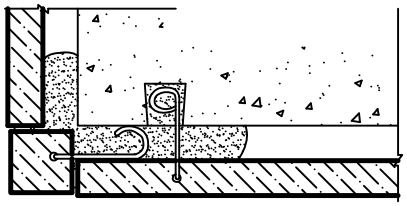


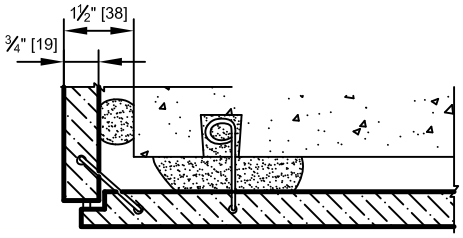
1 BUTT JOINT
EXTERNAL CORNER



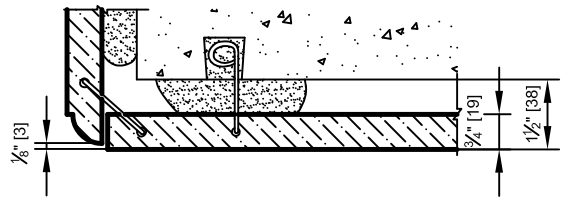
2 QUIRK MITER JOINT
EXTERNAL CORNER



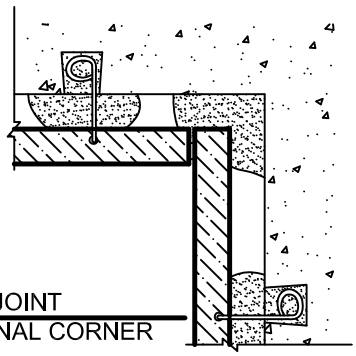
3 CORNER BLOCK JOINT
EXTERNAL CORNER



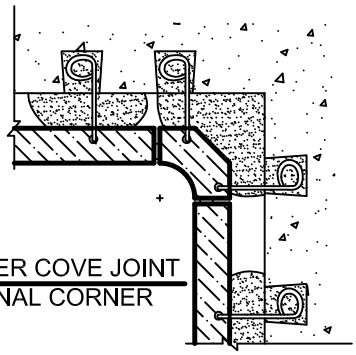
5 RABBETTED JOINT
EXTERNAL CORNER



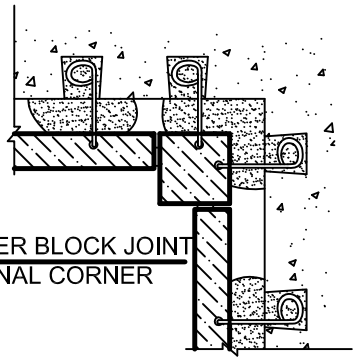
6 MOLDED JOINT
EXTERNAL CORNER



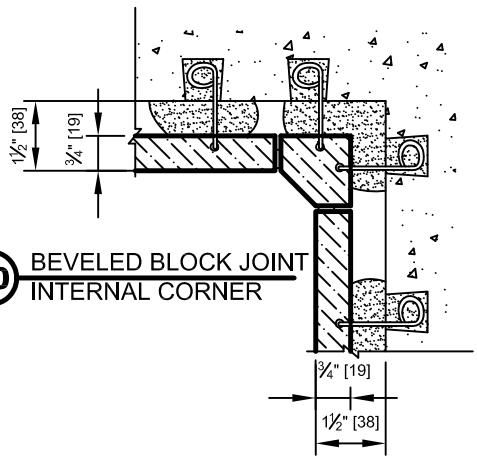
7 BUTT JOINT
INTERNAL CORNER



8 CORNER COVE JOINT
INTERNAL CORNER



9 CORNER BLOCK JOINT
INTERNAL CORNER



10 BEVELED BLOCK JOINT
INTERNAL CORNER

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INTERIOR STONE WALL CLADDING
CORNER DETAILS

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 15-D-20

SCALE: 3" = 1'-0"

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VERTICAL SURFACES – INTERIOR STONE BASE

1.0 INTRODUCTION

1.1 Installation Methods. There are several methods by which interior stone base 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 on the following page, and illustrations of examples at the close of this section.

1.2 Delivered ready to install. Generally, stone base is cut to required lengths by the fabricator, based on job-site measurements furnished by the stone contractor, and delivered to the job site ready to install.

1.3 Exposed stone edges must be gauged to the precise thickness specified. Gauging tolerance cannot be over ±1/32".

1.4 White portland cement is recommended for light-colored granite and marble. White portland cement with a low alkali content is recommended for limestone.

1.5 For additional information, refer to Chapter 13, Installation General Information.

1.6 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.

2.0 PRODUCT DESCRIPTION

2.1 Basic Use. Lowest or bottom part of structural elements such as columns, piers, and walls.

2.2 Fabrication. Stone base units are fabricated to dimensions specified on shop drawings, prefinished, and delivered to the job site ready to be cut into required lengths for installation.

2.3 Finishes. Exposed surfaces and edges are to be finished with any typical stone finish, usually polished.

2.4 Colors. Most of the commercially available varieties are suitable.

2.5 Sizes. Thicknesses of 3/8", ½", ¾", 7/8", 1¼", or as specified.

3.0 TECHNICAL DATA

3.1 Each stone variety used for interior stone base 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

3.1.4 Quartz-based Stone: ASTM C616, Standard Specification for Quartz-based Dimension Stone

3.1.5 Serpentine: ASTM C1526, Standard Specification for Serpentine Dimension Stone

3.1.6 Slate: ASTM C629, Standard Specification for Slate Dimension Stone

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3.1.7 Soapstone: No ASTM Standard exists at this time

3.1.8 Travertine: ASTM C1527, Standard Specification for Travertine Dimension Stone

4.0 INSTALLATION

4.1 Methods. Interior stone base can be installed either by the standard set method or the thin-set method.

4.2 Joints. Joints are pointed with white cement, grout, or nonstaining sealant. Joint width must be specified.

4.3 General Precaution. During construction, the General Contractor shall protect all stone from staining and damage.

NOTES:

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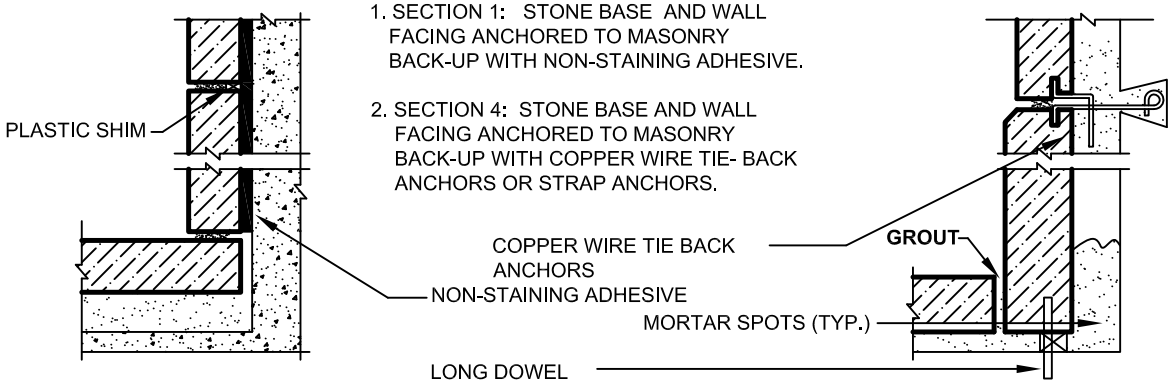
NOTES:
1. SECTION 1: STONE BASE AND WALL FACING ANCHORED TO MASONRY BACK-UP WITH NON-STAINING ADHESIVE.

2. SECTION 4: STONE BASE AND WALL FACING ANCHORED TO MASONRY BACK-UP WITH COPPER WIRE TIE- BACK ANCHORS OR STRAP ANCHORS.

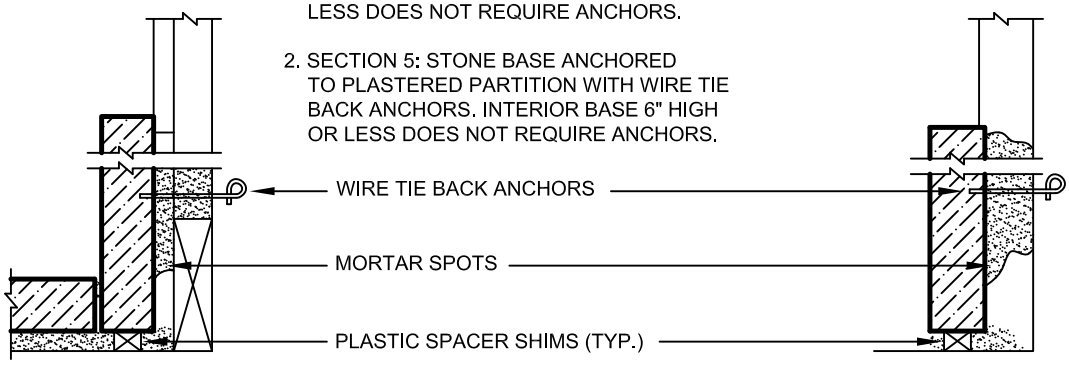


1 SECTION

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.

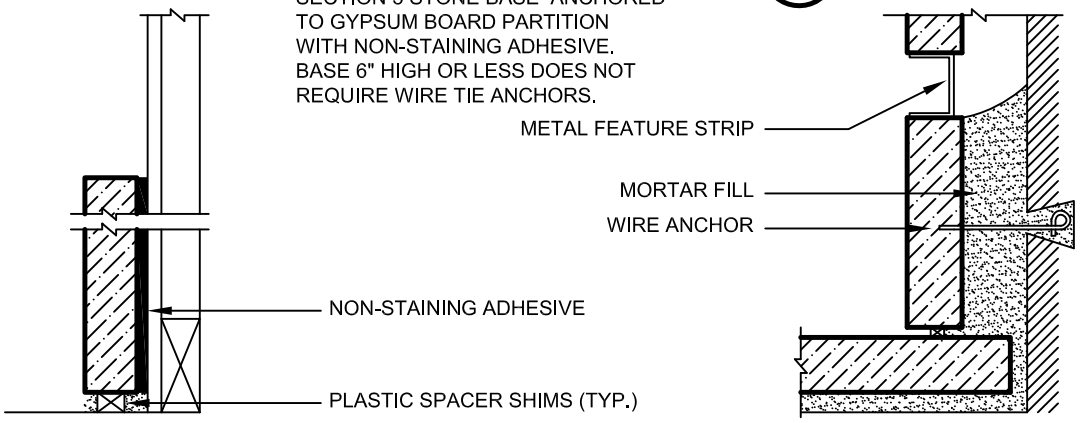
2. SECTION 5: STONE BASE ANCHORED TO PLASTERED PARTITION WITH WIRE TIE BACK ANCHORS. INTERIOR BASE 6" HIGH OR LESS DOES NOT REQUIRE ANCHORS.



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 CONTACT WITH STONE MUST BE CORROSION RESISTANT.

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INTERIOR STONE BASE TYPICAL DETAILS

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 15-D-21

SCALE: 6" = 1'-0"

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NOTES:

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VERTICAL SURFACES - STONE SOFFITS

1.0 INTRODUCTION

1.1 Installation Methods. There are several methods by which stone soffits can be installed. Consideration should be given to the various features of each method in making a selection for a particular installation. See detailed illustrations of examples at the close of this section.

2.0 DESIGN CRITERIA

2.1 Anchoring and Installation. Each soffit stone should be independently anchored and installed. When designing stone soffits, allow ample space above soffit for anchoring to the structure. Anchor quantity, type, and position shall be determined by load calculation and anchor strength, allowing adequate factors of safety in the design.

2.2 Soffit stones experience flexural stress due to gravity induced loads. Unlike windload, gravity loads are constant, and therefore allowable stresses in the stone panel design should be reduced to eliminate creep deformation.

2.3 Free spanning, exterior soffit stones of limited thickness may not have enough mass to resist uplifting forces caused by high wind conditions. It is therefore necessary to mechanically anchor the stone to resist upward in addition to downward forces.

2.4 Soffit installations encounter combined gravity and windloads working in the same direction. For this reason, fabrication tolerances with reference to panel thickness and anchor prep offset from panel face may become critical in soffit installations.

2.5 Caution. The use of wedge-type or expansion anchors in stone panels is not recommended due to the concentrated internal stresses experienced by the stone. In extreme cases these stresses can be great enough to fracture the stone panel.

2.6 Fascia Courses. Soffit stone of limited dimension may be attached to the fascia course by mechanical methods. Soffit stones of greater dimension may induce unacceptable rotational forces on the fascia stone. Reliance on adhesive attachment alone is not allowed.

2.7 Movement Joints: When anchoring soffit stones to overhead structure, care must be taken to recognize differential movement between floors and other structural elements. Movement joints must be adequately sized and accurately located to accommodate all anticipated movements. Ensure that movement joints are free of shims or other materials capable of transferring loads across the joint between the stones.

3.0 PRECAUTIONS

3.1 Only sound stone varieties should be used. Marble for soffit conditions is limited to soundness classification Group "A" and "B" marbles. If the soundness of any proposed stone cannot be reliably verified, other means of reinforcement will be necessary.

3.2 All stone soffit panels are to be mechanically anchored. Thin-setting thin stone tiles in soffit and ceiling applications is not recommended without the specific endorsement of the thin-set manufacturer.

3.3 For additional information, refer to Chapter 13, Installation General Information.

3.4 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.

4.0 PRODUCT DESCRIPTION

4.1 Basic Use. Horizontal underside of structural elements such as beams, arches, and cornices.

4.2 Fabrication. Soffits are precut and prefinished to dimensions specified on shop drawings, and delivered to the job site ready to install.

4.3 Finishes. Polished, honed, abrasive, thermal, and natural cleft for interior use; honed, abrasive, thermal, natural cleft, rough, and textured for exterior use. Polished marble or limestone is not recommended for exterior use.

4.4 Colors. Most of the commercially available varieties are suitable.

4.5 Sizes. Thicknesses of 1¼", 1½", 2", or greater are common. The actual required thickness is subject to the strength and durability of the selected stone.

5.0 TECHNICAL DATA

5.1 Each stone variety used for soffits should conform to the applicable ASTM standard specification and the physical requirements contained therein. The specification for each stone type are as follows:

5.1.1 Granite: ASTM C615, Standard Specification for Granite Dimension Stone

5.1.2 Limestone: ASTM C568, Standard Specification for Limestone Dimension Stone

5.1.3 Marble: ASTM C503, Standard Specification for Marble Dimension Stone (Soundness Groups A & B)

5.1.4 Quartz-based Stone: ASTM C616, Standard Specification for Quartz-based Dimension Stone

5.1.5 Slate: ASTM C629, Standard Specification for Slate Dimension Stone

5.1.6 Serpentine: ASTM C1526, Standard Specification for Serpentine Dimension Stone

5.1.7 Travertine: ASTM C1527, Standard Specification for Travertine Dimension Stone

6.0 INSTALLATION

6.1 Preparatory Work. The General Contractor must furnish suitable structural substrate to accommodate loads imposed upon it by the soffit anchorage.

6.2 Method. Soffits can be installed by conventional anchorage techniques or preassembled systems. Anchors shall be of non-staining and corrosion resistant metals.
6.2.1 Each soffit stone should be independently anchored and installed.

6.2.2 Joint widths shall be a minimum of 1/4". Wider joints are frequently required to accommodate thermal expansions and/or building movements. Caulk with nonstaining sealant.

6.3 General Precaution. During construction, the General Contractor shall protect all stone from staining or damage.

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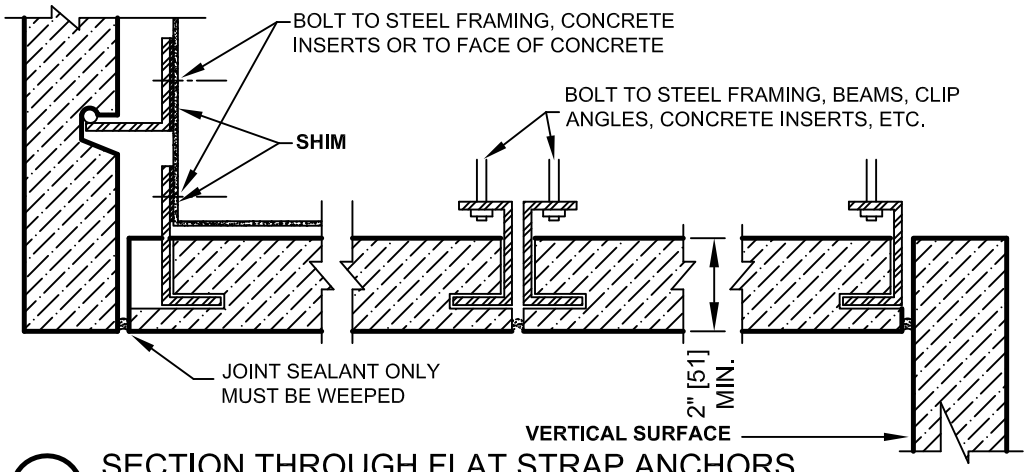
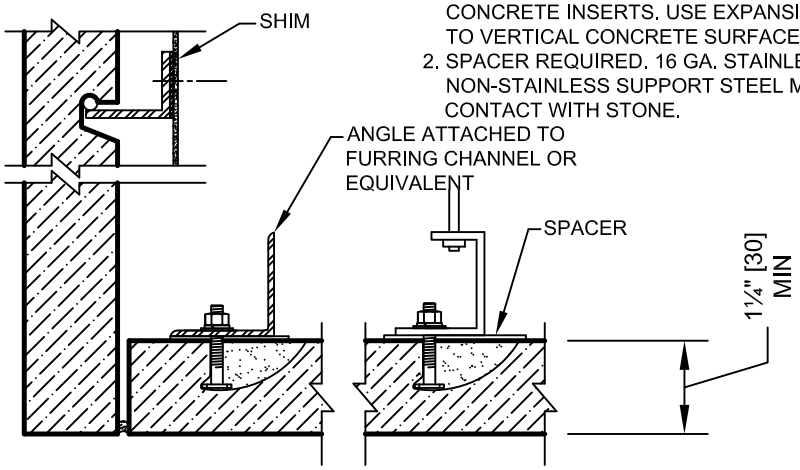
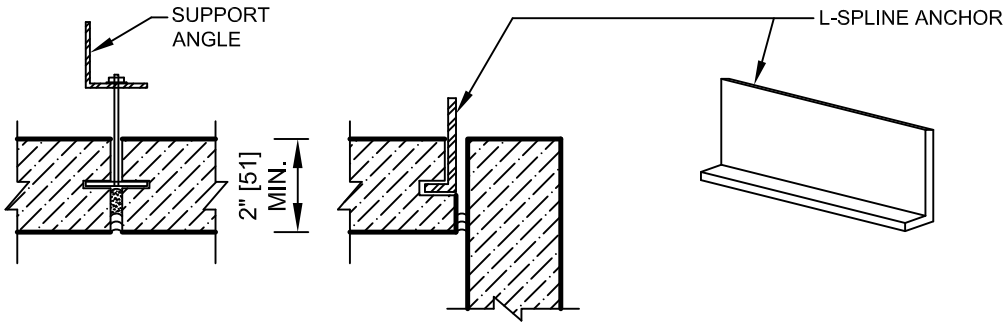


1 SECTION THROUGH FLAT STRAP ANCHORS

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 T-31 BACK ANCHORS



3 SECTION THROUGH DISC & L-SPLINE ANCHORS

NOTE: EACH STONE SOFFIT PIECE SHOULD BE ANCHORED INDEPENDENTLY FROM OTHER SOFFIT AND VERTICAL PIECES.

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STONE SOFFITS
EXTERIOR SOFFIT DETAILS

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 15-D-22

SCALE: 3" = 1'-0"

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NOTES:

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VERTICAL SURFACES - STONE FIREPLACE FACINGS

1.0 INTRODUCTION

1.1 Methods. There are several methods by which stone fireplace facings may be installed. Consideration should be given to each method when making a selection for a specific installation. See information about installation methods on the following page, and illustrations of examples at the close of this section.

2.0 DESIGN CRITERIA

2.1 Fireplace headers and legs (uprights) may be thin-set if stone is no thicker than ½". Fastening of stone slab thicker than ½" must be mechanical unless specifically designed and approved by the thin-set manufacturer.

2.2 Exposed stone edges must be gauged to the precise thickness specified. Gauging tolerance cannot be over ±1/32".

2.3 Backup Materials/Temperature. Cracking of fireplace facings is primarily due to expansion and contraction of backup materials. Ensure that stone surface temperatures do not exceed ability to safely and comfortably touch the stone facing when a fire is burning in the fireplace. Setting space between stone and backup should be at least ¾".

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.

2.5 For additional information, refer to Chapter 13, Installation General Information.

2.6 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 PRODUCT DESCRIPTION

3.1 Basic Use. As interior stone fireplace facings for commercial, institutional, and residential use.

3.2 Finishes. Polished, honed, natural cleft.

3.3 Colors. Most of the commercially available varieties are suitable.

3.4 Sizes. Thicknesses of 3/8", ½", ¾", 7/8", 1¼", or as specified.

4.0 TECHNICAL DATA

4.1 Each stone variety used for fireplace facings should conform to the applicable ASTM standard specification and the physical requirements contained therein. The specification for each stone type are as follows:

4.1.1 Granite: ASTM C615, Standard Specification for Granite Dimension Stone

4.1.2 Limestone: ASTM C568, Standard Specification for Limestone Dimension Stone

4.1.3 Marble: ASTM C503, Standard Specification for Marble Dimension Stone

4.1.4 Quartz-based Stone: ASTM C616, Standard Specification for Quartz-based Dimension Stone

4.1.5 Slate: ASTM C629, Standard Specification for Slate Dimension Stone

4.1.6 Serpentine: ASTM C1526, Standard Specification for Serpentine Dimension Stone

4.1.7 Soapstone: No ASTM Standard exists at this time

4.1.8 Travertine: ASTM C1527, Standard Specification for Travertine Dimension Stone

5.0 INSTALLATION

5.1 Standard Set System. Stone facings are set firmly against mortar spots located at anchors.

5.2 Thin Set System. A nonstaining adhesive should be spread over the backup wall with a notched trowel and the stone facing positioned plumb against the adhesive. Used for stone no thicker than ½".

5.3 Back Buttering. 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.

5.4 General Precaution. During construction, the General Contractor shall protect all stone from staining and damage.

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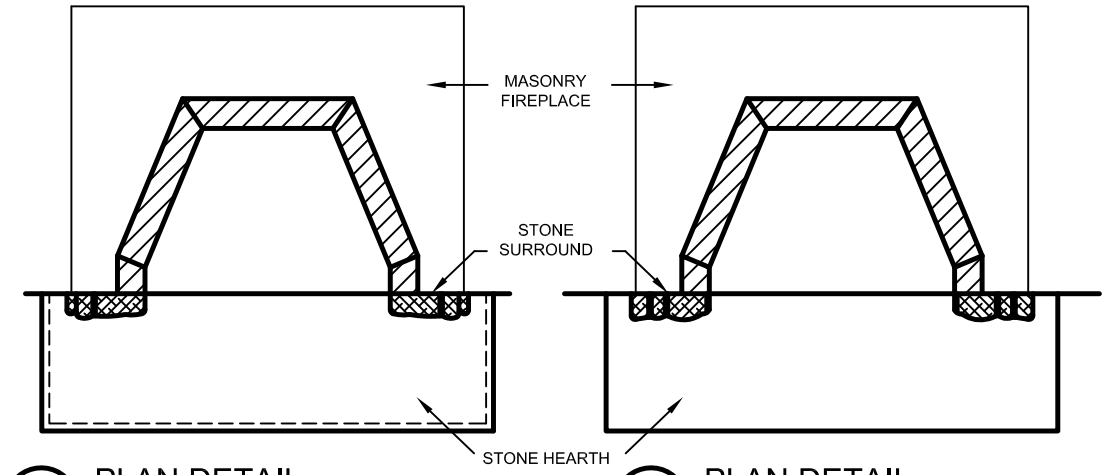
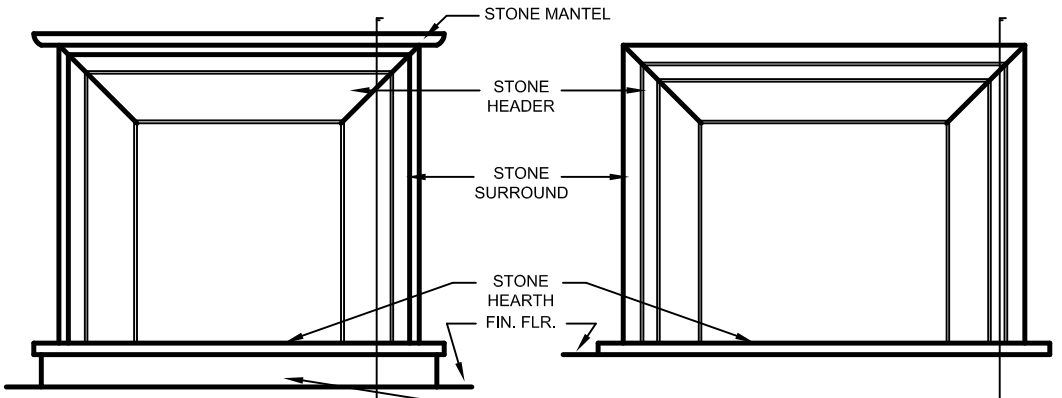


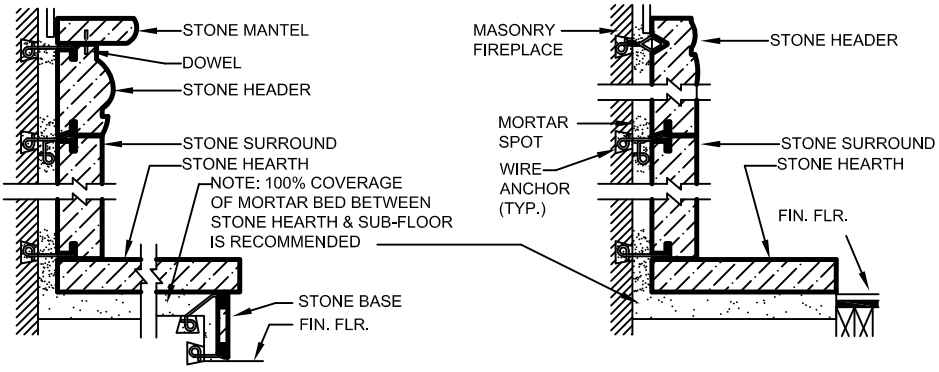
1 PLAN DETAIL
Scale: ½" = 1'-0"

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 FACINGS TYPICAL DETAILS

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 15-D-23

SCALE: As Noted

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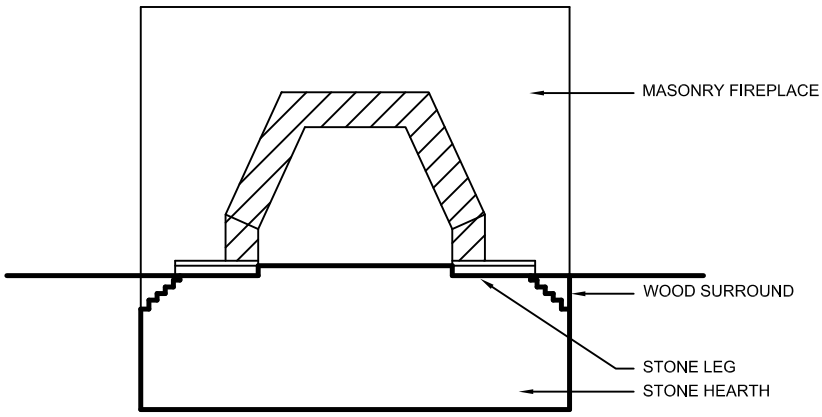
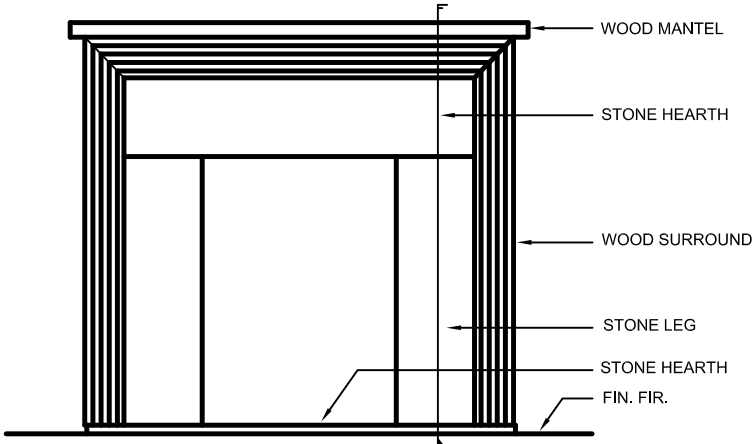
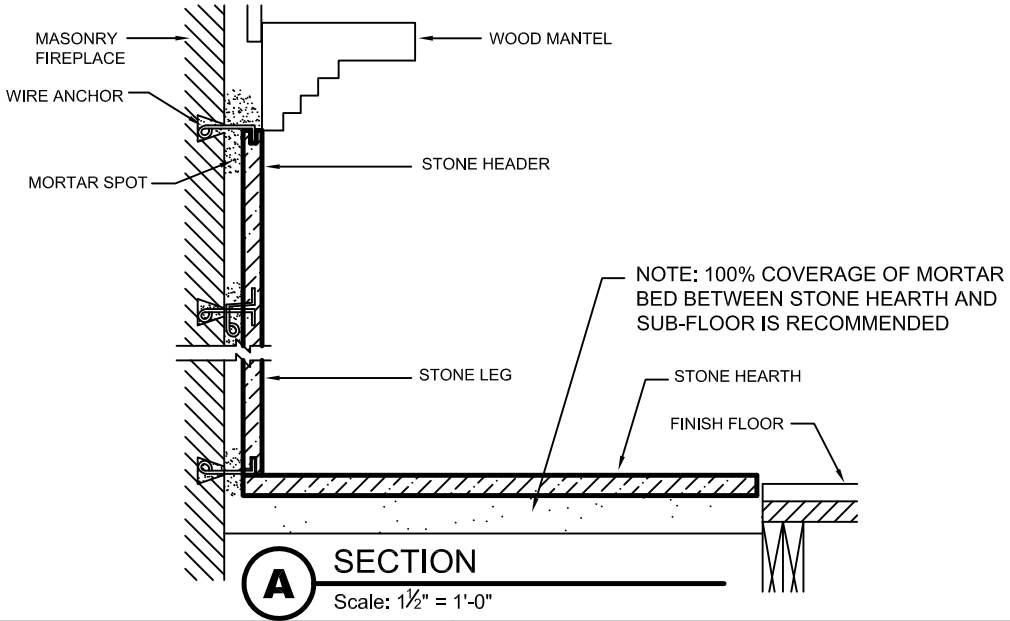


1 PLAN DETAIL
Scale: ½" = 1'-0"



2 ELEVATION
Scale: ½" = 1'-0"



A SECTION
Scale: 1½" = 1'-0"

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STONE FIREPLACE FACINGS TYPICAL DETAILS

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 15-D-24

SCALE: As Noted

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WET AREAS – GENERAL INFORMATION

1.0 INSTALLATION OF DIMENSION STONE IN WET AREAS

This chapter of the Marble Institute of America'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 chapter 13, Installation – General Information.

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] The Marble Institute of America 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.*

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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.

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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.

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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" 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 the 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.

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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" 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

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1/16" 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 15, 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 or medium bed 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'. 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" above the finished surface of the shower curb (6" 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" 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" 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" above the finished surface of the shower curb (6" 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 or medium 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.

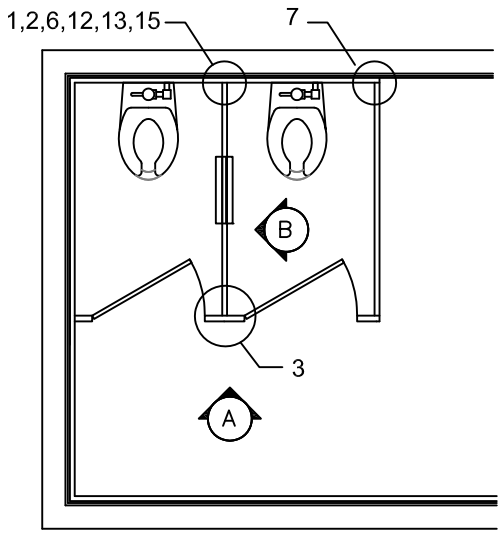
2.0 PENETRATIONS

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.

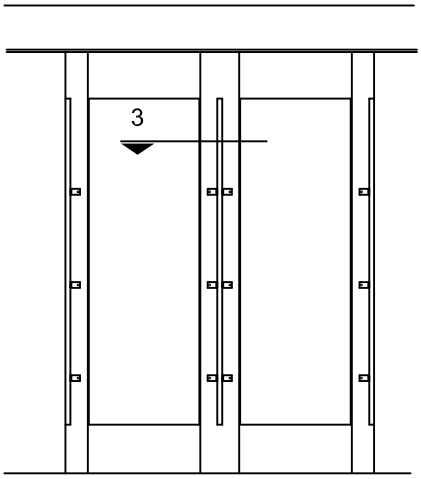
2.2 All openings, cut-outs or protrusions through the waterproofing system should be sealed with a suitable flexible sealant.

2.3 Any opening penetrating the water-proof envelope must be flashed and sealed to become an integral part of the system.

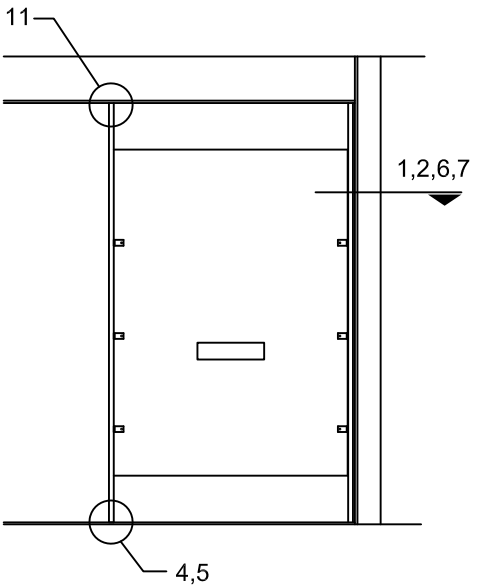
2.4 Any penetrations through the stone shall be made waterproof with a non-staining flexible sealant.



PLAN
TYPICAL LAYOUT



ELEVATION A
HARDWARE MOUNTED



ELEVATION B
HARDWARE MOUNTED

FLOOR SUPPORTED STALL

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0	01 Aug, '13

STONE TOILET PARTITIONS
FLOOR–SUPPORTED PARTITION DETAILS

MIA DIMENSION STONE DESIGN MANUAL VII

DRWG NO: 16–D–1

SCALE: ¼" = 1'–0"

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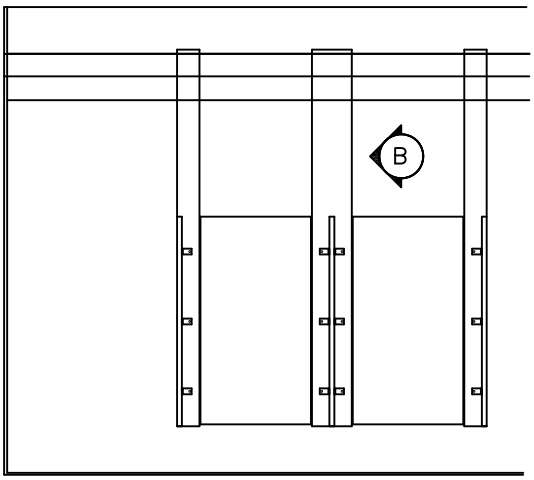

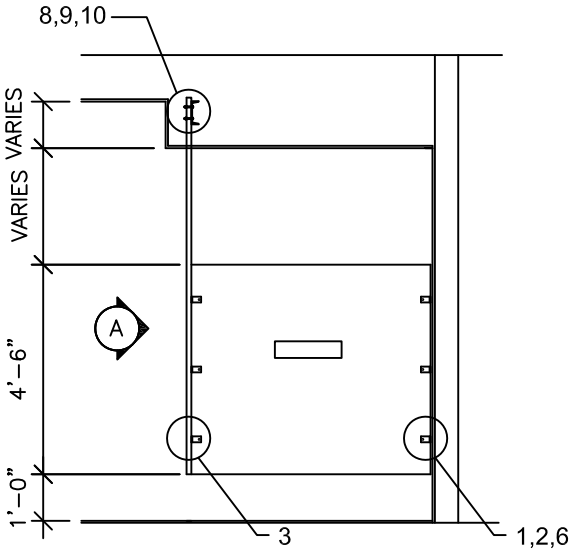

ELEVATION A
HARDWARE MOUNTED

ELEVATION B
HARDWARE MOUNTED

CEILING MOUNTED STALL

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STONE TOILET PARTITIONS
CEILING–MOUNTED PARTITION DETAILS

MIA DIMENSION STONE DESIGN MANUAL VII

DRWG NO: 16–D–2

SCALE: ¼" = 1'–0"

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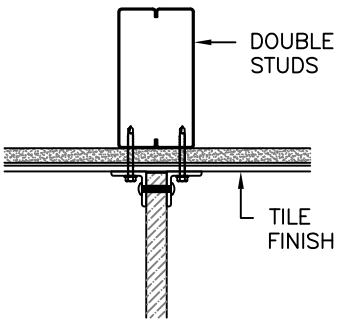
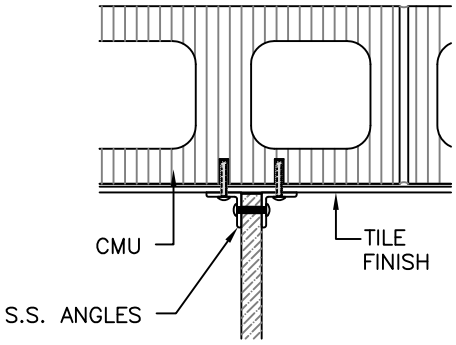
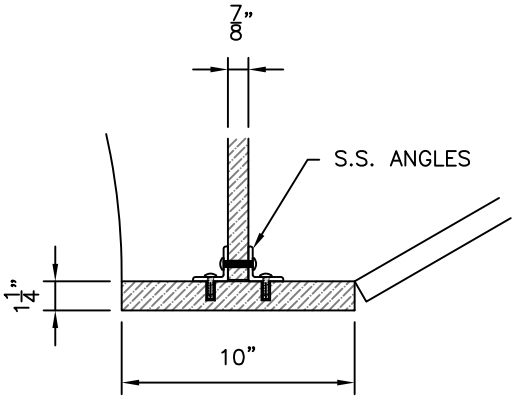


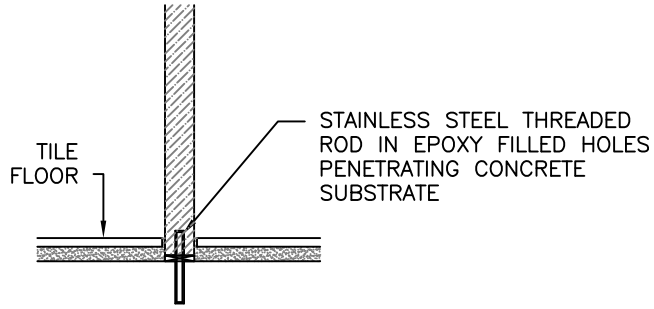
PLAN 1
HARDWARE MOUNTED



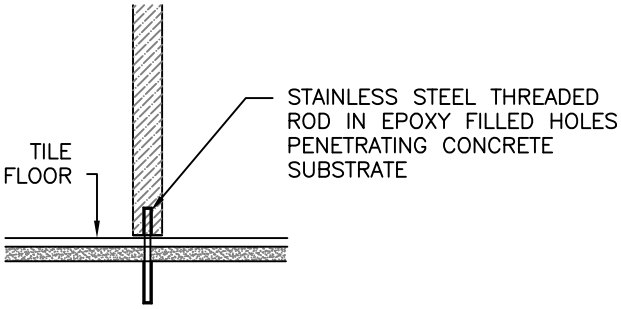
PLAN 2
HARDWARE MOUNTED



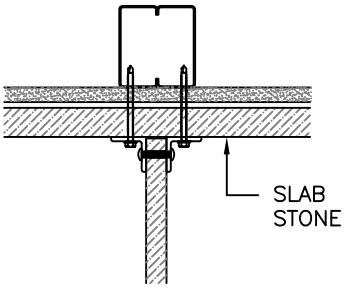
PLAN 3
HARDWARE MOUNTED



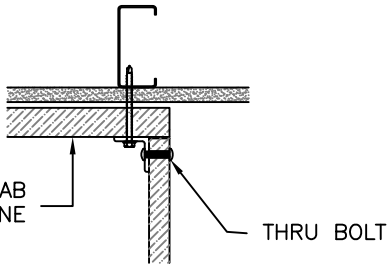
SECTION 4
FLOOR SUPPORTED



SECTION 5
FLOOR SUPPORTED



PLAN 6
HARDWARE MOUNTED



PLAN 7
HARDWARE MOUNTED

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STONE TOILET PARTITIONS
FLOOR–SUPPORTED PARTITION DETAILS

MIA DIMENSION STONE DESIGN MANUAL VII

DRWG NO: 16–D–3

SCALE: 1½" = 1'–0"

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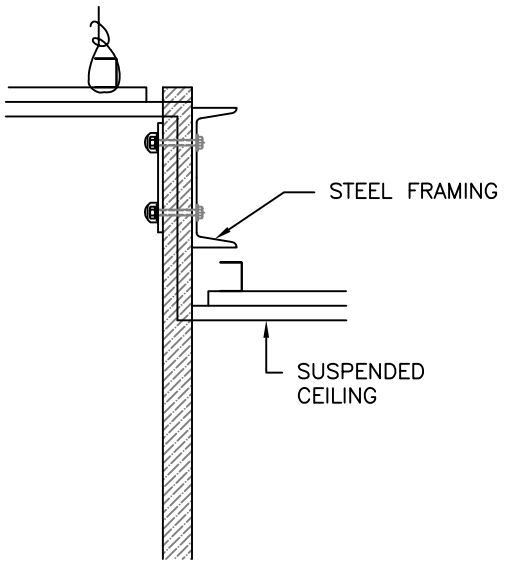
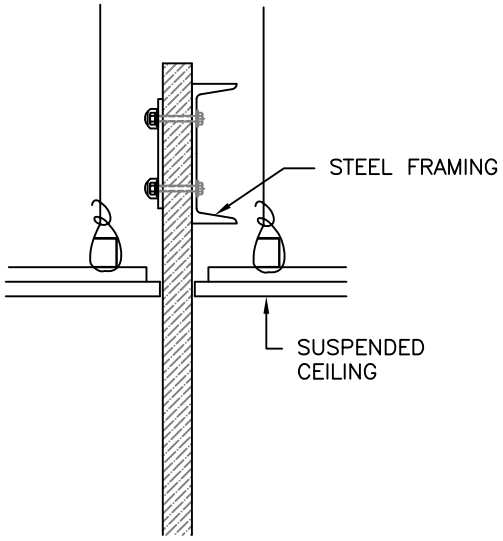
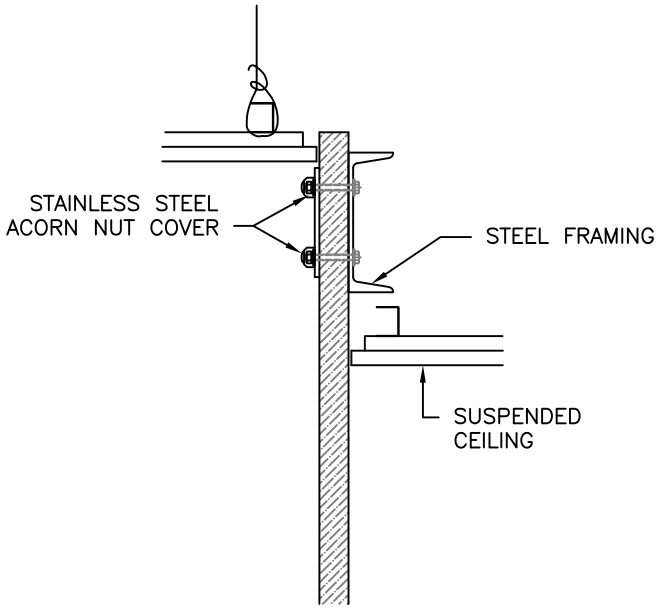


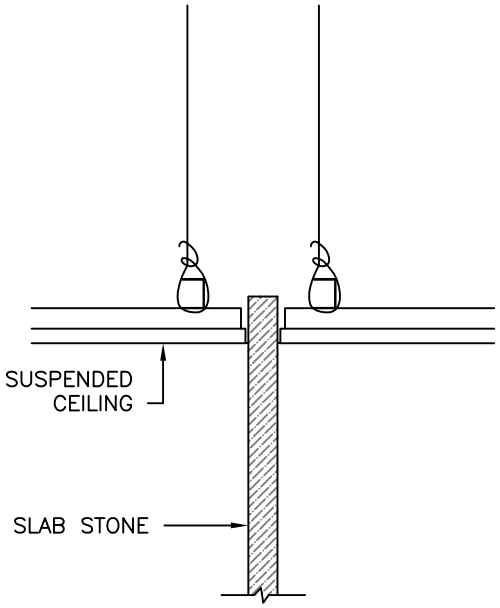
DETAIL 8
CEILING MOUNTED



DETAIL 9
CEILING MOUNTED



DETAIL 10
CEILING MOUNTED



DETAIL 11
FLOOR MOUNTED

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STONE TOILET PARTITIONS
CEILING MOUNTING DETAILS

MIA DIMENSION STONE DESIGN MANUAL VII

DRWG NO: 16–D–4

SCALE: 1½" = 1'–0"

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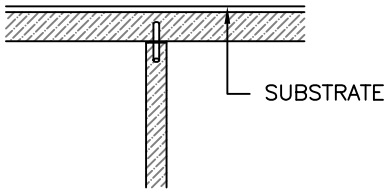
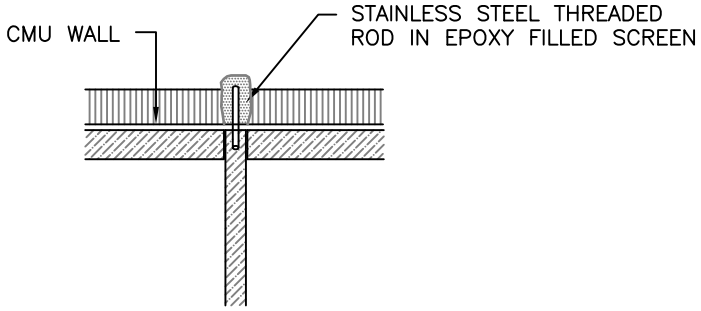
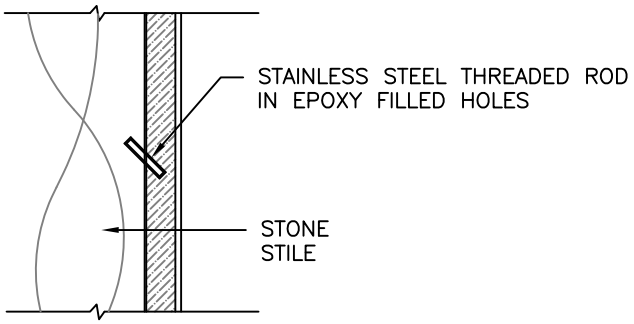


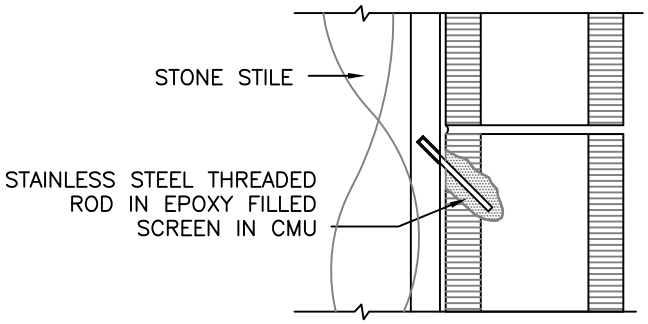
PLAN 12
DOWEL MOUNTED



PLAN 13
DOWEL MOUNTED



SECTION 14
DOWEL MOUNTED



SECTION 15
DOWEL MOUNTED

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STONE TOILET PARTITIONS
DOWEL–MOUNTED PARTITION DETAILS

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DRWG NO: 16–D–5

SCALE: 1½" = 1'–0"

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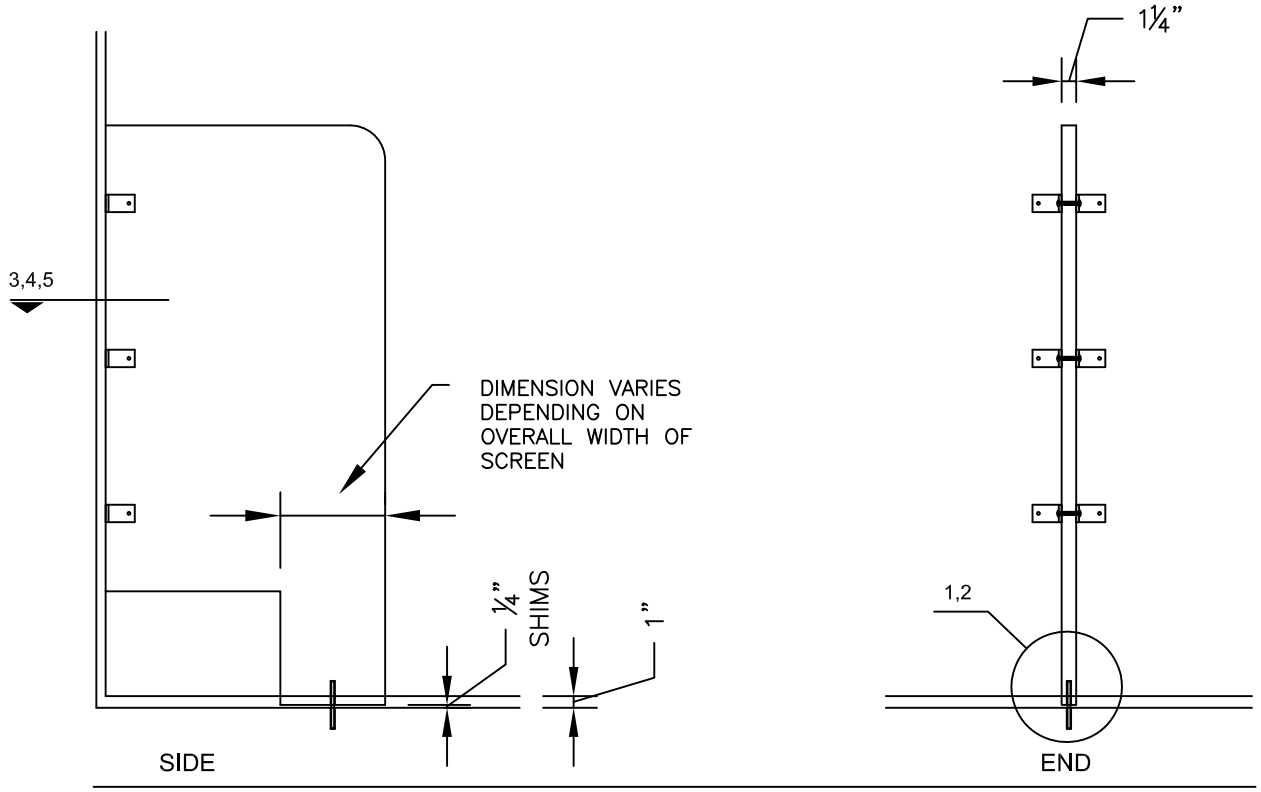
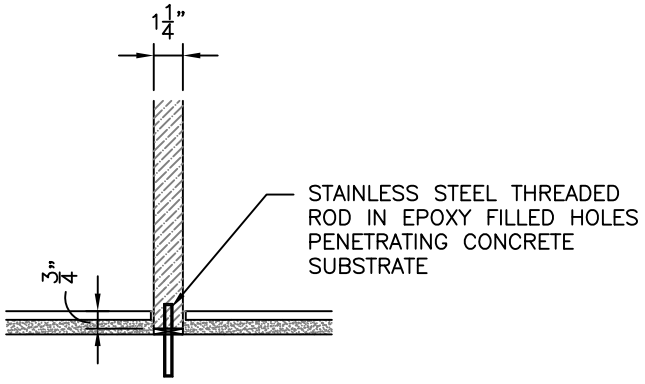


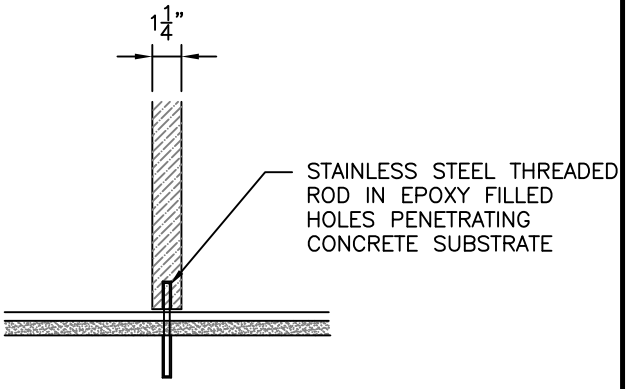
URINAL SCREEN ELEVATIONS - FLOOR SUPPORTED

3/4"=1'-0"



DETAIL 1

LEG PENETRATING FLOOR



DETAIL 2

LEG RESTING ON FLOOR

1 1/2"=1'-0"

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STONE URINAL PARTITIONS
FLOOR–SUPPORTED PARTITION DETAILS

MIA DIMENSION STONE DESIGN MANUAL VII

DRWG NO: 16–D–6

SCALE: AS NOTED

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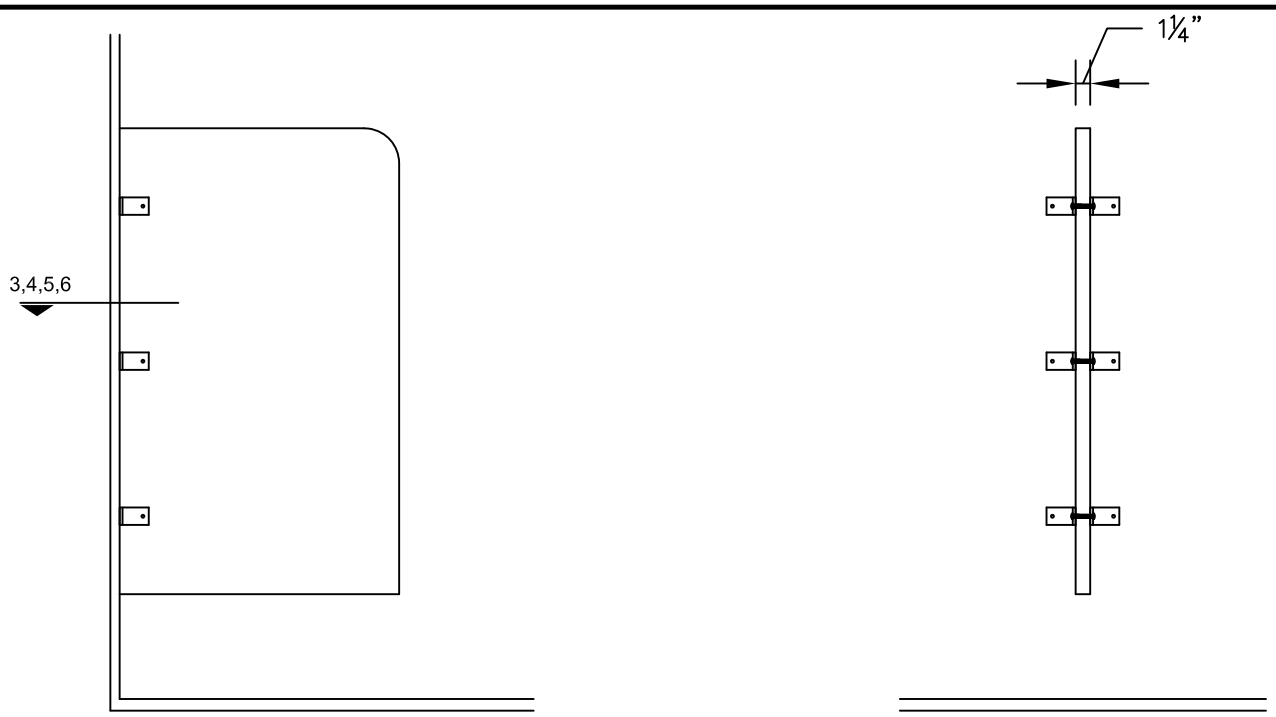
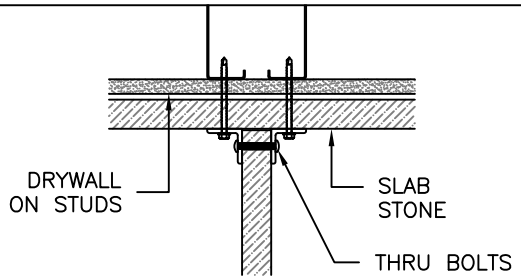
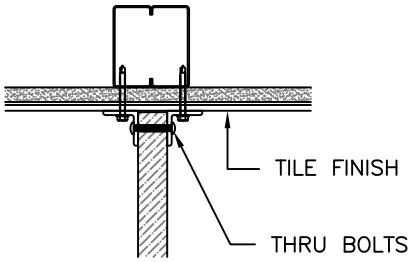


URINAL SCREEN ELEVATIONS - WALL MOUNTED

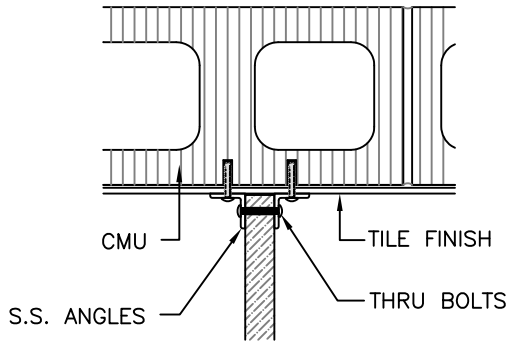
3/4"=1'-0"



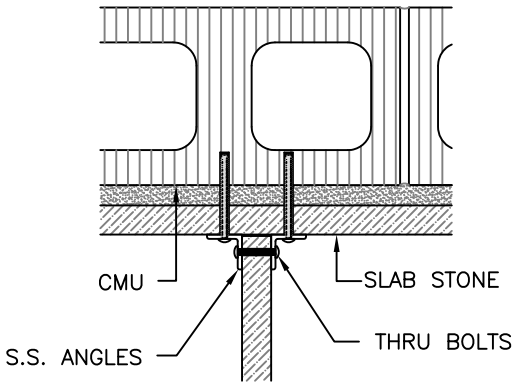
PLAN 3
HARDWARE MOUNTED



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 DETAILS

MIA DIMENSION STONE DESIGN MANUAL VII

DRWG NO: 16–D–7

SCALE: AS NOTED

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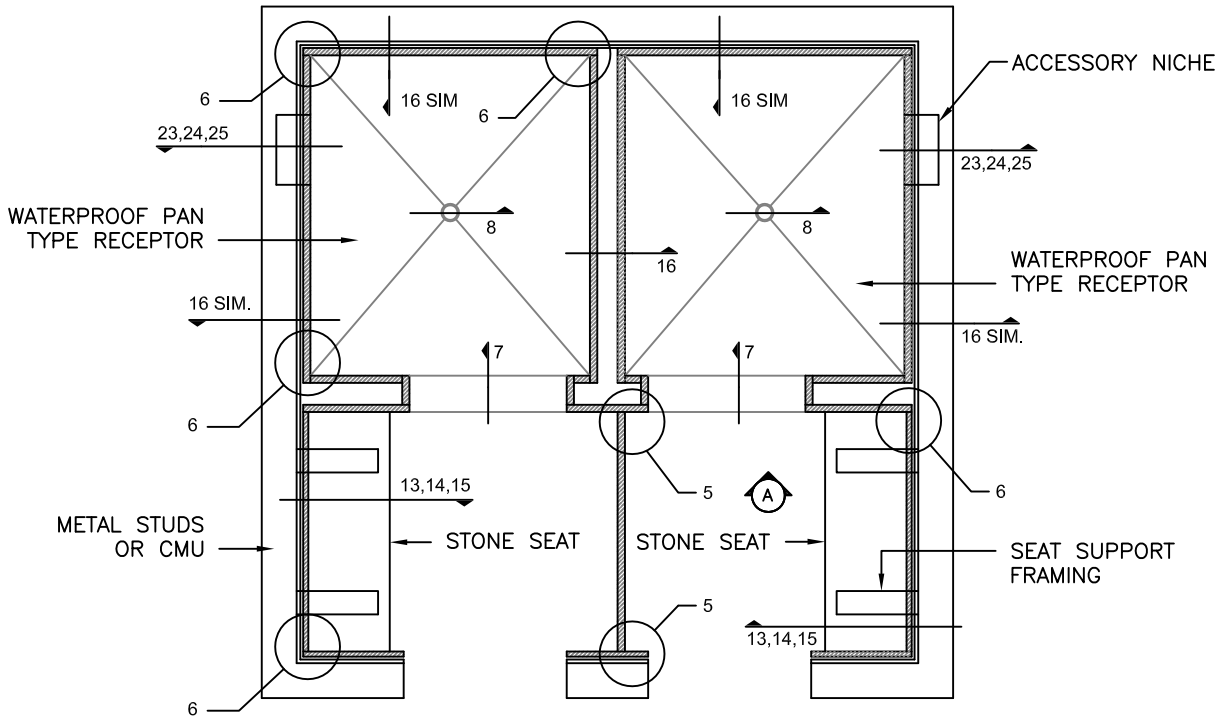
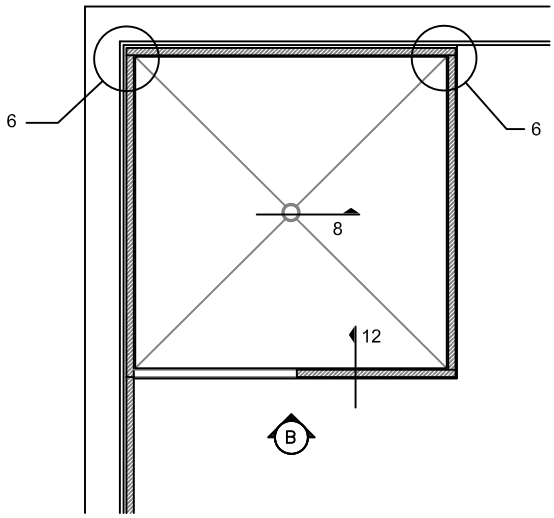


PLAN

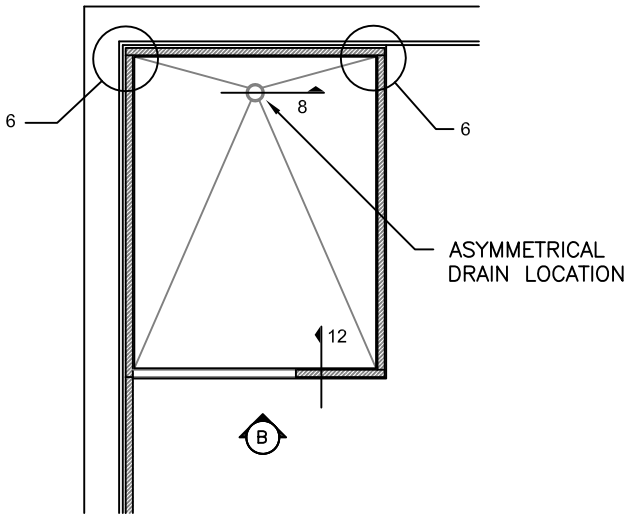
WATERPROOF PAN RECEPTOR TYPE

3/8"=1'-0"



PLAN

PRECAST RECEPTOR TYPE



PLAN

PRECAST RECEPTOR TYPE

3/8"=1'-0"

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STONE SHOWER PARTITIONS
TYPICAL PLANS

MIA DIMENSION STONE DESIGN MANUAL VII

DRWG NO: 16–D–8

SCALE: 3/8" = 1'–0"

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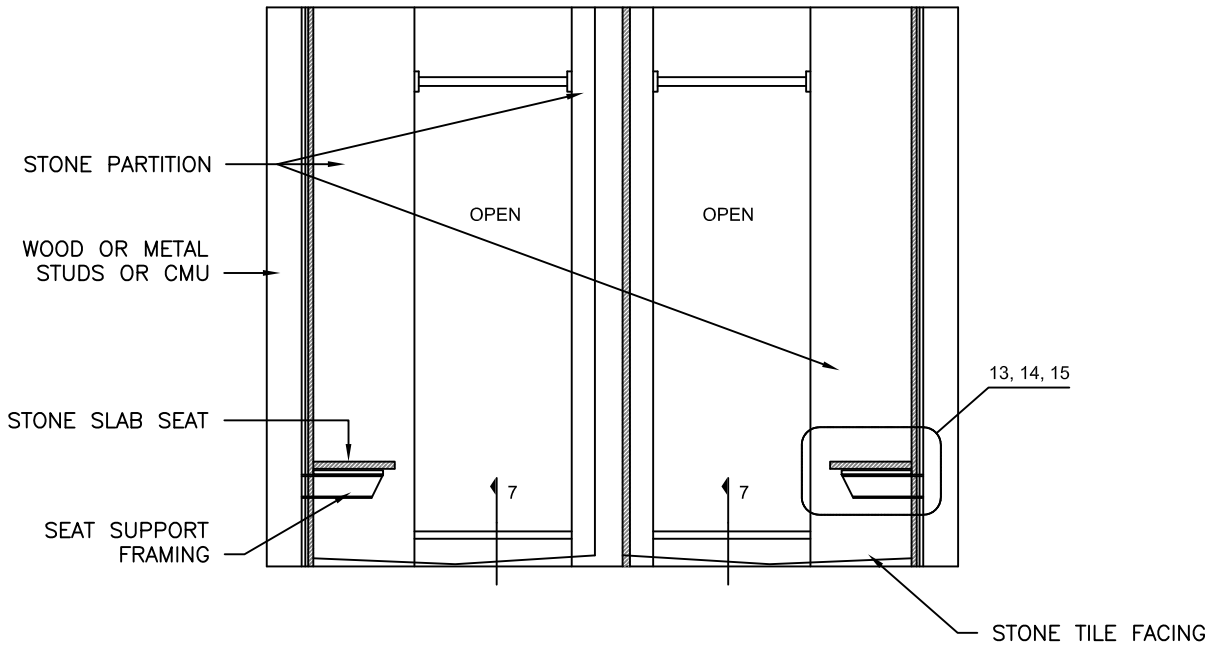
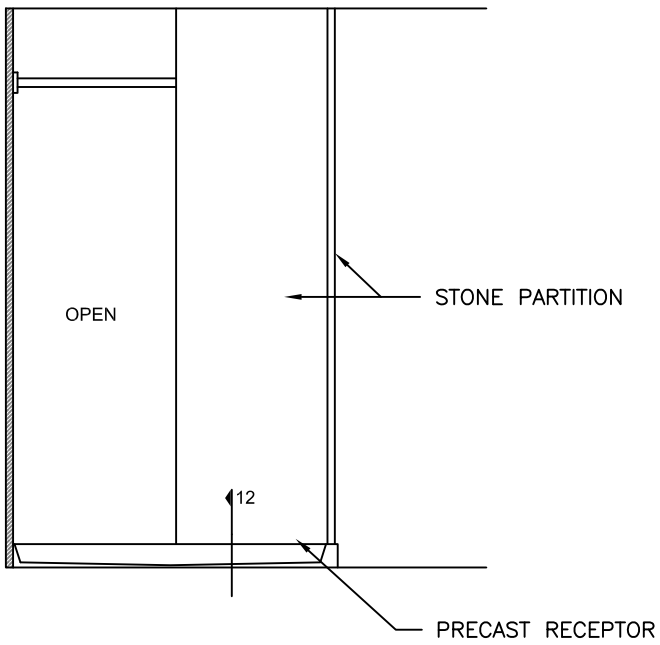


ELEVATION A
WATERPROOF PAN RECEPTOR TYPE

3/8"=1'-0"



ELEVATION B
PRECAST RECEPTOR TYPE

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STONE SHOWER PARTITIONS
TYPICAL ELEVATIONS

MIA DIMENSION STONE DESIGN MANUAL VII

DRWG NO: 16–D–9

SCALE: 3/8" = 1'–0"

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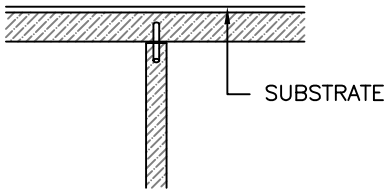
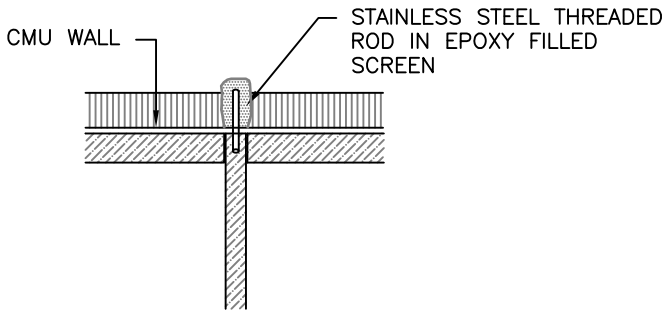
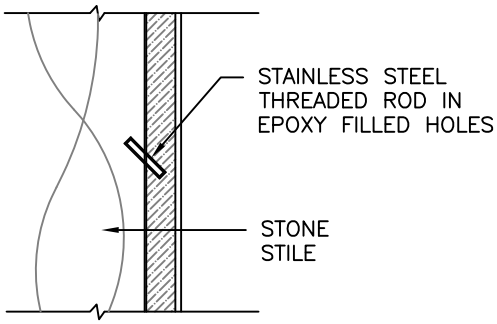


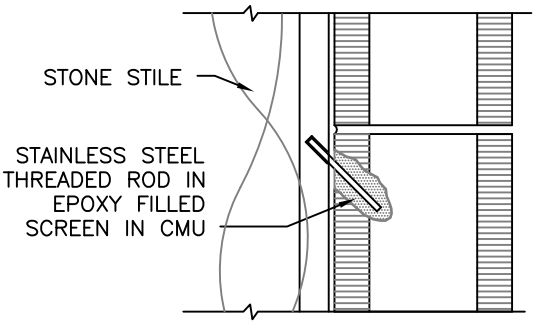
PLAN 1
DOWEL MOUNTED



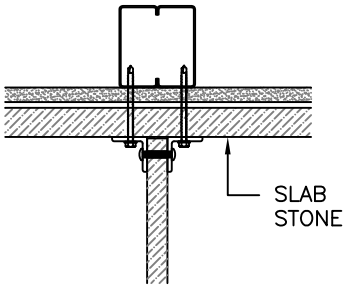
PLAN 2
DOWEL MOUNTED



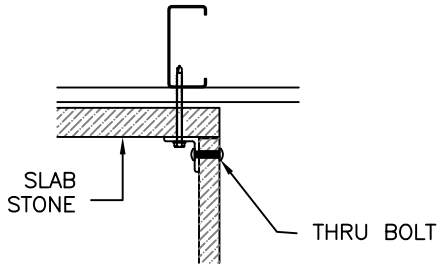
SECTION 3
DOWEL MOUNTED



SECTION 4
DOWEL MOUNTED



PLAN 5
HARDWARE MOUNTED



PLAN 6
CORNER

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STONE SHOWER PARTITIONS
TYPICAL DETAILS

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SCALE: 1½" = 1'–0"

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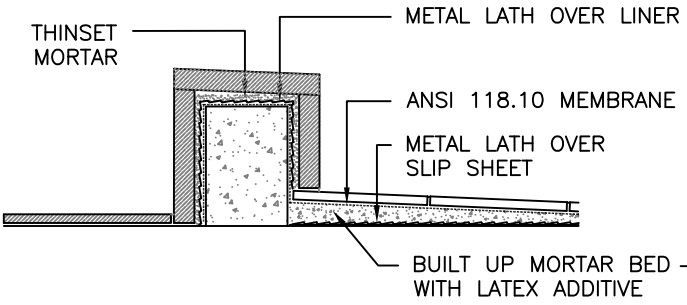
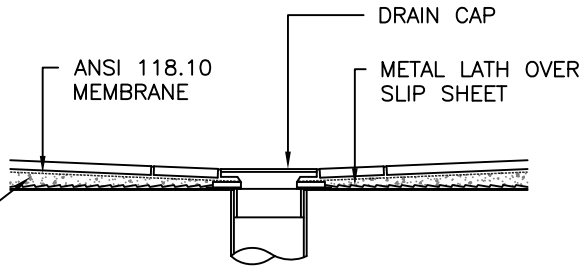
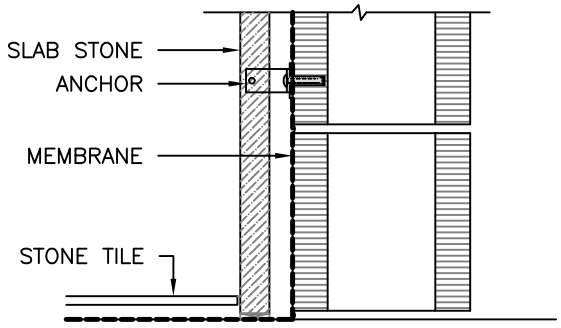


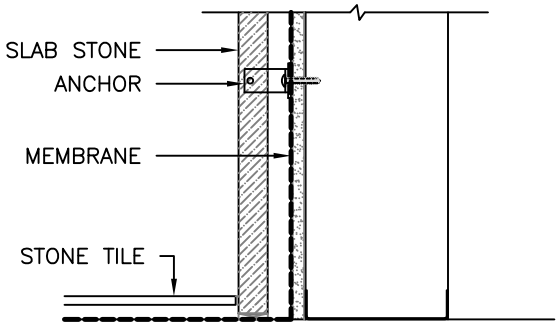
SECTION 7
SHOWER STALL CURB



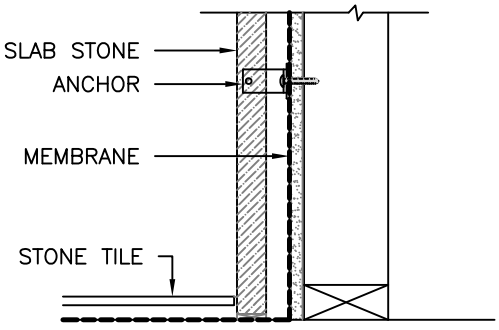
SECTION 8
SHOWER STALL DRAIN



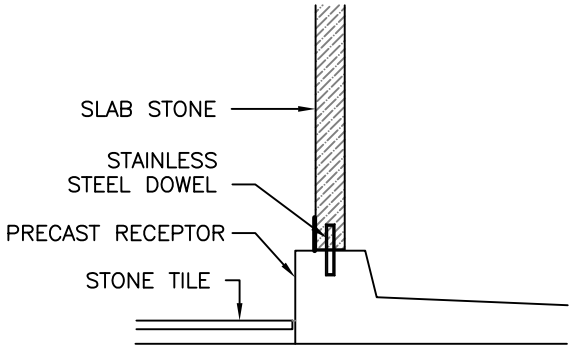
SECTION 9
BOTTOM OF STONE AT CMU



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
TYPICAL DETAILS

MIA DIMENSION STONE DESIGN MANUAL VII

DRWG NO: 16–D–11

SCALE: 1½" = 1'–0"

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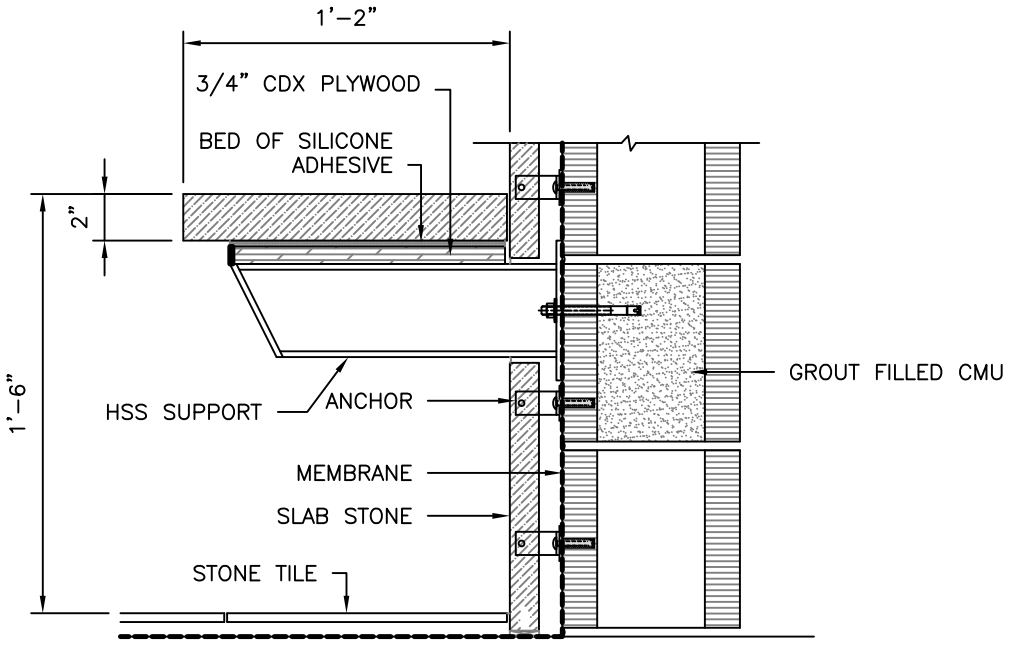
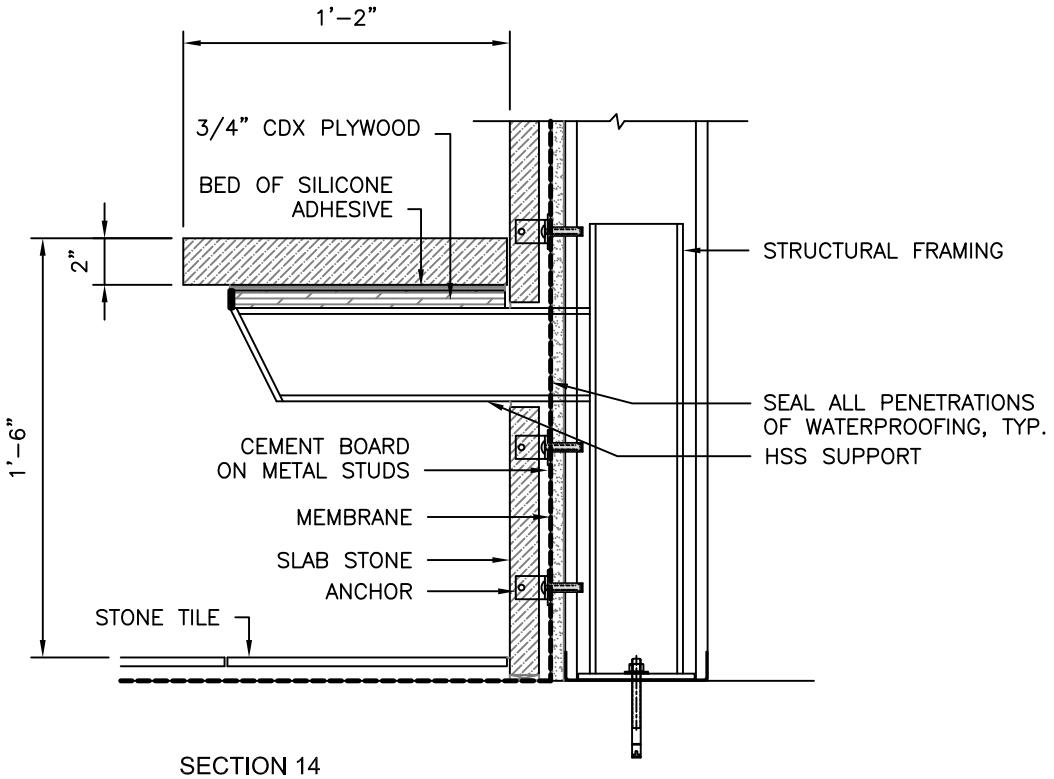


SECTION 13

STONE SEAT AT CMU WALL



SECTION 14

STONE SEAT AT METAL STUD WALL

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STONE SHOWER PARTITIONS
TYPICAL DETAILS

MIA DIMENSION STONE DESIGN MANUAL VII

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SCALE: 1½" = 1'–0"

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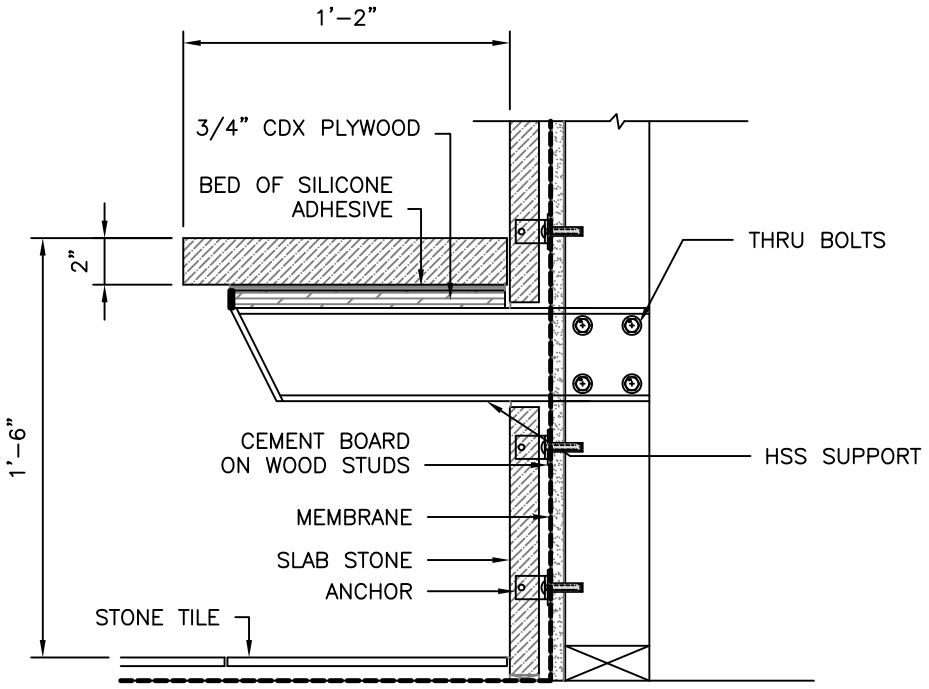
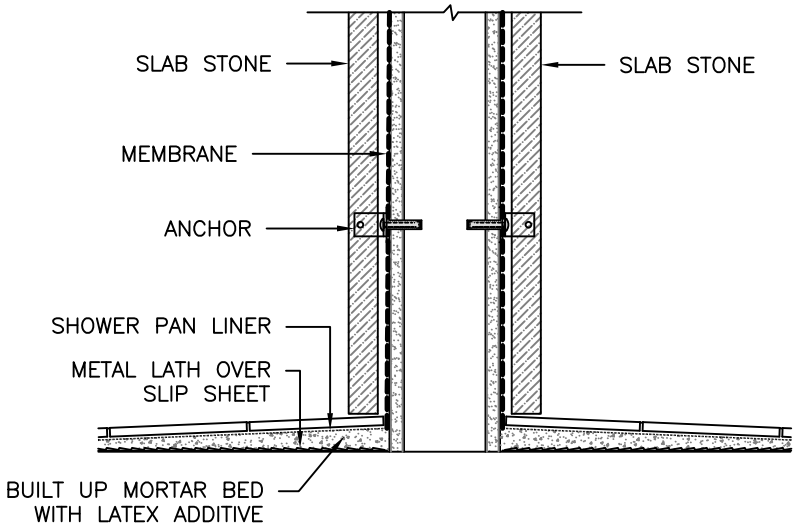


SECTION 15

STONE SEAT AT WOOD STUD WALL



SECTION 16

STONE CLAD SHOWER DIVIDER WALL

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STONE SHOWER PARTITIONS
TYPICAL DETAILS

MIA DIMENSION STONE DESIGN MANUAL VII

DRWG NO: 16–D–13

SCALE: 1½" = 1'–0"

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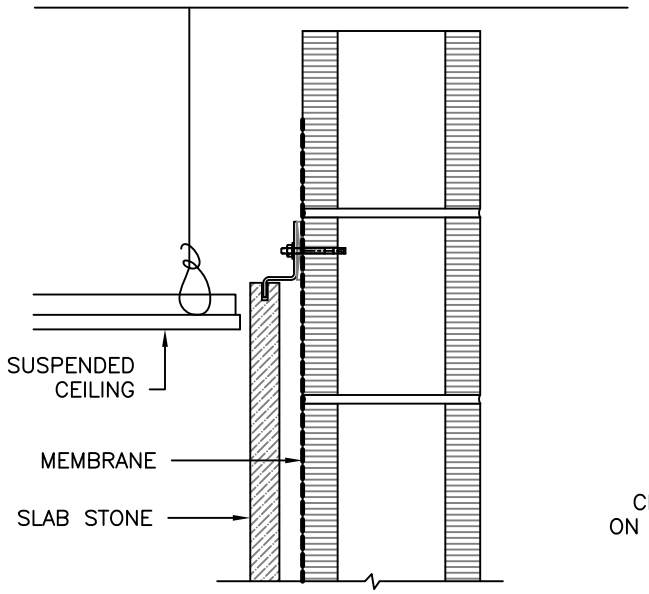
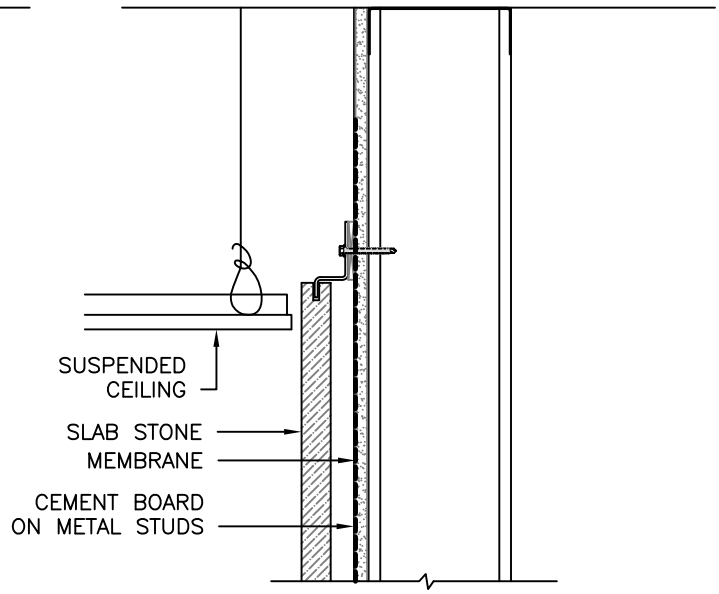
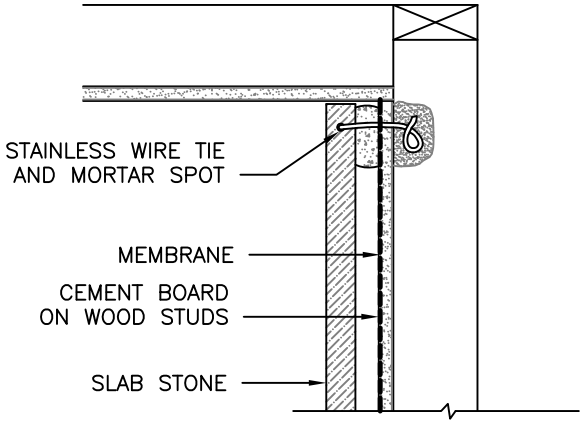


SECTION 17
TOP OF STONE AT CMU



SECTION 18
TOP OF STONE AT METAL STUDS



SECTION 19
TOP OF STONE AT WOOD STUDS

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STONE SHOWER PARTITIONS
TYPICAL DETAILS

MIA DIMENSION STONE DESIGN MANUAL VII

DRWG NO: 16–D–14

SCALE: 1½" = 1'–0"

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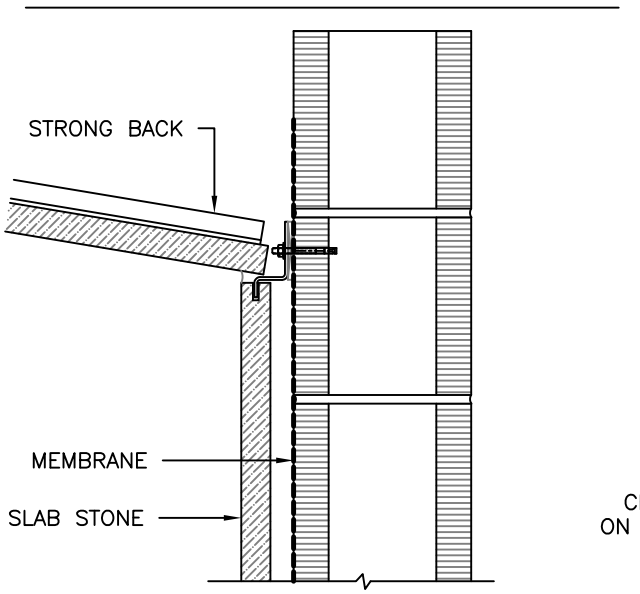
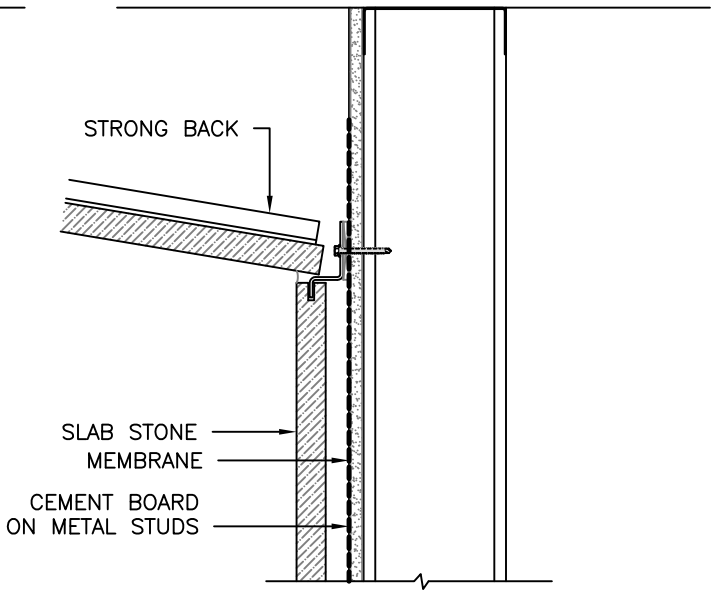
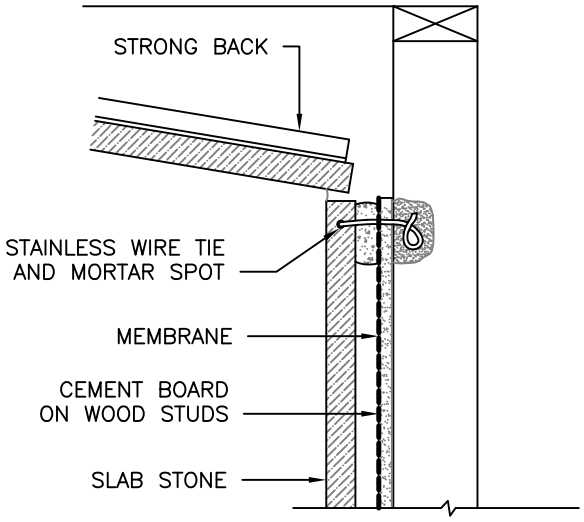


SECTION 20
SLOPING STONE CEILING AT CMU



SECTION 21
SLOPING STONE CEILING AT METAL STUDS



SECTION 22
SLOPING STONE CEILING AT WOOD STUDS

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STONE SHOWER CEILINGS
TYPICAL DETAILS

MIA DIMENSION STONE DESIGN MANUAL VII

DRWG NO: 16–D–15

SCALE: 1½" = 1'–0"

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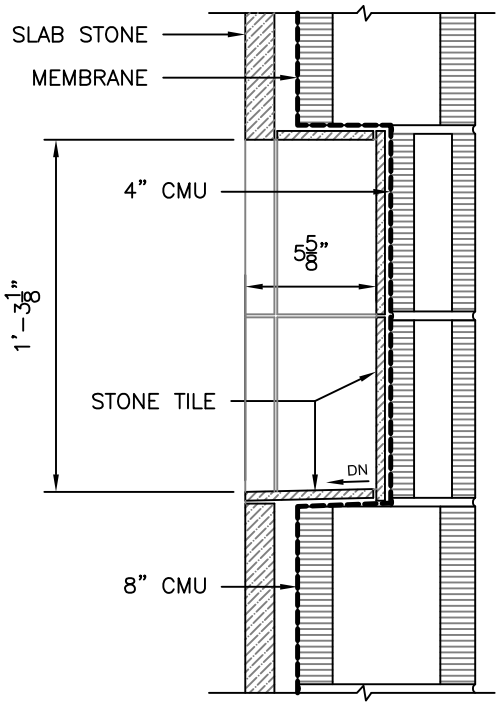
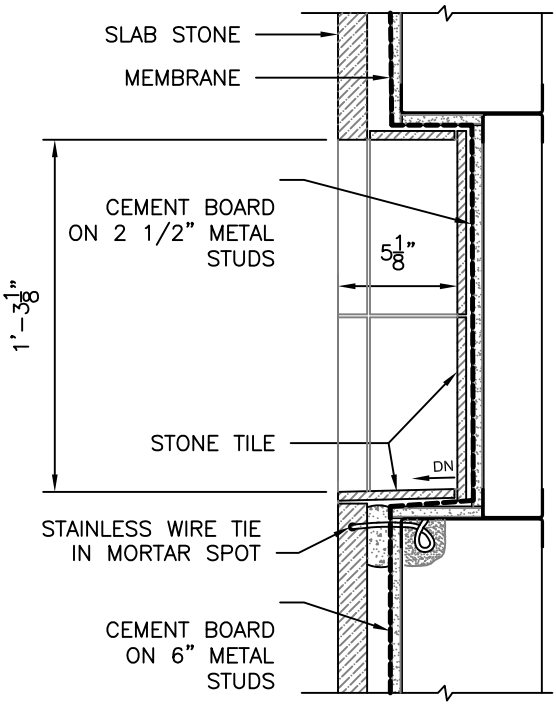
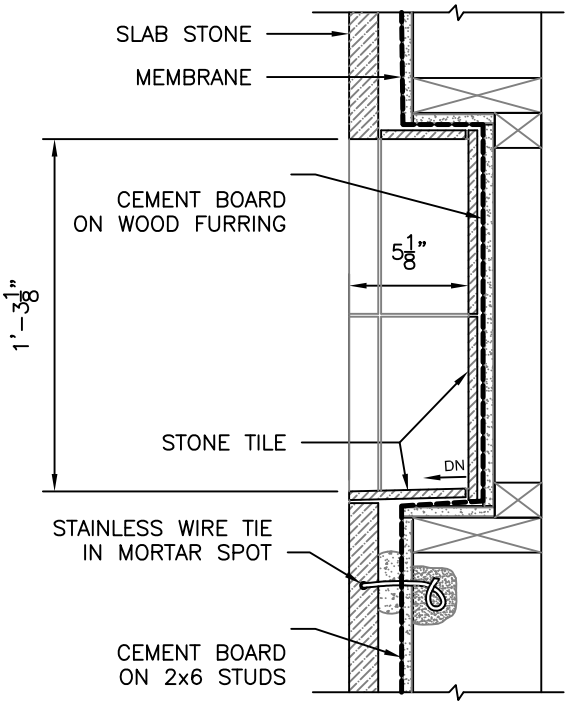


SECTION 23
ACCESSORY NICHE AT CMU



SECTION 24
ACCESSORY NICHE AT METAL STUDS



SECTION 25
ACCESSORY NICHE AT WOOD STUDS

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STONE SHOWER ACCESSORY NICHE
TYPICAL DETAILS

MIA DIMENSION STONE DESIGN MANUAL VII

DRWG NO: 16-D-16

SCALE: 1½" = 1'-0"

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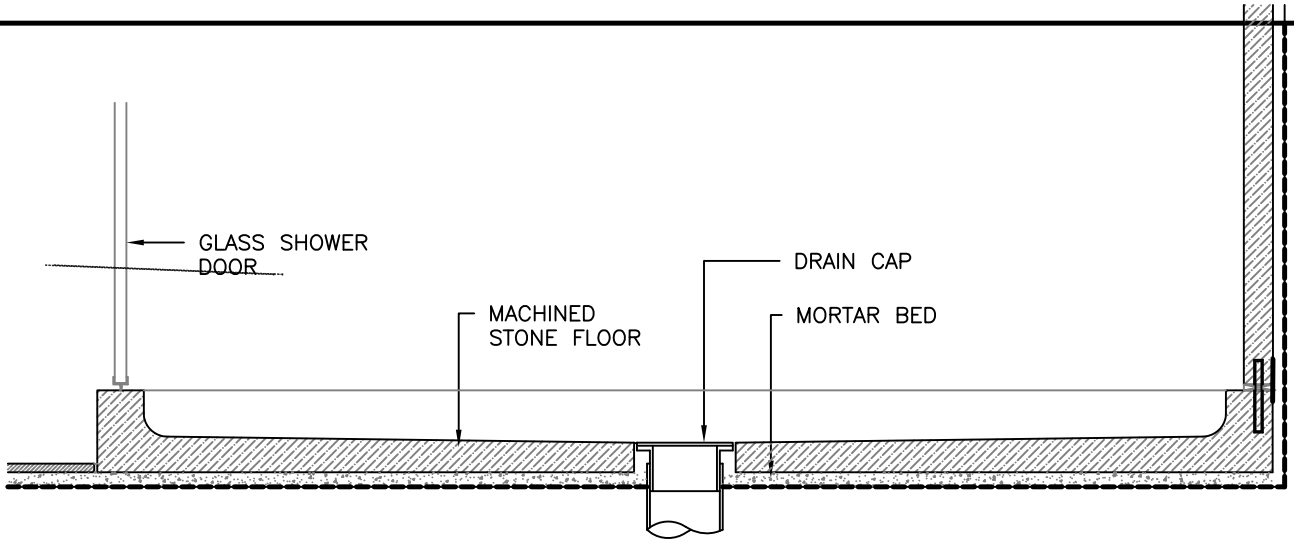
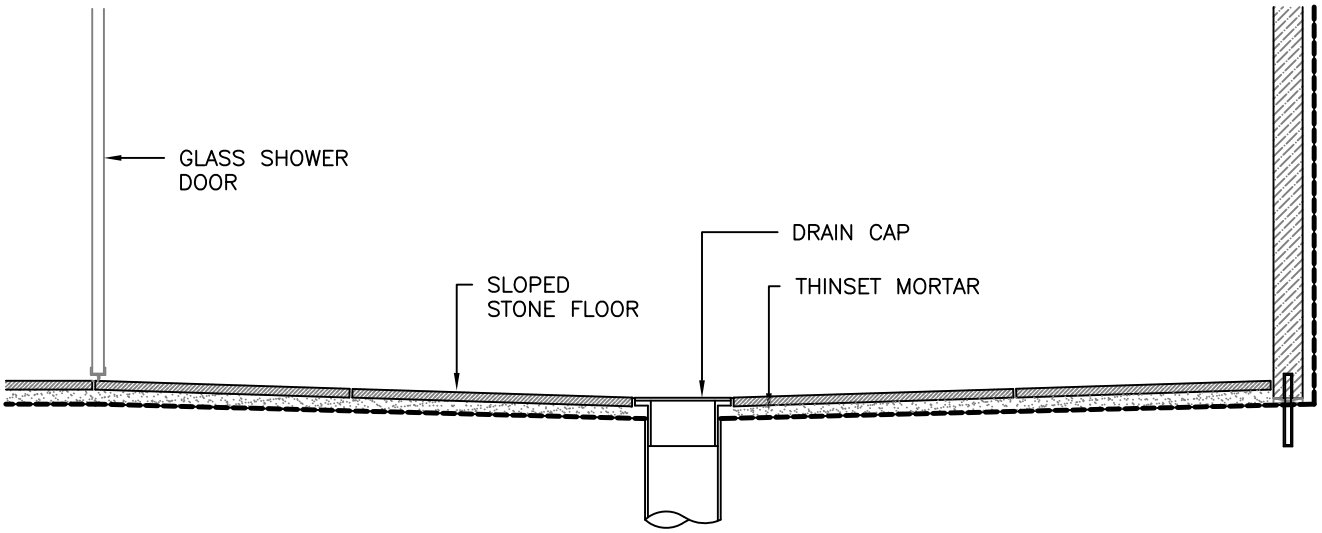


SECTION 26
MACHINED SHOWER FLOOR



SECTION 27
BARRIER FREE SHOWER FLOOR

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STONE SHOWER PARTITIONS
TYPICAL DETAILS

MIA DIMENSION STONE DESIGN MANUAL VII

DRWG NO: 16–D–17

SCALE: 1½" = 1'–0"

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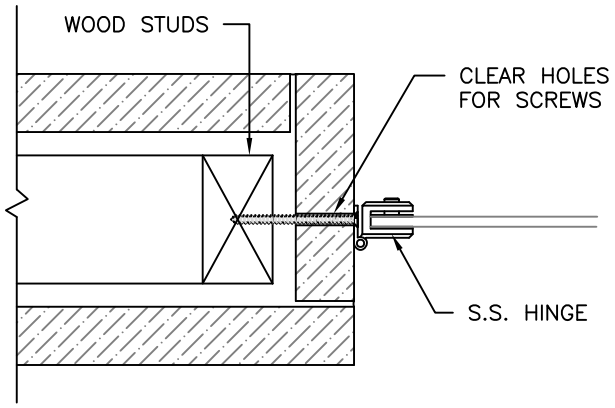
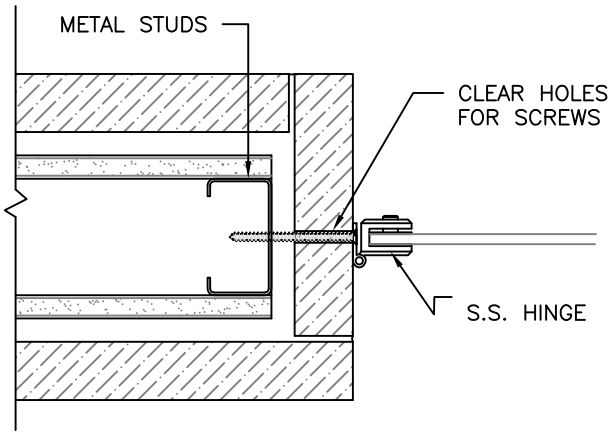
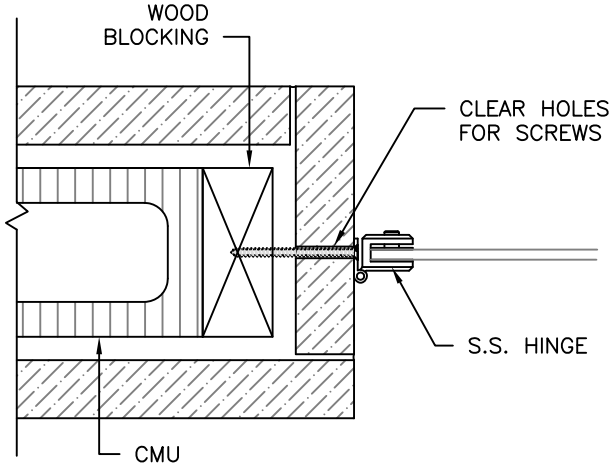


PLAN SECTION 28
JAMB AT SHOWER DOOR HINGE



PLAN SECTION 29
JAMB AT SHOWER DOOR HINGE



PLAN SECTION 30
JAMB AT SHOWER DOOR HINGE

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STONE SHOWER DOOR JAMBS
TYPICAL DETAILS

MIA DIMENSION STONE DESIGN MANUAL VII

DRWG NO: 16–D–18

SCALE: 3" = 1'–0"

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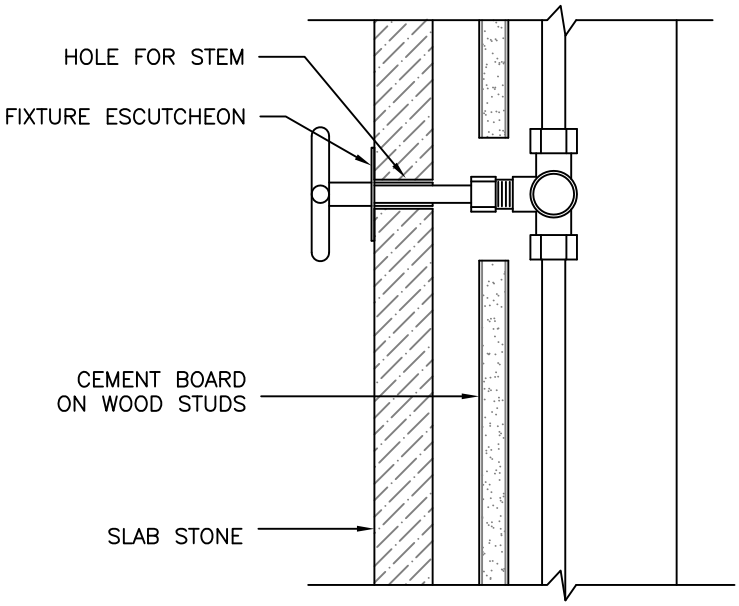
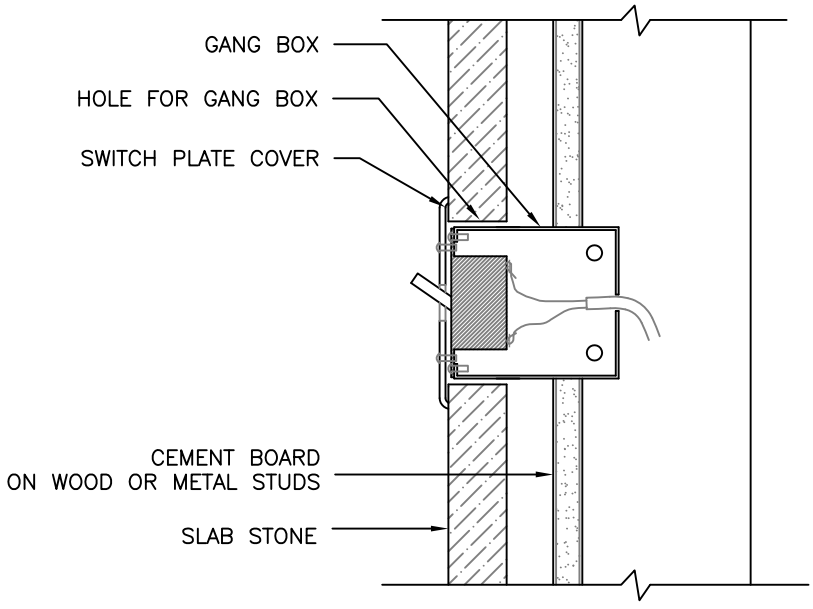


SECTION 31
PLUMBING CONTROL VALVE



SECTION 32
LIGHT SWITCH PENETRATION

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STONE SHOWER PARTITIONS
TYPICAL DETAILS

MIA DIMENSION STONE DESIGN MANUAL VII

DRWG NO: 16–D–19

SCALE: 3" = 1'–0"

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NOTES:

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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 Marble Institute of America 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.

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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

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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 MIA 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". Full-height backsplashes cover the entire area between the countertop and the upper cabinets. Backsplashes are normally made of the same

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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 MIA 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.

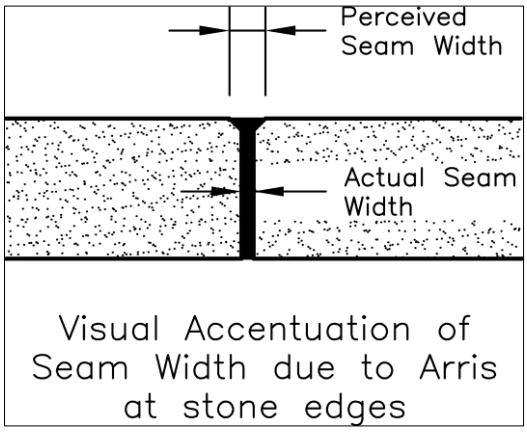
10.5 Final Positioning and Joint Filling. Final positioning of the stone is done either manually or with the aid of commercially available stone-alignment tools. The filling of the seams is normally completed prior to final positioning of the stone units, allowing the filler material to extrude out of the joint as the stones are pulled into alignment. The stone surface may be masked to prevent contact by the filler material (refer to MIA *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.

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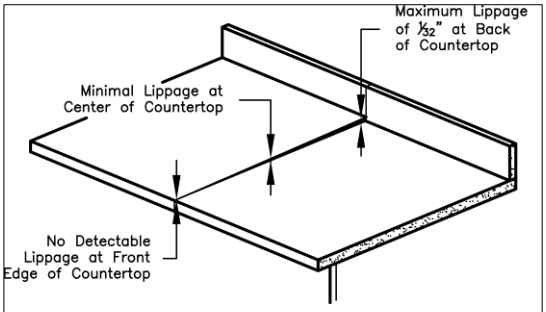
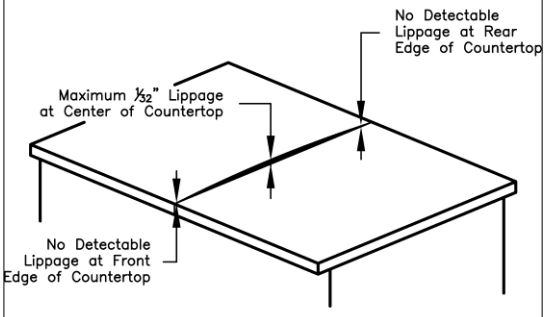


Allowable Lippage Due to Slab Warp
(For Standard Counter with Backsplash)



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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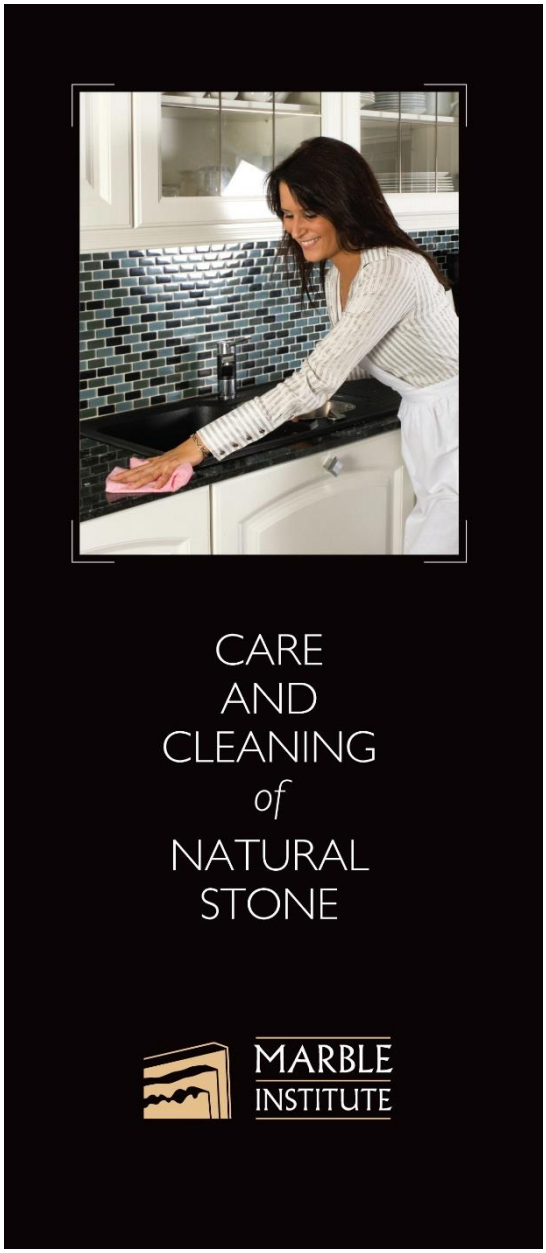
14 pp. brochure (2012) available from MIA.



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.

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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".

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.

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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.

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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 MIA 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", 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:

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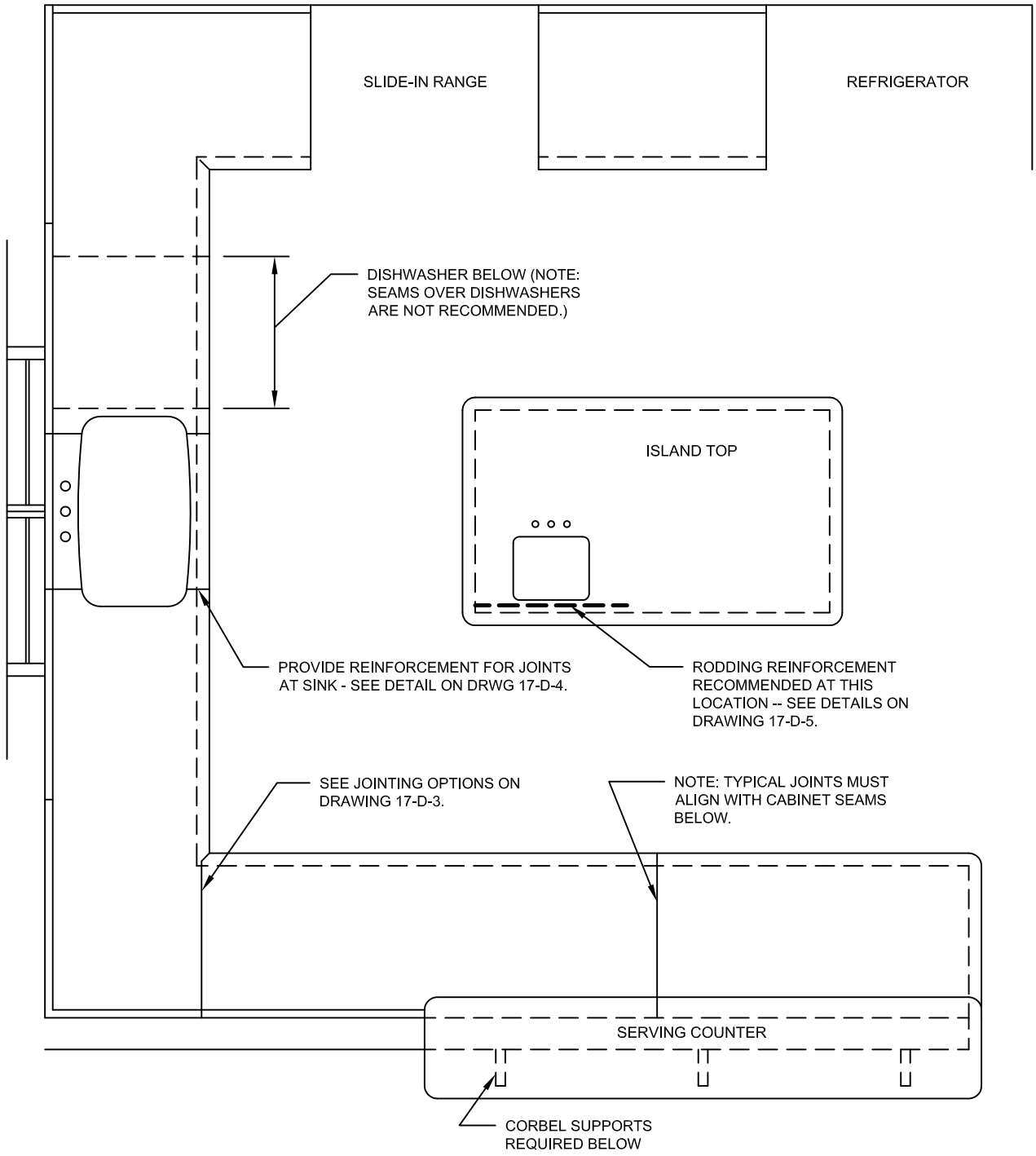

TYPICAL KITCHEN LAYOUT
(WITH JOINTS AT SINK)

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TYPICAL KITCHEN LAYOUT

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DRWG NO: 17–D–1

SCALE: ½" = 1'-0"

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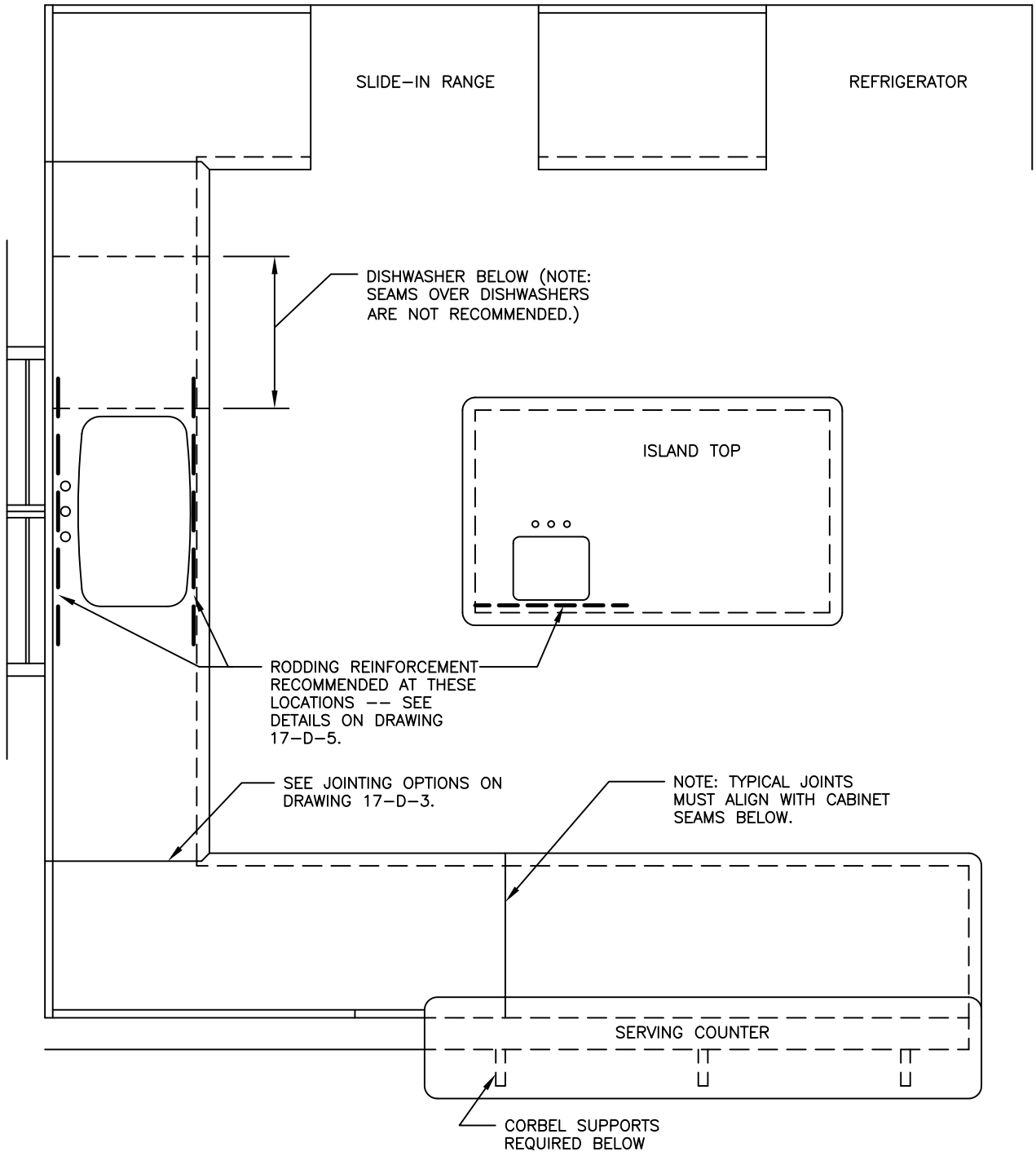

TYPICAL KITCHEN LAYOUT (WITH JOINTS AT CORNERS IN LIEU OF SINK)

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TYPICAL KITCHEN LAYOUT

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 17–D–2

SCALE: ½" = 1'–0"

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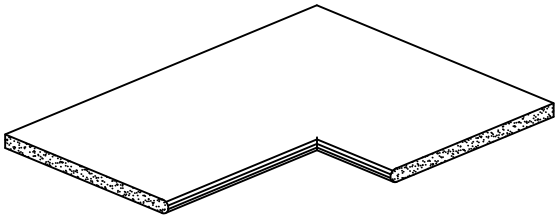
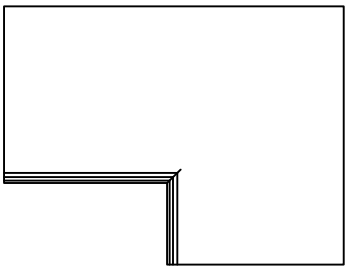
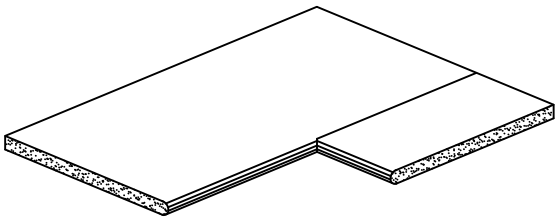
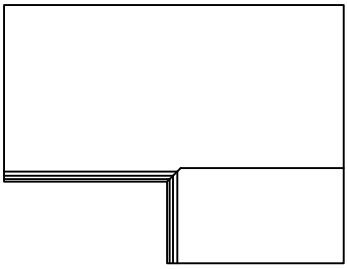


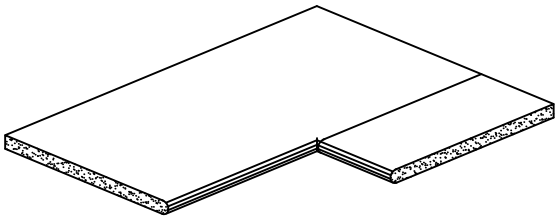


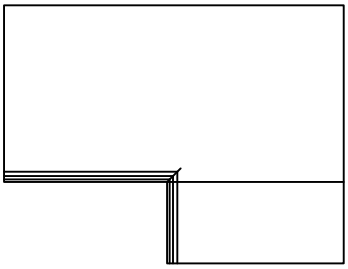
NO JOINT IN CORNER
THIS IS PERHAPS THE MOST PREFERRED DETAIL VISUALLY, AS IT PROVIDES THE CLEANEST–LOOKING RETURN. SOME HAND GRINDING WILL BE REQUIRED AT THE INTERIOR CORNER. THE LOSS OF YIELD IN THE STONE SLAB ADDS TO THE COST OF THE PROJECT. THIS DETAIL IS SOMEWHAT MORE SUSCEPTIBLE TO CRACKING IF THE COUNTERTOP IS NOT SHIMMED UNIFORMLY, OR IF THERE IS MOVEMENT IN THE CABINETS AFTER THE INSTALLATION OF THE COUNTERTOP.



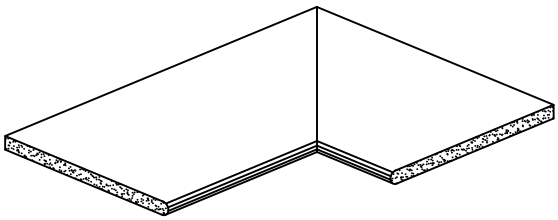


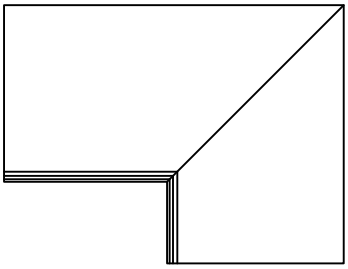
MITER JOINT THROUGH BULLNOSE EDGE DETAIL
THIS DETAIL IS WELL SUITED FOR EDGING MACHINES, AS IT REQUIRES NO HAND GRINDING OF THE BULLNOSE.





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

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DRWG NO: 17–D–3

SCALE: ½" = 1'–0"

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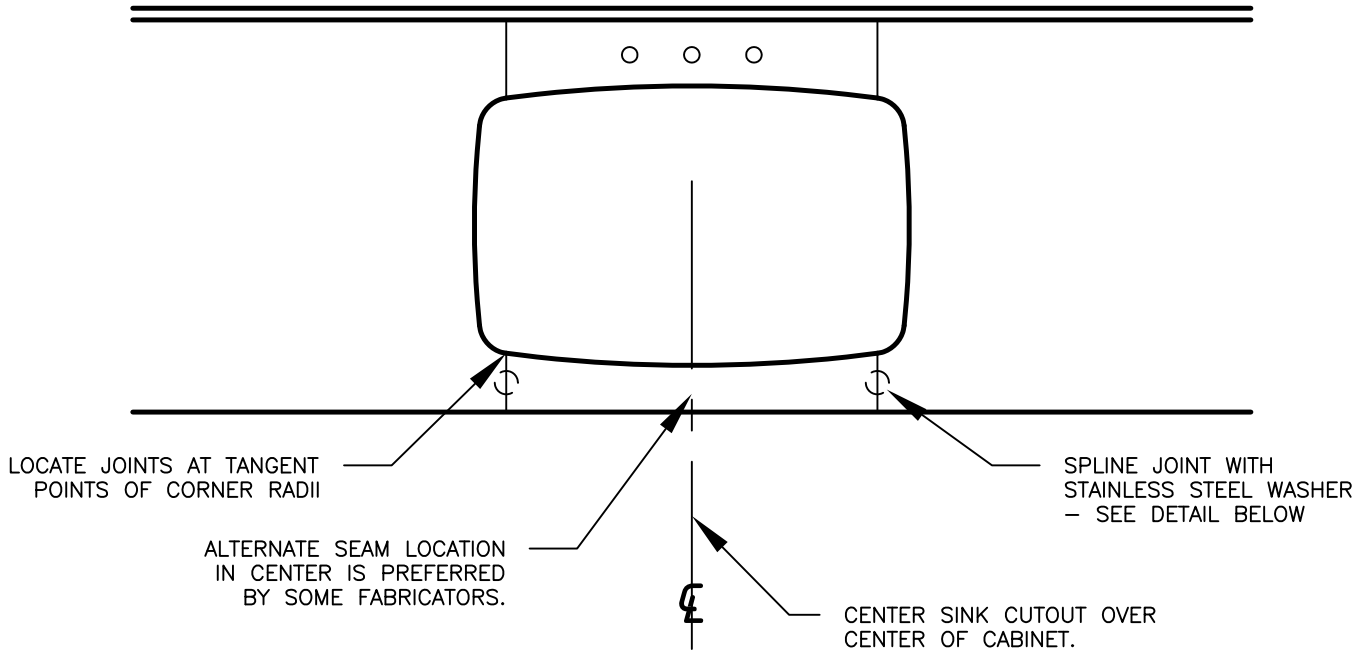
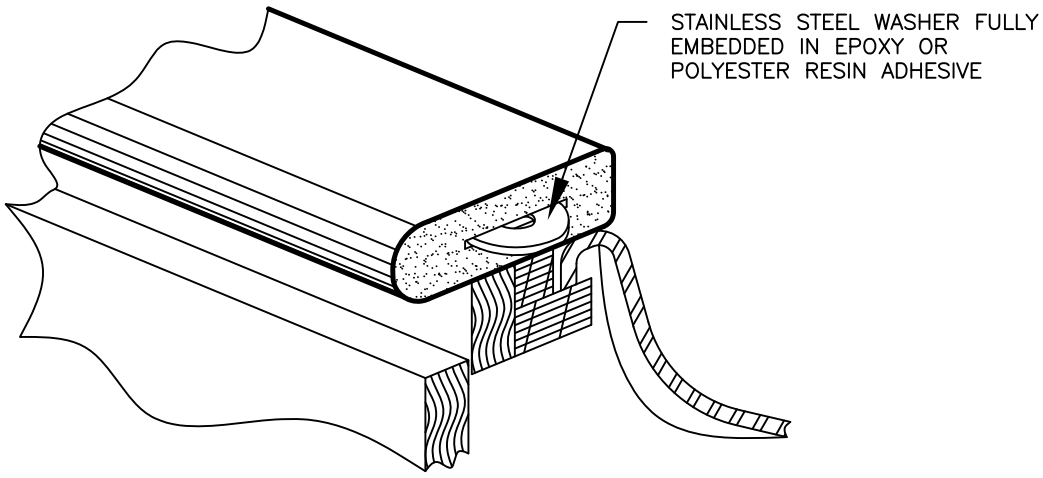


PARTIAL PLAN WITH JOINTS LOCATED AT SINK



DETAIL OF SPLINE JOINT REINFORCEMENT

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TYPICAL JOINERY @ KITCHEN SINK

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DRWG NO: 17–D–4

SCALE: 1" = 1'–0"

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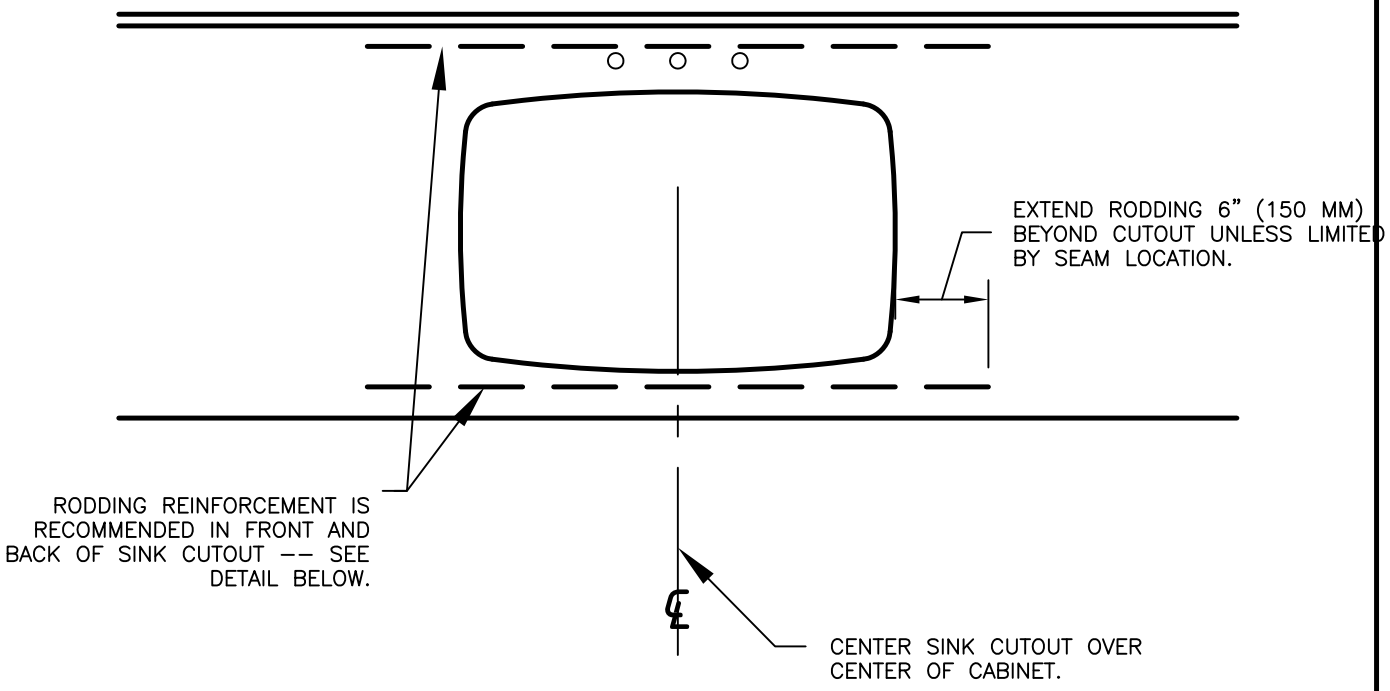
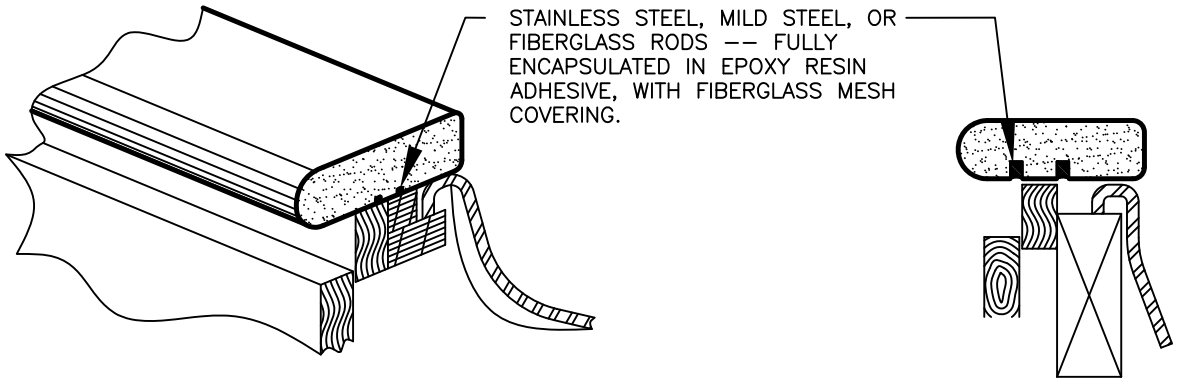


PARTIAL PLAN WITH NO JOINTS AT SINK



DETAIL OF RODDING REINFORCEMENT

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DETAIL OF RODDING REINFORCEMENT

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 17-D-5

SCALE: 1" = 1'-0"

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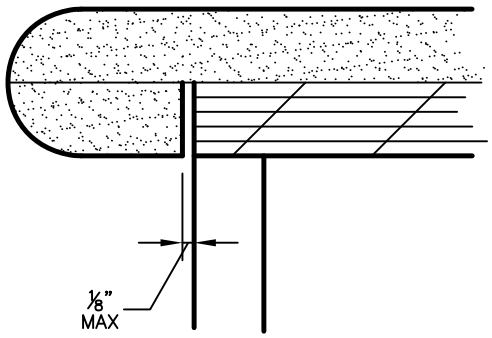
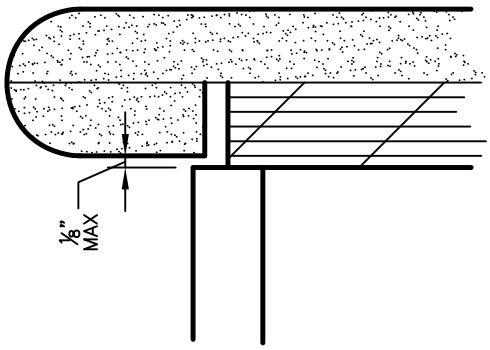
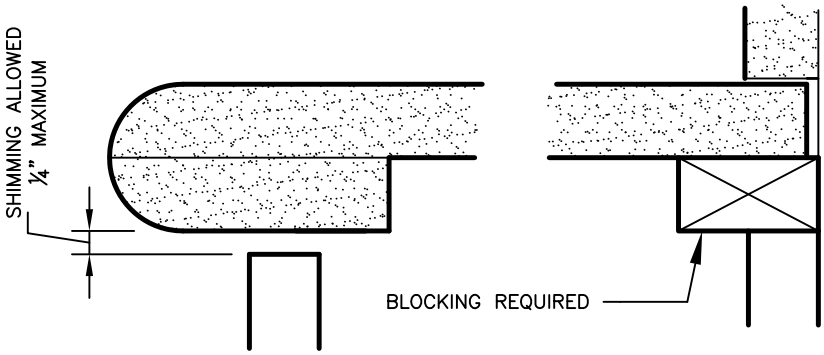


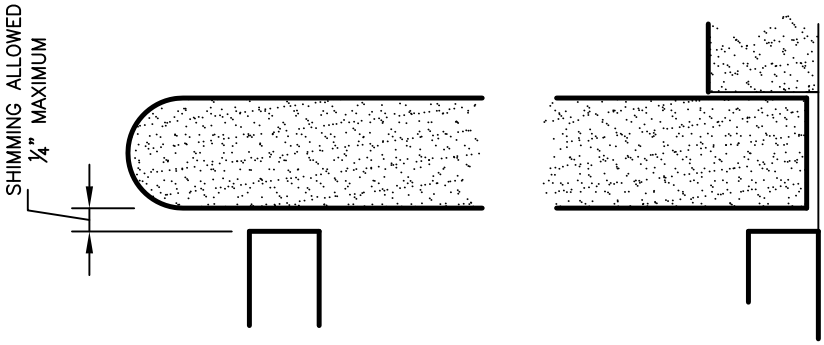
TYPICAL DETAIL AT
FLUSH SUBTOPS



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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TYPICAL COUNTERTOP SUPPORT DETAILS

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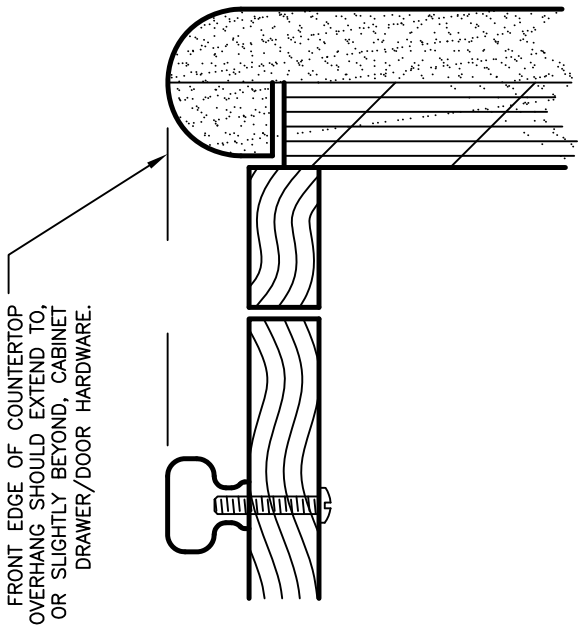
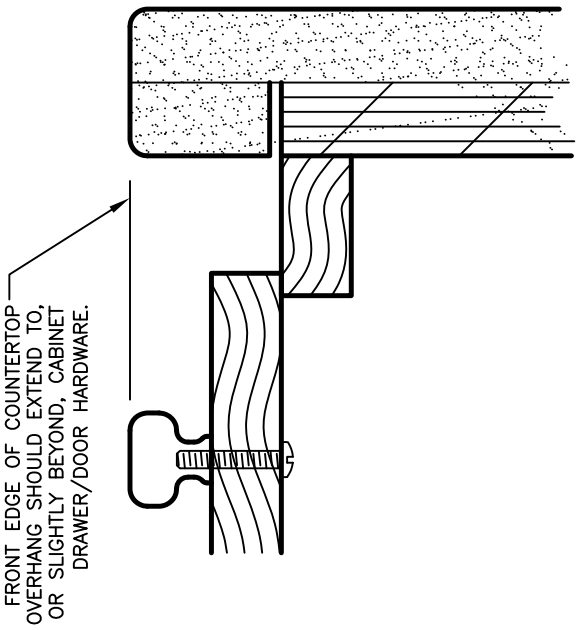
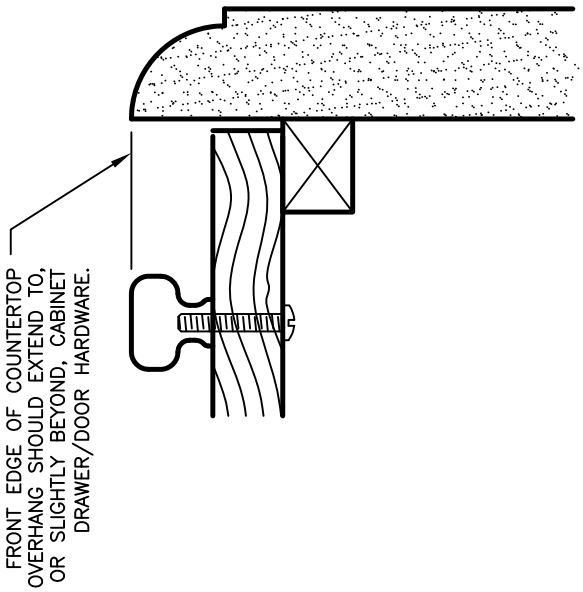


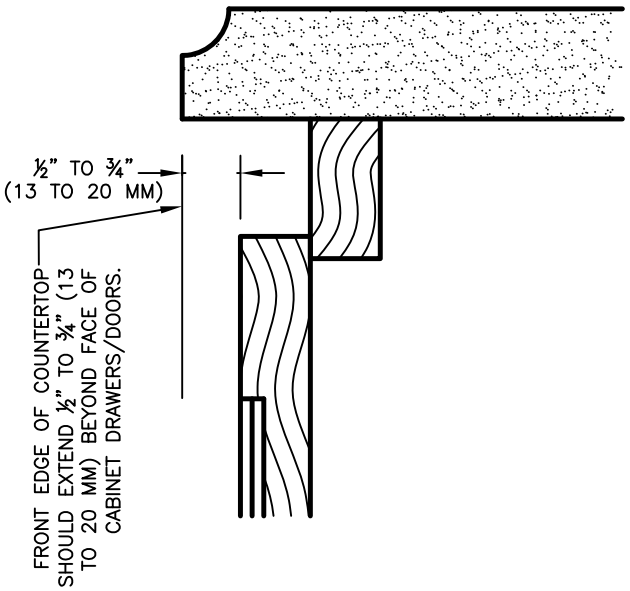
DOORS FLUSH WITH CABINETS



DOORS OVERLAPPING CABINETS



DOORS COVERING CABINETS



RECESSED OR FLUSH HARDWARE

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RECOMMENDED COUNTERTOP OVERHANG

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DRWG NO: 17–D–7

SCALE: 6" = 1'–0"

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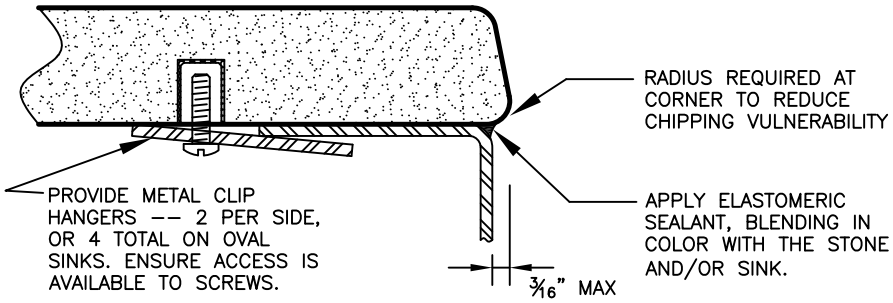
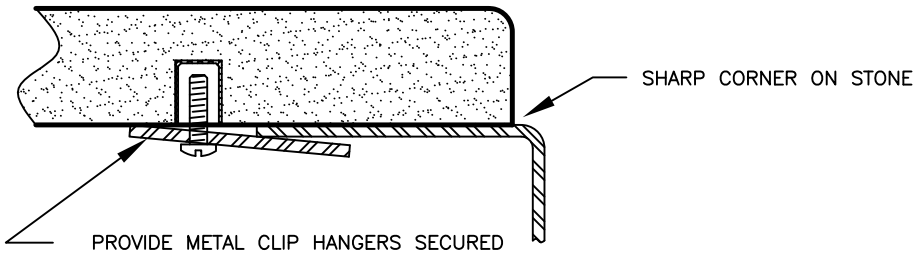
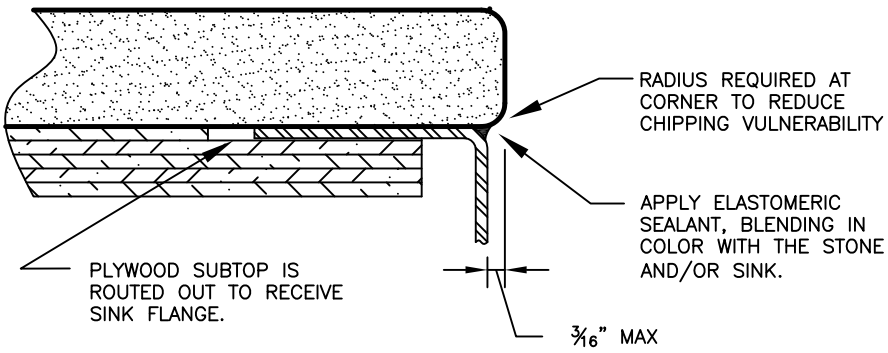


DETAIL WHEN COUNTERTOP OVERHANGS EDGE OF SINK



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

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DRWG NO: 17–D–8

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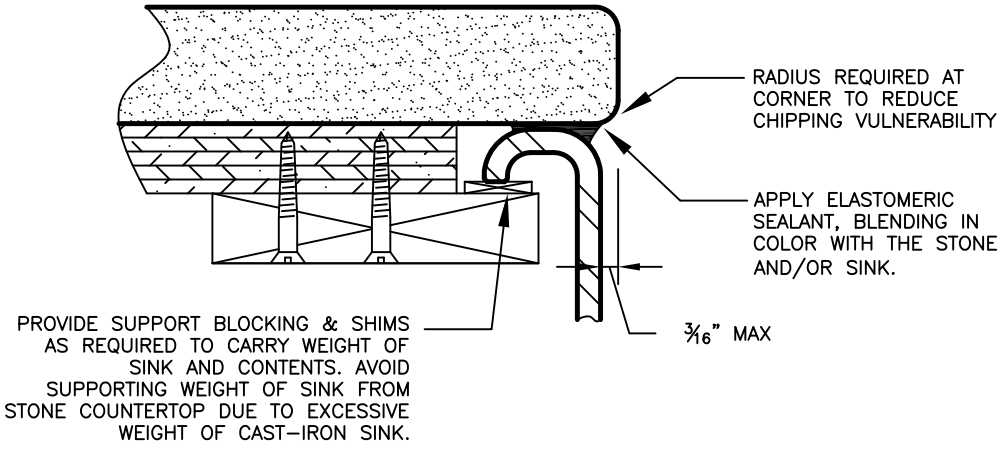
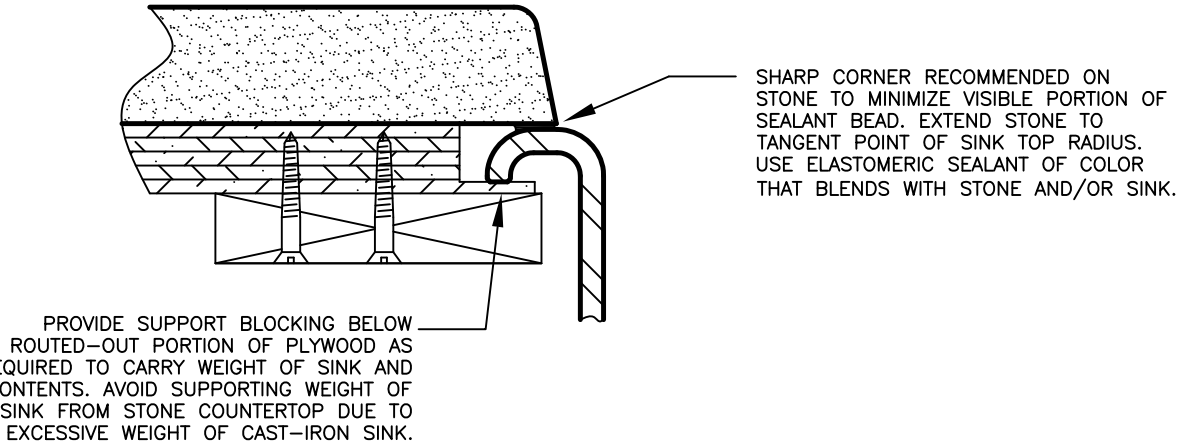
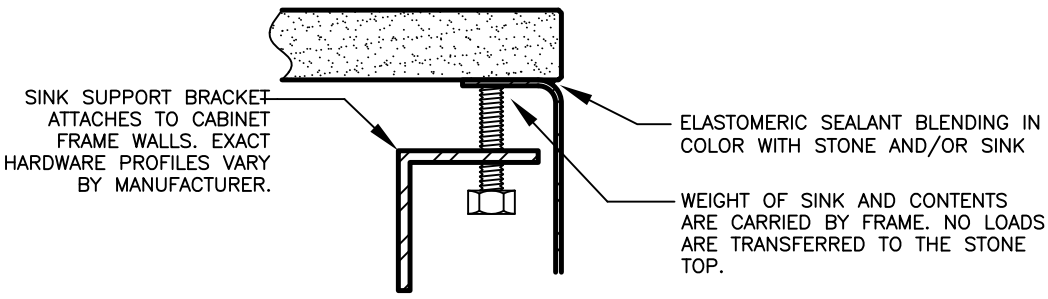


DETAIL FOR COUNTERTOP OVERHANGING SINK EDGE



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

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DRWG NO: 17-D-9

SCALE: 6" = 1'-0"

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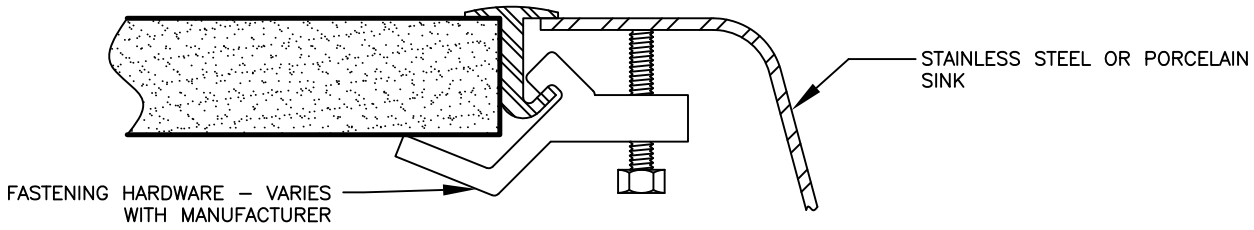
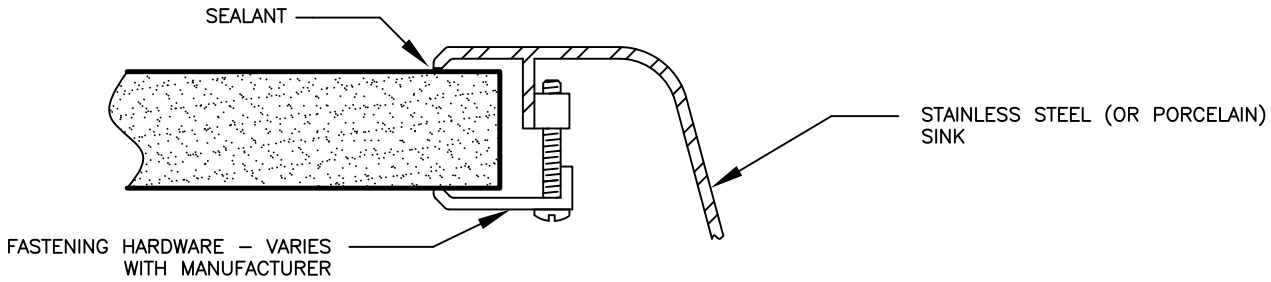
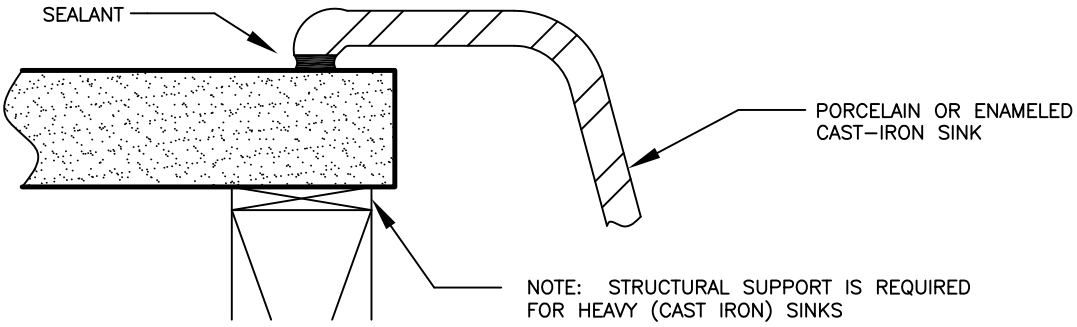


DETAIL FOR SINK SUPPORTED BY METAL FRAME



TYPICAL DETAIL FOR STAINLESS STEEL SINKS



DETAIL FOR SINK SUPPORTED BY METAL FRAME

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SUPPORT DETAILS FOR RIMMED OR "DROP–IN" SINK STYLES

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DRWG NO: 17–D–10

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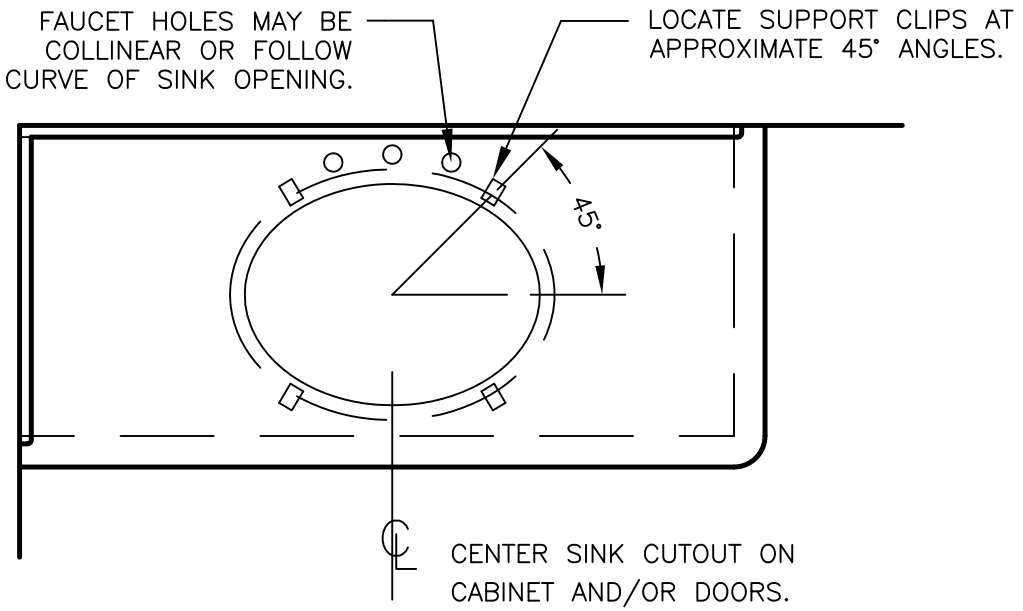
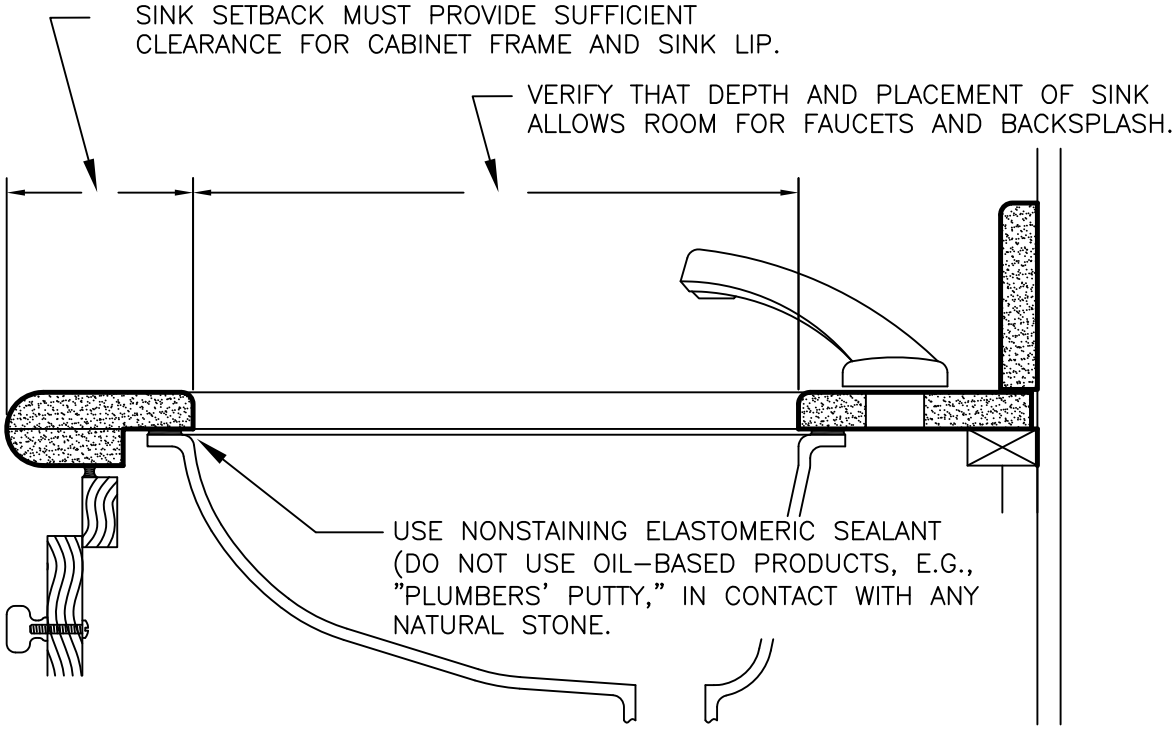


PLAN VIEW OF TYPICAL VANITY



SECTION THROUGH VANITY COUNTER

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VANITY TOP DETAILS

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 17–D–11

SCALE: 3" = 1'–0"

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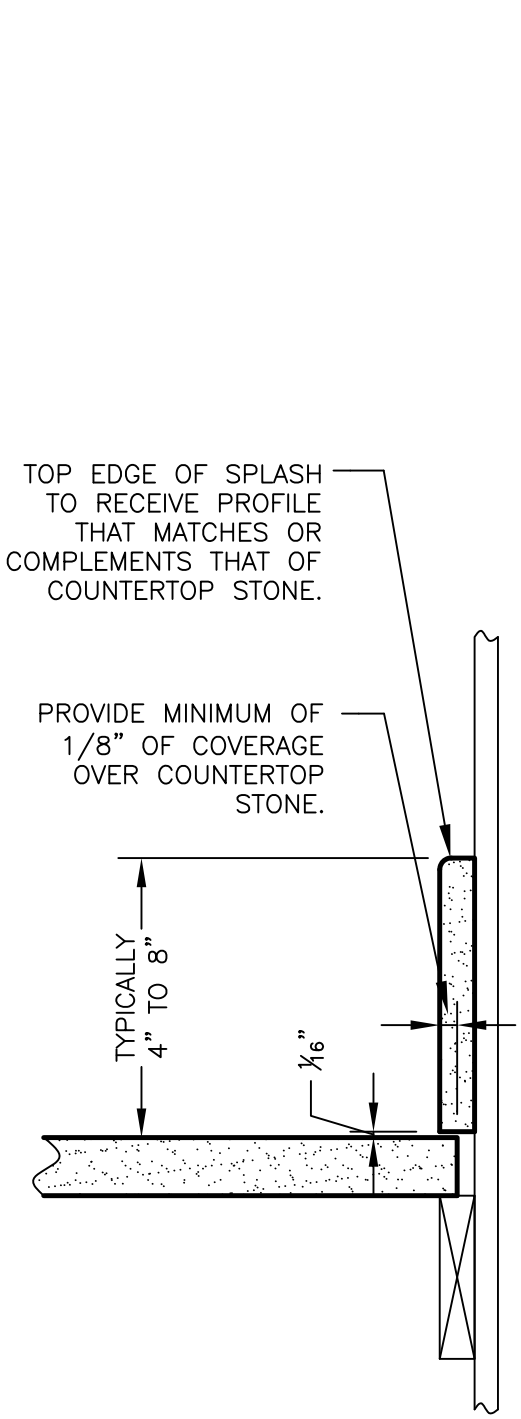
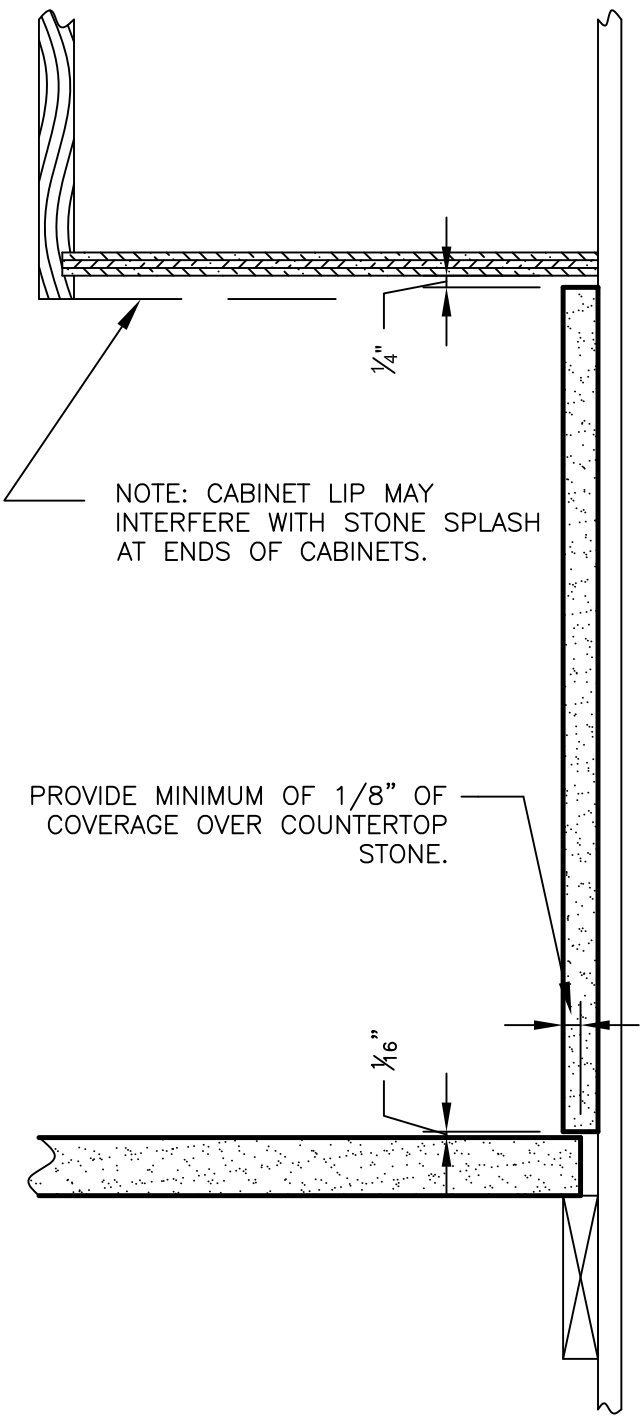


SECTION THROUGH PARTIAL–HEIGHT BACKSPLASH



SECTION THROUGH FULL–HEIGHT BACKSPLASH

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BACKSPLASH DETAILS

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DRWG NO: 17–D–12

SCALE: 3" = 1'–0"

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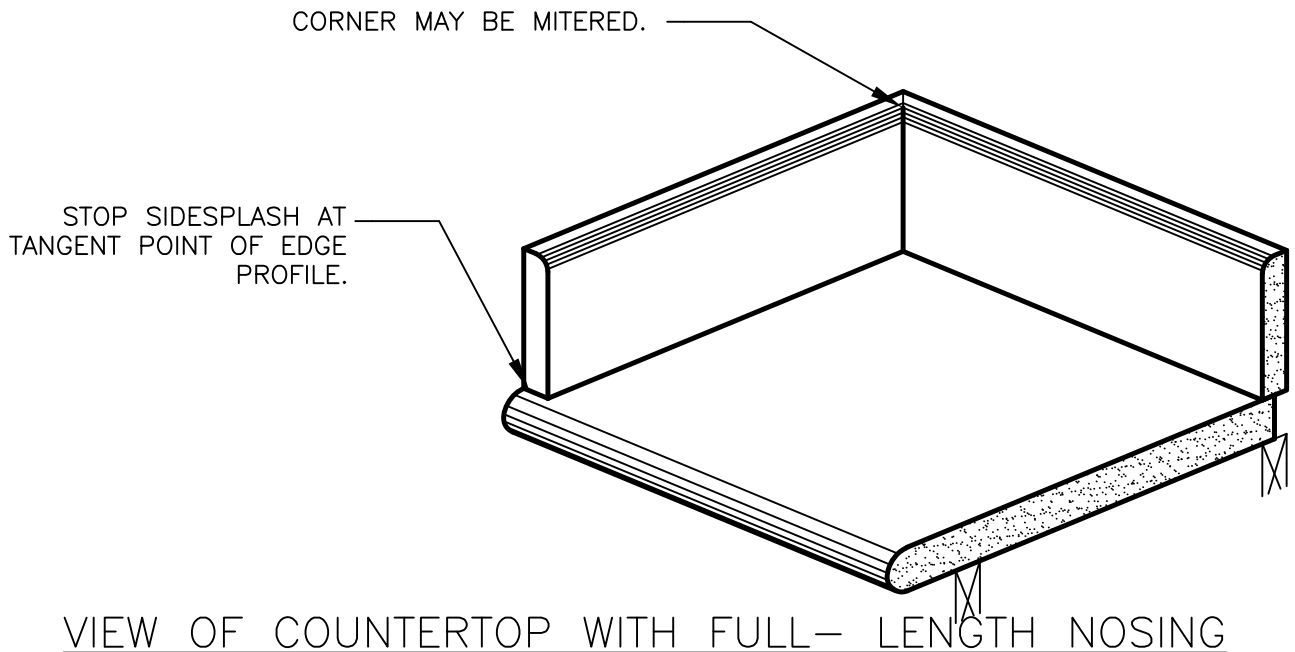
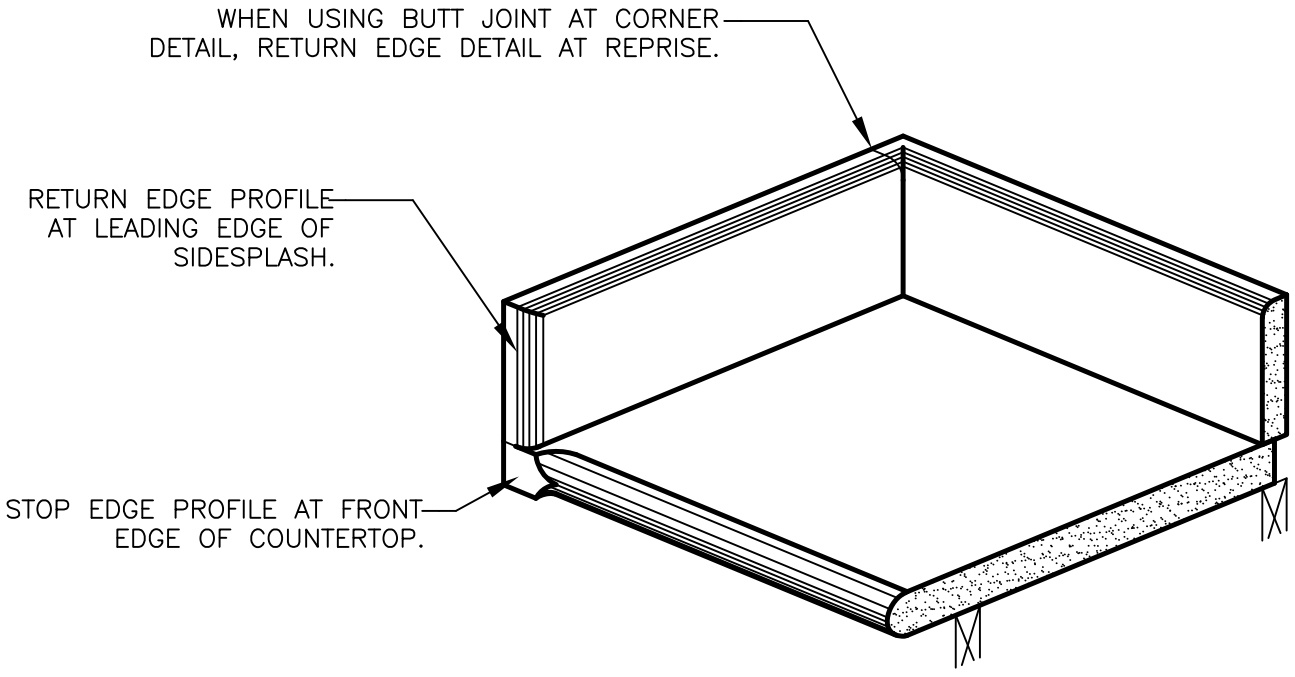


VIEW OF COUNTERTOP WITH FULL– LENGTH NOSING PROFILE



VIEW OF SIDESPLASH CONTINUING TO EDGE OF COUNTERTOP

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OPTIONS @ SIDESPLASH

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 17–D–13

SCALE: N.T.S.

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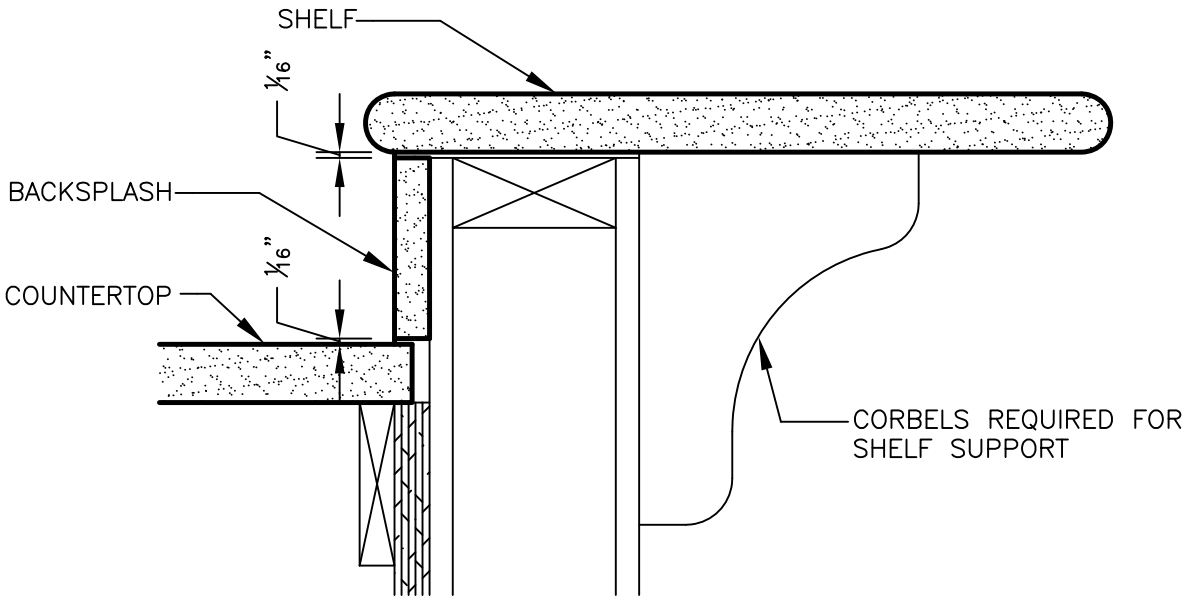
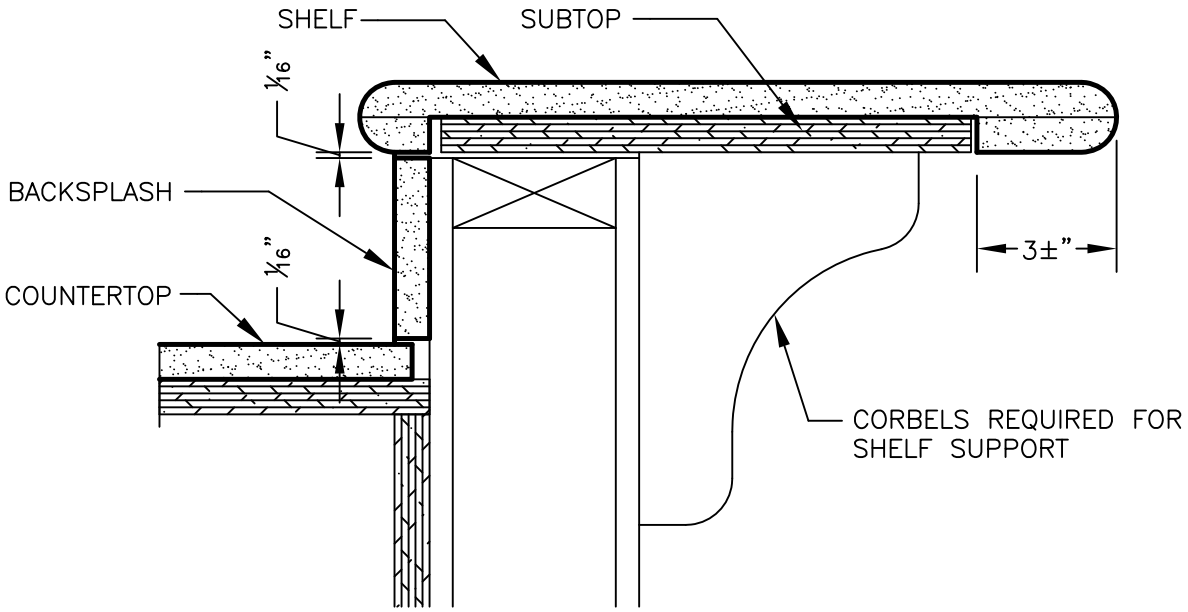


DETAIL OF STONE SHELF WITHOUT SUBTOP



DETAIL OF STONE SHELF WITH SUBTOP

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STONE SHELF DETAILS

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 17–D–14

SCALE: 3" = 1'–0"

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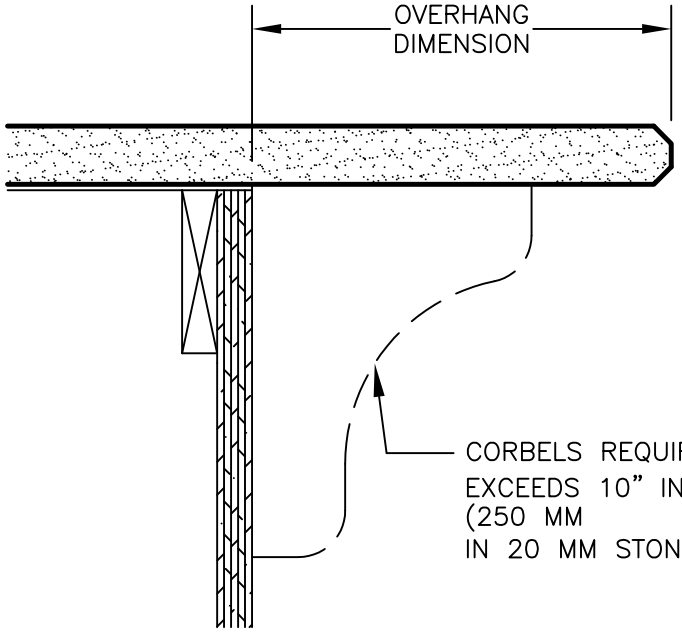
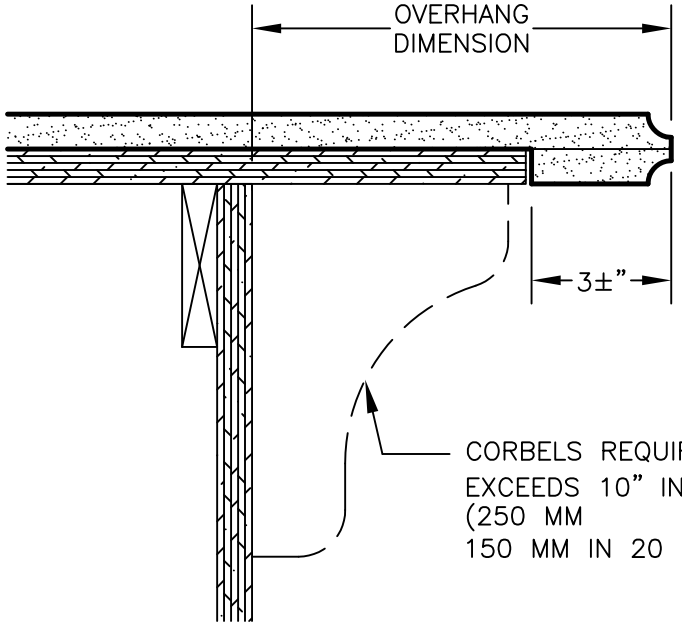


DETAIL OF COUNTERTOP OVERHANG WITHOUT SUBTOP



DETAIL OF COUNTERTOP OVERHANG WITH SUBTOP

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COUNTERTOP OVERHANG DETAILS

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 17–D–15

SCALE: 3" = 1'–0"

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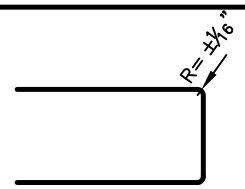
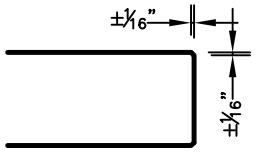
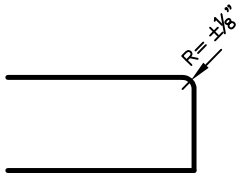


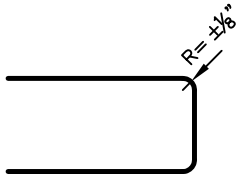
Straight with Radius Eased Edges (1)



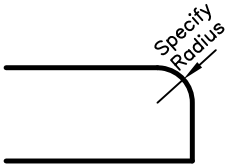
Straight with Chamfer Eased Edges (1)



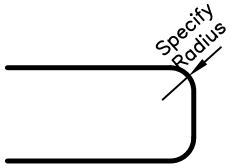
Pencil Round (2)



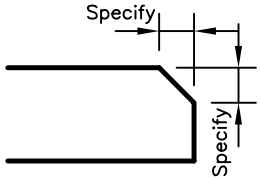
Double Pencil Round (2)



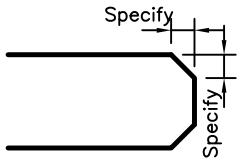
Radius (3)



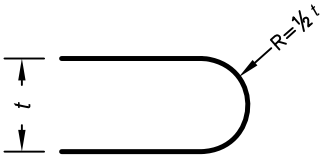
Double Radius (3)



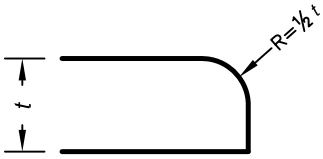
Chamfer (3)



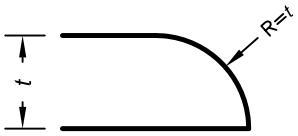
Double Chamfer (3)



Full Bullnose

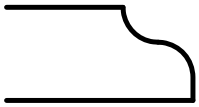


Half Bullnose

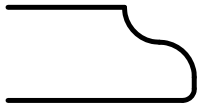


Demi Bullnose

Chiseled or "Rocked"



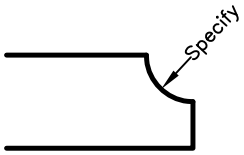
Ogee



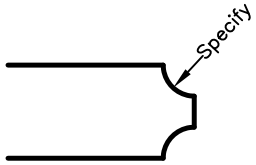
Ogee Roundover

Dupont

Normandy



Cove (3)



Double Cove (3)

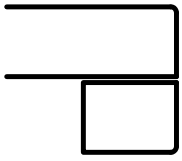
Cove Ogee

Cove Dupont

Stair Tread

Waterfall (or Triple Waterfall)

Platner (or Knife Edge)



Laminated (4)

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

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 17–D–16

SCALE: N.T.S.

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EXAMPLE SHOP DRAWING

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 17–D–17

SCALE: ½" = 1'-0"

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NOTES:

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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, Installation General Information.

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.

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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" from exterior face. Joints should be at least 1-1/4" 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.

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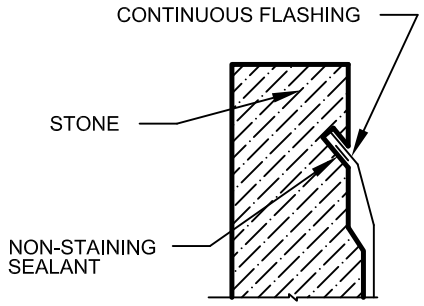
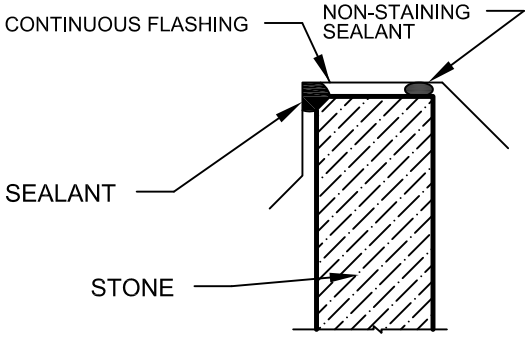
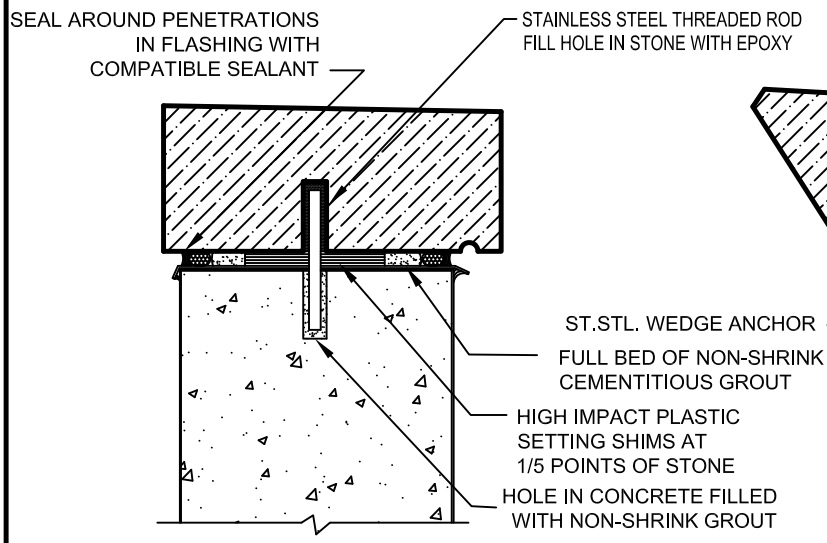


1 PARAPET DETAIL

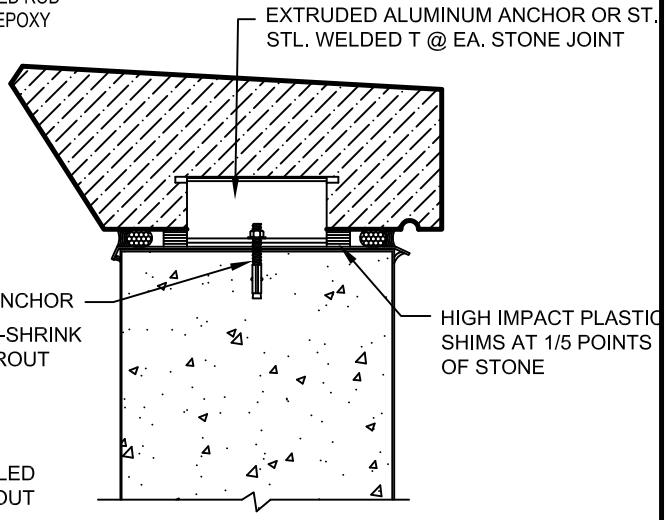


2 PARAPET DETAIL

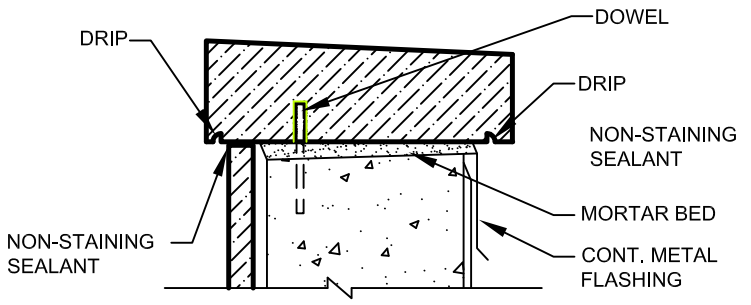
NOTE: MINUMUM RECOMMENDED STONE THICKNESS FOR THESE DETAILS IS 1-1/4".



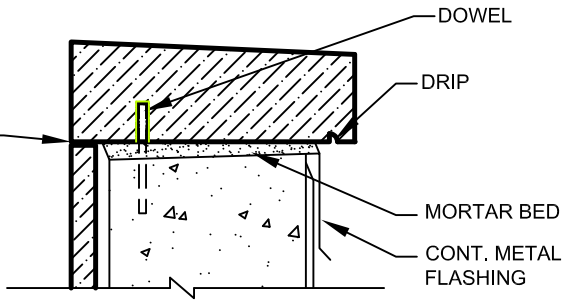
3 COPING DETAIL



4 COPING DETAIL



5 COPING DETAIL



6 COPING DETAIL

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EXTERIOR STONE VENEER FLASHING & COPING DETAILS

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 18-D-1

SCALE: 3" = 1'-0"

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NOTES:

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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, Installation General Information.

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" and 1¼", 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

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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.

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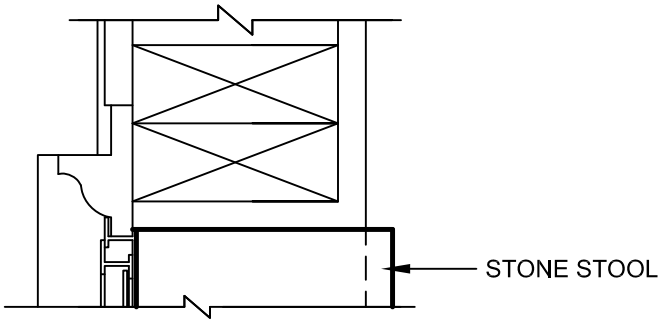
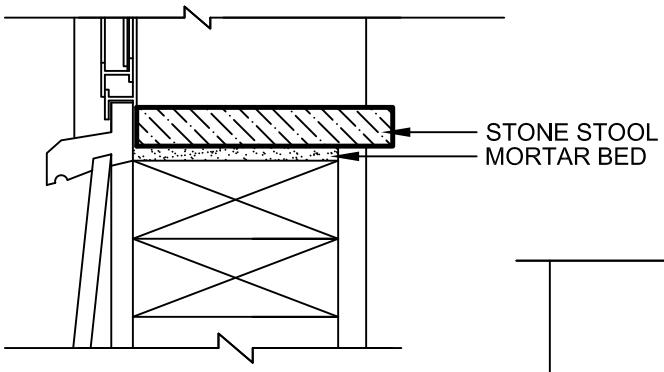
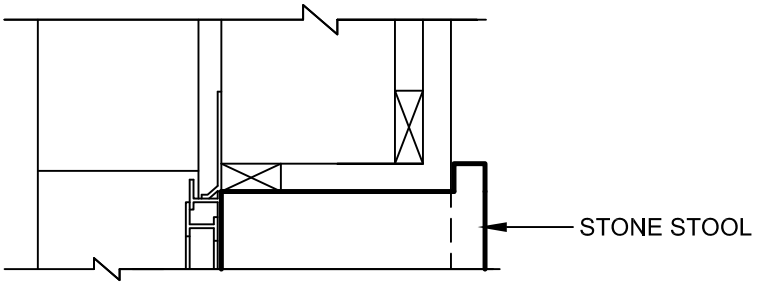


1 PLAN SECTION
(WOOD FRAME CONSTRUCTION)

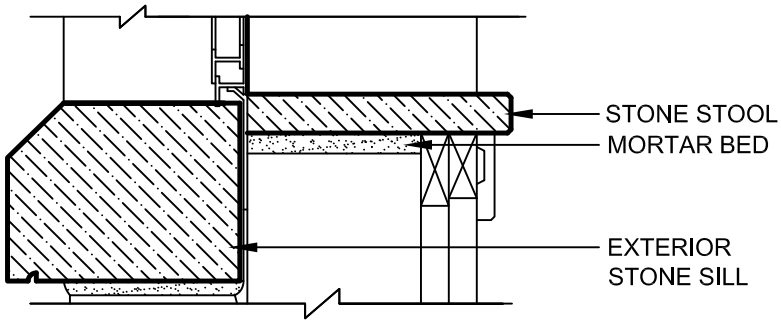


2 SECTION
(WOOD FRAME CONSTRUCTION)



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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REV	DATE
0	Aug 2006
1	Oct 2006

THIN STONE STOOLS AND CUBIC SILLS—WINDOW STOOL DETAILS

MIA DIMENSION STONE DESIGN MANUAL VIII

DRWG NO: 18-D-2

SCALE: 3" = 1'-0"

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NOTES:

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