Travertine

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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 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.

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

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 40ºF to 20ºF (4ºC to -6ºC) shall be followed, except that no additives shall be used in the setting mortar, and below 20ºF (-6ºC), all work shall be done in heated enclosures.

5.2.11 Individually set thin tile (nominal 3/8") 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

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 ($SrSO_4$).

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 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.

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 re-commended 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.