HORIZONTAL SURFACES

1. DESIGN CRITERIA

1.1. STONE SELECTION

1.1.1. STONE PRODUCT DEFINITIONS

1.1.1.1. TILE: A stone tile is a thin, flat piece of natural stone used as finishing material, with a thickness ranging from ¼" to ⅝" (6 to 16 mm) inclusive and having no dimension greater than 2' 0" (610 mm). Tiles are normally supplied in typical sizes, with atypical pieces being field cut to fit, although in some cases when detailed shop drawings are prepared, factory cutting of atypical pieces can occur.

1.1.1.2. CUT-TO SIZE: Cut-to-size stone products, also referred to as "slab stock" stone products, are custom fabricated pieces of natural stone. Fabrication of these products normally occurs in a factory setting, where each piece is custom fabricated to fit, but partial fabrication may also occur in the field at the time of installation.

1.1.1.3. Natural stone tiles and cut-to-size products may have different fabrication tolerances due to their different methods of fabrication. Refer to the specific stone description chapter for fabrication tolerances.

1.1.1.4. LABOR ASSIGNMENT: The successful installation of both dimension stone and stone tile is dependent upon the experience and craft knowledge of the firm contracted to install the stone. The Natural Stone Institute endorses the use of NSI Accredited Natural Stone companies. See www.naturalstoneinstitute.org for a directory of installation companies accredited by the NSI.

1.1.2. SAMPLES: The Dimension Stone Contractor shall furnish samples of the various dimension stones to be used. Samples shall indicate the extremes of color, veining, texture, and marking that the stone supplied to the project will have. Samples must be reviewed as a complete set and approved or rejected in their entirety, without stipulation.

1.1.2.1. Pending the scope of the installation and the variability of the stone product, a mockup of a specified size and extent, may be required to adequately demonstrate the range of the material's color and character. Mockups are intended to demonstrate the full range of color tones and natural characteristics of the stone to be expected across the entire project yet condensed into the much smaller surface area of the mockup. Therefore, the effects of the variation and characteristics of the stone will be more concentrated, and appear more extreme, than the actual project since the actual project will have less frequent occurrences of these elements.

1.1.2.2. Pending the scope of the installation and the variability of the stone product, a "dry-lay" may be required to adequately demonstrate the range of the material's color character, and finish, with the advantage of predetermining the actual position and orientation of each stone panel. The dry-lay allows the design professional to see the actual blend of the finished floor, and also allows the arrangement of pieces to be adjusted per his/her desires. Since each stone panel is dedicated to a specific location, crating and handling must be skillfully executed to prevent damage as there may or may not be a suitable replacement available for a given stone. A dry lay is generally considered to be a wise investment for decorative interior office lobby, floor and wall projects. It provides a beneficial team building experience and the formal approval of all stone prior to shipment helps eliminate jobsite anxiety and rejections.

1.1.2.3. Inspection of supplied material to evaluate compliance with approved samples/mockups/dry-lays shall be done at a viewing distance of not less than 6'-0" (2 m), with natural lighting, and an angle perpendicular to the face of the stone.

1.1.3. THICKNESS Suggested minimum thicknesses for Horizontal stone surfaces:

1.1.3.1. Exterior Stone Pavers, Pedestrian Traffic: 1¼" (30 mm).

1.1.3.2. Exterior Stone Pavers, Vehicular Traffic: Is best determined by engineering analysis, but is generally 3" (75 mm) or thicker.

1.1.3.3. Interior Residential Stone Flooring: ⅜" (10 mm).

1.1.3.4. Interior Commercial Flooring, light duty (e.g., retail shops, tenant areas of office buildings): ⅜" (10 mm).

1.1.3.5. Interior Commercial Flooring, Heavy Duty/High Traffic: ¾", or 1¼" (20 or 30 mm) pending stone variety selection and level of traffic loading.

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

1.1.3.7. Note: Regardless of the stone thickness, loading as a result of building maintenance equipment oftentimes requires protection of the stonework to prevent damage from the equipment.

1.1.4. SHOP DRAWINGS: Detailed, scale shop drawings which include elevations, plan views and section details shall be provided by the stone contractor. Shop drawings shall address:

1.1.4.1. Stone Type and Finish
1.1.4.2. Stone sizes, thicknesses, joinery and patterning
1.1.4.3. Reference to building column grid lines
1.1.4.4. Vein and Rift directions, if appropriate
1.1.4.5. Joint sizes and treatments
1.1.4.5.1. Typical Joints
1.1.4.5.2. Expansion Joints
1.1.4.5.3. Movement Joints

1.1.4.6. Identification of mortar, adhesive, and grout types.

1.1.4.7. Relationship to adjacent building materials, cavities, and placement tolerances of support systems.

1.1.4.8. Details of mechanical anchorage, including anchor devices and metallurgy of same.

1.1.5. FABRICATION: Stone paving units are precut and prefinished to dimensions specified on shop drawings and are usually delivered to the job site ready to install.

1.1.6. CARVING: All carving shall be performed by stone carvers in strict accordance with approved full-size details or models, with allowance for documented industry tolerances. Architectural drawings shall show approximate depth and relief of carving. Carving shall be left as it comes from the tool, unless otherwise specified.

1.1.7. FIELD REPAIR: Shop fabrication is generally preferred over field fabrication as quality control is more easily monitored in the controlled environment of a shop setting. When field fabrication is necessary, it shall be accomplished by skilled, experienced mechanics. Conditions or occurrences that may exist which would necessitate field fabrication:

1.1.7.1. Inability to verify field dimensions or conditions prior to stone being in transit to the installation site.

1.1.7.2. Requirement to coordinate with related components that are being installed concurrently with the stone.

1.1.7.3. Changes in the scope or design of the installation.

1.1.7.4. Repair or patching is sometimes necessary due to damage of material either on-site or in transit. By allowing these repairs to be made on-site, progress of the job can be maintained, thus aiding the successful completion of the work. Repairs should not detract from the desired appearance or strength of the completed installation. The means and methods or examples should be discussed and/or demonstrated for approval prior to performing the repair.

1.1.8. STONE COLORS and VARIETIES: Pending the material successfully meeting the specified performance requirements, most of the commercially available varieties are suitable provided they meet or exceed the necessary performance specifications of the project.

1.1.9. SIZES and THICKNESSES may need to be determined by engineering analyses. The following properties should be considered when determining size and thickness of stone paving units:

1.1.9.1. Flexural Strength (Ref: ASTM C880) of the stone

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

1.1.9.3. The anticipated loads.

1.1.9.4. Stone thickness tolerances.

1.1.9.5. Size and availability limitations of stone blocks and/or slabs

1.1.9.6. Compatibility of the chemical composition of setting bed and the stone material's reaction to the chosen setting bed materials. (Pre-construction testing for compatibility is recommended).

1.1.9.7. Factors of Safety

1.1.10. STONE FINISHES

1.1.10.1. Exterior stone pavements shall have textured surfaces such as flamed (a.k.a. "thermal"), sanded, bush-hammered, cleft, or other suitably textured finishes.

1.1.10.2. Interior stone flooring finishes may include honed, polished, sanded, flamed (a.k.a. "thermal"), sawn, sanded, and natural cleft, and other finishes.

1.1.10.3. Many proprietary finishes are offered from suppliers which may be suitable but are not included in the above, generic lists.

1.2. TECHNICAL DATA

1.2.1. PHYSICAL PROPERTY VALUES. Final design should always be based on the specific property values of the stone to be used. These values may be obtained from the Stone Supplier. When current (≤3 years, per ASTM C1799) reliable physical property data is not available from the supplier, re-testing of the stone should be considered.

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

1.2.2.1. Granite: ASTM C615, Standard Specification for Granite Dimension Stone

1.2.2.2. Limestone: ASTM C568, Standard Specification for Limestone Dimension Stone

1.2.2.3. Marble: ASTM C503, Standard Specification for Marble Dimension Stone

1.2.2.4. Onyx: No ASTM Standard exists at this time

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

1.2.2.6. Serpentine: ASTM C1526, Standard Specification for Serpentine Dimension Stone

1.2.2.7. Slate: ASTM C629, Standard Specification for Slate Dimension Stone

1.2.2.8. Soapstone: No ASTM Standard exists at this time

1.2.2.9. Travertine: ASTM C1527, Standard Specification for Travertine Dimension Stone

1.3. ABRASION RESISTANCE

Class of usage establishes the minimum abrasion resistance that a stone requires to withstand the foot traffic requirements of the project. This is determined according to the ASTM C241 or C1353 test methods for abrasion resistance and is reported as H_a when tested per ASTM C241 or I_w when tested per ASTM C1353. The two scales correlate well in the range of values contained within this section and are considered to be interchangeable. Extremely hard stone varieties will produce vastly different values between the two test methods, but this is insignificant since the requirements of this section will easily be satisfied. There are three recognized classes of usage for interior stone flooring, plus additional classifications for thresholds, steps, and exterior surfaces:

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

1.3.2. Moderate Traffic class is reserved for residential entranceways and small commercial installations where pedestrian traffic is less than 50 persons per minute. Stone must have a minimum H_a or I_w of 7.0

1.3.3. Heavy Traffic class is reserved for commercial installations (banks, shopping malls, train or bus stations, etc.) where pedestrian traffic is greater than 50 persons per minute. Minimum H_a or I_w is 10.0 for general areas, increasing to 12.0 for elevator lobbies, halls, and other areas of traffic concentration.

1.3.3.1. Consider higher abrasion resistance than listed above for those areas immediately accessible from outdoors. Solid contaminants (grit) that collects on the shoes of pedestrians will be carried into the interior walking surface and act as an abrasive.

1.3.4. Exterior paving should have a minimum H_a or I_w of 12.0.

1.3.5. Thresholds: H_a or I_w of the varieties selected should be a minimum of 12.0.

1.3.6. Stairs: Thresholds: H_a or I_w of the varieties selected should be a minimum of 12.0. Higher abrasion resistance should be considered for stairs that experience abrasive grits from streets or snowmelting applications.

1.3.7. These classifications are for the stone's abrasion resistance only. The stone's finish (polished, honed, thermal, etc.) will wear with traffic. Polished finish on stones with low abrasion indices (generally $\leq$ 20.0, although exceptions exist) are not suitable for most moderate and any heavy-traffic areas as the gloss will be reduced by the abrasion of the foot traffic. Stone with high abrasion resistance will generally maintain a polished surface in foot traffic areas. Stones with lesser abrasive indices are likely to abrade in service, and generally perform better if supplied in honed finish. While a polished finish in softer stone varieties will be dulled by foot traffic, a honed finish on a soft stone will oftentimes become glossier due to foot traffic.

1.3.8. Limitations. If several varieties of stone are used together, the abrasive resistance (H_a or I_w) of the stones should be similar. Proper testing (ASTM C241 or ASTM C1353) should be performed on each stone variety. If the abrasion resistance of either stone is $<$20.0, then the difference in abrasion resistance between the stones shall be $\leq$5.0. This can be ignored when using stones with higher abrasion resistance indices (generally $\geq$20.0, although exceptions exist), since the resultant wear will generally be minimal.

1.4. FRICTION

Slips and falls may be caused by inadequate available friction or due to a sudden change in available friction. For example, a spilled beverage or other contaminant may reduce available friction in a given area. Because of this, the maintenance of a floor is an important factor in its ability to provide a safe walking surface. Local building codes normally take precedence over other regulatory agencies. Natural stone used for paving provides an adequate available static coefficient of friction for human ambulation when supplied with an appropriate finish and properly maintained. Proper maintenance includes prompt cleanup of spills and correcting other conditions that can cause a sudden reduction in a floor's static or dynamic coefficient of friction. Aftermarket products are available for application on natural stones to increase available friction if required. Such products must be applied and maintained according to the manufacturer's recommendations.

1.4.1. Testing of frictional properties to ascertain appropriate traction levels per ANSI 326.3 (American National Standard Test Method for Measuring Dynamic Coefficient of Friction of Hard Surface Flooring Materials) is recommended.

1.5. SUBSTRATES

1.5.1. DEFLECTION. Deflection must be limited in the substrate for installation of stone finishes. Stone thickness of less than ¾" (20 mm) is considered to contribute no flexural strength to the assembly, providing decorative and abrasion resistance properties only. Stone of ¾" (20 mm) or greater thickness may be considered to be part of the structural assembly provided its suitability has been verified by comprehensive engineering analysis.

1.5.2. CAST-IN-PLACE CONCRETE FLOORS. The substrate shall be designed for a total load deflection not exceeding L/360, as measured between control or expansion joints.

1.5.3. FRAME CONSTRUCTION. The subfloor areas over which stone finishes are to be installed must be designed to have a total load deflection not exceeding L/720.

1.5.3.1. The use of strongbacks, cross-bridging or other means of reinforcement is recommended to limit differential deflection between adjacent framing members.

1.5.4. Impact loading and rolling loads shall be considered when designing substrate floor assemblies.

1.5.5. Preloading the floor prior to installation may be required to lessen the effects of the deformation due to the dead load of the stone and other components.

1.5.6. MATERIAL WEIGHTS: For estimating purposes, mortar bed weight can be approximated as 0.75 lb per square foot per each 1/16" of thickness (2.3 kg/m² per each mm of thickness). Stone weight can be approximated as 1 lb per square foot per each 1/16" of thickness (3 kg/m² per each mm of thickness).

1.5.7. SELF-LEVELING UNDERLAYMENTS. Gypsum-based and self-leveling underlayments are not recommended for use with stone paving, except in conjunction with an approved primer and waterproofing or crack isolation membrane (See ANSI A118.10-118.12). If using this method, careful adherence to the manufacturer's recommended procedure is required.

1.6. JOINTS

Width of Joints between Stones. Joints between stones should be of sufficient width to ensure that the grout being used can be placed throughout the full depth of the stone and properly compacted within the joint.

1.6.1. Typical joint widths for stone installation:

1.6.1.1. EXTERIOR STONE PAVEMENT: Minimum ¼" (6 mm), preferably ⅜" (10 mm). Joints of ½" (12 mm) or larger are frequently required for large unit size installation.

1.6.1.2. INTERIOR STONE FLOORING INSTALLATION: Minimum 1/16"

(1.5 mm), preferably ⅛" (3 mm). Joints of ¼" (6 mm) or larger are frequently required for large unit size installation.

1.6.2. Joints of ½" to 1" (12 to 25 mm) are frequently required for installing stones with split, or "snapped" edges.

1.6.3. Stone units with "cleft" or other non-planar surface finishes generally require larger joints to minimize perceived lippage. Joint widths of ¾" or 1" (20 to 25 mm) are not uncommon with these material finishes.

1.6.4. An arris, or chamfer is commonly used on stone edges to reduce the vulnerability of chipping during handling and transport. Joints between stone units having an arris or chamfer will appear wider than the actual dimension when filled.

Installation of natural stone with tight joints is not recommended.

1.6.5. Where vertical surfaces meet horizontal paving, the joint should be filled with an elastomeric sealant in lieu of grout. These joints should be at least ⅜" (10 mm) in width and continue through the stone assembly to the substrate or backing (membranes may remain continuous). Follow the sealant manufacturer's recommendation to determine if primer or backer rod is required.

1.6.5.1. Installation sequencing is generally easier if the walls are installed first and the floor material abuts the wall face, although some designers prefer to have the horizontal surface extend under the vertical surface, for aesthetic reasons. In either case, protection of completed work must be provided.

1.6.6. EXPANSION AND MOVEMENT JOINTS: Expansion and/or movement joints are essential for the success of stone installations. Various methods require proper design and location of expansion joints as shown in "Method EJ171," from the Tile Council of North America Installation Handbook. Because of the limitless conditions and structural systems in which stone can be installed, the Specifying Authority shall show locations and details of expansion joints on project drawings.

1.6.6.1. FINAL DESIGN. It is not the intent of this manual to make movement and expansion joint recommendations for a specific project. The Architect must specify expansion and movement joints and show location and details on drawings.

1.6.6.2. Movement Joints are also required in fields of paving. Movement joints extend through the finish layer only and provide an interruption to the accumulation of shear stress resulting from differential in expansion between the finish layer and substrate layers of the paving assembly. Reference ANSI A108.01 section 3.7 and ANSI A108.02 section 4.4 for guidance on movement joint location and design.

1.6.6.3. Expansion, isolation, or construction joints in the substrate must continue through the entire stone installation assembly.

1.7. LIPPAGE

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

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

1.7.3. Industry lippage tolerances will not be attainable in heavily textured surfaces, including flamed coarse-grained stones, cleft, or water-jet finishes. In those installations, joint width should be increased to limit perceived lippage, and in some cases joints as wide as ¾" (20 mm) may be required.

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

2. RELATED MATERIALS

2.1. MEMBRANES

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

2.1.2. Comply with the membrane manufacturer's written instructions regarding the applicability and installation of the membrane product.

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

2.1.3.1. CLEAVAGE MEMBRANES: Cleavage membranes are used in thick-bed installations below a reinforced mortar bed to intentionally prevent the bond between the stone setting system and the substrate slab, allowing independent movement (free floating) of the stone and setting system.

2.1.3.2. CRACK ISOLATION MEMBRANES: Crack Isolation membranes are used to isolate the stone from minor in-plane cracking of the substrate surface in thin-set applications. Crack Isolation membranes are used in thin-set applications and can be sheet applied, trowel applied, or liquid applied.

2.1.3.3. UNCOUPLING MEMBRANES: Uncoupling membranes are sheet applied, and geometrically configured to provide a small airspace which accommodates lateral flexibility between the tile and the substrate, reducing the transfer of stresses to thin-set stone installation systems. Uncoupling membranes are most frequently used on wood frame support systems.

2.1.3.4. WATERPROOF MEMBRANES: Waterproof membranes are used to prevent the migration of liquid water. These membranes are most commonly liquid applied, although sheet products are available. Some waterproofing membranes also function as crack isolation membranes.

2.1.3.5. SOUND ATTENUATION MEMBRANES: Sound attenuation membranes are used to reduce audible transmission from one level to the level below in multi-story construction. These membranes are most commonly used in condominium and office buildings.

2.1.3.6. MEMBRANE SPECIFICATIONS: Specifications for various membranes can be found in ANSI A118:

2.1.3.6.1. A118.10 American National Standard Specifications for Load Bearing, Bonded, Waterproof Membranes for Thin-set Ceramic Tile and Dimension Stone Installation

2.1.3.6.2. A118.12 American National Standard Specifications for Crack Isolation Membranes for Thin-Set Ceramic Tile and Dimension Stone Installation

2.1.3.6.3. A118.13 American National Standard Specification for Bonded Sound Reduction Membranes for Thin-set Ceramic tile Installation

2.2. SURFACE SEALERS

2.2.1. Sealing the Face of the Stone: This section does not imply that sealing the face of the stone is a necessary practice. Application of sealers is a common practice in certain instances, such as when extremely high porosity stone is installed or when the stone floor is installed in a food or beverage service area. If any sealer coating is specified for any natural stone material, advice should be sought in detail from qualified sealer manufacturers, stone suppliers or installers (See Ch 3, pg. 3-5, section 5.10).

2.2.1.1. While commonly referred to as "sealers" the products used to treat stone surfaces are typically an "impregnating repellent" rather than a true sealer. These products, when properly applied, are designed to preserve the ability of the stone to transmit water vapor ("breathe").

2.2.2. MORTARS AND ADHESIVES Portland Cement Mortar: Portland cement mortar is a mixture of portland cement and washed sand, roughly in proportions of 1:3 (by volume) for floors. Hydrated lime may also be added in the mortar mixture up to ⅛ of the total volume. Additional additives, typically latex or acrylic, may be included in this mortar recipe. The stone is typically set with this mortar while the mortar bed is still in a plastic state.

2.2.2.1. Portland cement mortars may be reinforced with metal lath or welded wire mesh for thick set setting bed systems, especially when a slip sheet is used

2.2.2.2. Portland cement mortars are structurally strong, generally resistant to prolonged contact with water, and can be used to plumb and square surfaces installed by others.

2.2.3. DRY-PACK MORTAR: Contrary to its name, "Dry-Pack" mortar isn't actually dry, but rather it is simply under-hydrated compared to mortar mixes that are placed in a plastic state. The mortar is a mixture of portland cement and water, typically containing 1 part portland cement to 3 to 4 parts (by volume) clean washed sand.

2.2.3.1. A simple field test for the level of hydration of the dry-pack is that one should be able compact it into a "ball" in one's hand. If the mortar can be extruded between one's fingers when squeezing the ball of mortar, it is over-hydrated.

2.2.3.2. Despite being under-hydrated at the time of installation, dry-pack mortar will eventually achieve full cure due to reaction between the portland cement and water of opportunity.

2.2.3.3. Dry-Pack mortars are commonly used in exterior or other wet exposure areas. The absence of hydrated lime in this mixture eliminates the possibility of lime solids leaching to the surface.

2.2.4. THIN-SET MORTAR: Thin-set mortar, oftentimes called "dry-set mortar", is a mixture of portland cement (although a few are not cement-based) with sand and additives providing water retention. Thin-set mortars are also frequently used as a bond coat for setting stone.

2.2.4.1. Thin-set mortar is available as a factory-sanded mortar to which only water need be added. Cured thin set mortar is generally tolerant of prolonged contact with water but does not form a water barrier.

2.2.4.2. Thin-set mortar is not intended to be used in trueing or leveling the substrate surfaces as tile is being installed.

2.2.4.3. Specifications for various thin-set mortar varieties can be found in ASNI A118 as below:

2.2.4.3.1. A118.1: American National Standard Specifications for Dry-Set Cement Mortar

2.2.4.3.2. A118.3: American National Standard Specifications for Chemical Resistant, Water Cleanable Tile-Setting and -Grouting Epoxy and Water Cleanable Tile-Setting Epoxy Adhesive

2.2.4.3.3. A118.4: American National Standard Specifications for Modified Dry-Set Cement Mortar

2.2.4.3.4. A118.5: American National Standard Specifications for Chemical Resistant Furan Mortars and Grouts for Tile Installation

2.2.4.3.5. A118.8: American National Standard Specifications for Modified Epoxy Emulsion Mortar/Grout

2.2.4.3.6. A118.11: American National Standard Specifications for EGP (Exterior Glue Plywood) Latex-Portland Cement Mortar

2.2.4.3.7. A118.15: American National Standard Specifications for Improved Modified Dry-Set Cement Mortar

2.2.5. LIMESTONE (or other light-colored stones) SETTING MORTAR. Cement used in mortars for setting limestone and other light-colored stones shall be white portland cement per ASTM C150, or white masonry cement per ASTM C91. Nonstaining cement shall not contain more than 0.03% of water-soluble alkali when determined in accordance with procedure 15, calculation 16 of ASTM C91 or Federal Specification SS-C181C. However, if a large amount of standard cement has been used in the backup material and an effective water barrier has not been provided between the stone and the backup, the use of nonstaining cement may not prevent discoloration. Discoloration will reduce or disappear as the stone dries. The Indiana Limestone Institute recommends a 1:1:6 (portland: lime: sand) or Type N mortar be used with Indiana Limestone. At the present time, there are few masonry cement mortars produced labeled "nonstaining."

2.3. GROUTS

Cementitious grouts used as joint fillers can be sanded or unsanded as required. Sanded grouts tend to have greater strength and durability than unsanded grouts but can introduce the risk of surface scratching when installed in stone varieties that are softer than the aggregate in the grout and may be difficult or impossible to install in narrow width joints.

2.3.1. Pigments used in colored grouts can be difficult to blend in an even manner. This may cause color spotting and shading in the finished product.

2.3.2. Sanded portland cement grout is normally field-mixed in proportions of one part portland cement to one part clean, fine-graded sand (per ASTM C144) used for joints up to ¼" (6 mm) wide; 1:2 for joints up to ½" (12 mm) wide; and 1:3 for joints over ½" (12 mm) wide. Hydrated lime, not exceeding 1/5 part, may be added. Damp curing is preferable.

2.3.2.1. Sanded portland cement grout should be applied with caution over softer varieties of stone with honed or polished finishes because it may scratch the stone surface. Masking of the stone may be necessary.

2.3.3. Unsanded Grout portland cement grout is a commercially available mixture of portland cement and other ingredients, producing a water-resistant, dense, uniformly colored material, and is normally available in white or gray colors. Damp curing is advantageous for this material. Unsanded grout is commonly used for narrow joint widths (≤⅛" [≤3 mm]) or with soft varieties of stones with polished finish which can be scratched by the aggregate contained in a sanded grout.

2.3.4. Polymer Modified Portland Cement Grout is a mixture of any of the preceding grouts with polymer admixtures. The common polymer types are latex and acrylic. This grout is suitable for all installations subject to ordinary use and for most commercial installations. The use of polymer additives in portland cement grout increases the flexibility and reduces the permeability of the grout. Consult the grout and polymer manufacturers for specific instructions.

2.3.4.1. Specifications for polymer modified portland cement grouts can be found in A118.7 American National Standard Specifications for High Performance Cement Grouts for Tile Installation.

2.3.5. COLORING OF GROUTS: Many manufacturers offer grouting materials in colors. Architects and Designers find them pleasing for aesthetic reasons. Since some stones are more porous than others, test to determine the stability of the relationship between the colored joint filler and the stone before proceeding. Make certain pigments contained in the colored grout do not stain the stone.

2.4. JOINT SEALANTS

2.4.1. Unlike grouting, which is commonly specified in the stone specification, building sealants are normally covered in a separate specification section.

2.4.2. Sealants should comply with the requirements documented in ASTM C920 Standard Specification for Elastomeric Joint Sealants.

2.4.3. Common joint sealant chemistries include silicone, urethane, polysulfide and latex.

2.4.3.1. Urethane sealants are commonly preferred for horizontal stone surfaces because their typically higher modulus provides greater resistance to abrasion and penetration.

2.4.3.2. Strict adherence to the written instructions of sealant manufacturer is required.

2.4.3.3. Primers may be required for some sealant/substrate combinations. Refer to the manufacturer's requirements.

2.4.3.4. Some grades of silicone sealants are not recommended by their manufacturers for application on high calcite content materials. Consult the Sealant Manufacturer's technical recommendation before applying a given sealant to calcite materials.

2.4.3.5. All sealants shall be tooled to ensure proper adhesion to the contact surfaces.

2.4.3.6. Specialty sealants exist for specific in-service conditions. For example, mildew-resistant silicone sealants formulated with fungicide are often used for sealing interior joints in showers and around tubs, sinks, and plumbing fixtures. Severe service areas (patios, decks, traffic surfaces) should be caulked with materials having sufficient abrasion resistance. Consult the Sealant Manufacturer's technical recommendations for sealants in these areas.

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

2.4.3.8. Some sealants contain plasticizers which may wick into the stone perimeter and cause staining. If exemplar applications are not available to verify that the sealant does not contain staining plasticizers, testing per ASTM C1248 or ASTM D2203 is highly recommended.

2.4.4. BACKER RODS: Proper selection of the backer rod can greatly influence the performance of the joint sealant.

2.4.4.1. The backer rod performs three functions:

2.4.4.1.1. Controls the depth and shape of the sealant profile.

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

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

2.4.4.2. Backer rods are available as either "open cell" or "closed cell" type. Closed cell backer rods are generally preferred as they do not absorb water like an open cell rod. Caution is necessary when installing closed cell rods to avoid puncturing the rods. A punctured rod, during periods of increasing temperature, will exhaust air as the air trapped within the rod expands. This can produce bubbles in the sealant or breach of the sealant joint.

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

2.4.4.4. Consult sealant manufacturer to verify warranties are compliant with project specifications.

2.5. PLYWOOD SUBFLOORS

2.5.1. Refer to APA form No. E30W for plywood installation methods.

2.5.2. Plywood subfloors, including tongue-and-groove plywood, must be installed with a gap (generally ⅛ inch [3 mm]) between the sheets to allow for expansion. Stagger all seam. All subfloor seams should occur over framing, with underlayment seams occurring approximately 25% into the span between framing members. Plywood should have the strength axis running perpendicular to the joist.

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

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

2.5.5. Use a construction adhesive in accordance with manufacturer's written directions.

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

2.5.7. Place screws 6" (150 mm) on center in both directions or per manufacturer's directions, whichever is less.

2.5.8. Align strength axis of both subfloor and underlayment layers.

2.5.9. A double layer (subfloor plus underlayment) is recommended for natural stone installations depending on joist spacing.

2.5.10. A crack suppression membrane is recommended when installing stone over frame construction.

2.5.11. Follow directions of manufacturers of all system components.

2.6. CEMENTITIOUS BACKER UNITS

2.6.1. Cementitious backer units are normally considered to be a bonding layer only, without providing a significant contribution to the flexural rigidity of the floor assembly.

2.6.2. Comply with manufacturer's instructions as to installation, bedding, taping, and fastening of cementitious backer units.

2.6.3. Specifications for cementitious backer units can be found in A118.9 American National Standard Specifications for Test Methods and Specifications for Cementitious Backer Units.

2.7. METAL EDGES AND TRANSITION STRIPS

2.7.1. Metal edges and/or transition strips of a different material are recommended required wherever stone flooring abuts a dissimilar flooring material.

2.7.2. Comply with manufacturer's instructions as to installation and fastening of preformed metal edge strips.

3. PAVEMENT SYSTEMS

3.1. EXTERIOR INSTALLATION METHODS:

3.1.1. MORTAR BED BONDED TO CONCRETE SUBSURFACE

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

3.1.1.2. Substrate slab shall be sloped toward drains to maintain a uniform depth of the mortar bed.

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

3.1.1.4. Concrete Slabs that require additional work to achieve these requirements such as grinding, feathering, patching or scarifying are considered as non-compliant with Industry Standards for stonework until remedial work has been completed by others.

3.1.1.5. METHOD. Stone paving should be installed in a full mortar bed consisting of one part portland cement and from three to four parts clean washed sand by volume. Minimum thickness of a mortar bed is 1¼" (30 mm). The recommended thickness is 2" (50 mm). Application of a bond coat of portland cement paste or other approved material (slurry) to both the paver and the substrate slab is required.

3.1.1.6. JOINTS. The joints may be pointed with suitable mortar or grout or filled with a resilient filler strip and approved sealant.

3.1.1.6.1. REINFORCING. Reinforcing of the mortar bed is recommended for beds of 2" (50 mm) depth or greater and shall be specified by the design professional.

3.1.2. MORTAR BED SEPARATED FROM CONCRETE SLAB. This method is used where the concrete slab may be problematic such as anticipated differential movement between the slab and the stone assembly. Other factors which favor selection of this installation method include:

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

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

3.1.2.3. Capillary moisture issues exist.

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

3.1.2.5. Where an unbondable membrane exists.

3.1.2.6. In these situations, the slab will require remedial treatment commensurate with the severity of the problem. These options usually involve a membrane of some type and as such the mortar bed cannot be bonded to the substrate. As with the bonded mortar bed systems, slope and tolerance of the slab shall be such so as to maintain an even thickness of the bed. Movement joint requirements will also remain the same; however, the membrane may remain continuous.

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

3.1.3. DRY-PACK MORTAR SYSTEMS

3.1.3.1. Contrary to its name, "Dry-Pack" mortar isn't actually dry, but rather it is simply under-hydrated compared to mortar mixes that are placed in a plastic state.

3.1.3.2. The rough concrete substrate below the stone paving installation shall be installed by others. The concrete elevation shall be low enough to provide a minimum bed depth of 2" (50 mm) between the stone and the concrete. The concrete shall be allowed to cure for a minimum of 28 days.

3.1.3.3. A crack isolation membrane shall be placed over the concrete slab to prevent bonding of the dry-pack mortar to the concrete. (Six mil polyethylene sheeting has been found to be effective and economical for this purpose.)

3.1.3.4. The mortar bed to receive the stone paving shall consist of dry-pack mortar, containing 1 part Portland cement to approximately three to four parts clean washed sand by volume. A simple field test for the level of hydration of the dry-pack is that one should be able to compact it into a "ball" in one's hand. If the mortar can be extruded between one's fingers when squeezing the ball of mortar, it is over-hydrated.

3.1.3.5. The dry-pack mortar bed shall be reinforced by 2" x 2" (50 mm x 50 mm) 16 gauge (1.5 mm) galvanized welded wire mesh or as specified by the design authority. The placement of the mesh shall be within the center one-third of the mortar bed.

3.1.3.6. The mortar should be spread evenly over the substrate and screeded flat to the desired elevation, then loosened or "fluffed up" with a shallow toothed rake to assist in compression of the dry-pack when tamping the stone paver into position.

3.1.3.7. Before positioning a stone paver onto the mortar bed, the back of the paver should be sponged clean, then dried, after which it shall be parged with either thinset, or a thick layer of neat cement paste. This process is often referred to as "back buttering".

3.1.3.8. Immediately before placing the stone paver on the mortar bed, the dry pack mortar should be sprinkled with water using a watering can with multiple small (≤ 1/16" [1.5 mm]) perforations.

3.1.3.9. The stone paver shall be placed on the mortar bed and tamped with a non-marring mallet until firmly bedded to the proper level of the floor. Several iterations of removal and replacement of the stone paver may be required to facilitate adding or removing bedding material before the proper level is achieved.

3.1.3.10. The specified joint width shall be maintained within documented tolerances between the paver units. Expansion and movement joints shall be included per industry recommendations in the pavement design.

3.1.3.11. Traffic shall be prevented from traversing the floor for a minimum of 24 hours after which it shall be grouted with the specified grout material. Grout shall not be over-hydrated, and the stiff grout mixture is to be compacted into the joints until level with the stone surface, then tooled to a slight concave profile.

3.1.4. PEDESTAL SUPPORTED SYSTEMS

3.1.4.1. PREPARATORY WORK: Adequate slope for surface drainage must be provided in rough concrete slab. Waterproofing and drainage system must be completed by other trades prior to installation of the stone.

3.1.4.2. Stone-supporting pedestals may be cast-in-place concrete, mortar, or plastic. Careful shimming is required to maintain the plane of the stone surface at the specified elevation and to prevent rocking of the finished stone paver. Commercially available threaded plastic shims are available to efficiently accomplish the elevation adjustment. (See illustration at the close of this section).

3.1.4.2.1. FLEXURAL STRENGTH. In a pedestal supported pavement system, the stone unit is a structural member that carries the live and dead loads back to the pedestals. Required thickness and pedestal spacing should be determined by a P.E. and must consider design loads, stone properties, intended traffic and appropriate safety factors. Atypical loading, such as maintenance vehicles, emergency vehicles, or performance structures must be considered when determining the anticipated loads.

3.1.4.3. OPEN JOINTS. The joints in this system are left open, allowing water to flow below the stone units to be collected and transported by the drainage system.

3.1.4.4. Advantages of this system include the elimination of the requirement to slope the stone surface to a drain, since the drainage is accomplished below the pedestrian deck, and the ease of removal and replacement of the pavers to facilitate maintenance or repair of the drainage system and waterproofing membranes below the stone pavers. An additional advantage is that because the joints are left open, the edges of the stone pavers are ventilated which prevents moisture from wicking into the stone edges (edge wicking of moisture can produce "picture framing" staining).

3.1.5. GRANULAR (SAND) BED METHOD

3.1.5.1. PREPARATORY WORK. Excavate unsuitable, unstable, or unconsolidated subgrade material and compact the area that has been cleared. Fill and level with densely graded crushed stone aggregate suitable for subbase material, or as otherwise directed by Specifying Authority.

3.1.5.2. METHOD. Place bedding course of sharp, normal weight limestone screening or concrete sand to a depth of approximately 1½" (40 mm) leveled to grade. Compact bedding course parallel to finish grade and tamp.

3.1.5.3. Stone pavers shall be laid upon the bedding course in successive courses. Every course of pavers shall be laid true and even and brought to grade by the use of non-marring mallets or similar tools, and shall be laid parallel to the base line. After the pavers are laid, the surface shall be swept and inspected. Cover surface with a wood board approximately 3" (75 mm) thick, 12" (300 mm) wide, and 6' (2 m) long, and tamp to intended position. Do all tamping immediately after laying pavers and do not allow tamper to come in contact with pavers. Broom sand into joints, tamping sand in joints to ensure full bedding around perimeter of stone.

3.1.5.3.1. Joints in granular bedded systems are typically "hand-tight" to prevent lateral migration of stone units. Some spalling at the stone surface can be expected as grains of sand get wedged into the nearly tight joints and exert pressure at the top edge of the stone as the pavers displace vertically under load.

3.2. INTERIOR INSTALLATION METHODS

3.2.1. TCNA HANDBOOK DETAILS. Since 2012, the Handbook for Ceramic, Glass, and Stone Tile Installation" by the Tile Council of North America has included a section dedicated to stone tile installation. The Natural Stone Institute has participated in the Tile Council of North America's (TCNA) development of this handbook and continues to participate in updates to the document. This document is reprinted every year, although the handbook committee meets only biennially, so substantial revisions are likely to appear only biennially. The details are not duplicated in the Natural Stone Institute publications. Contact the TCNA (www.tcnatile.com) or the Natural Stone Institute's Book Store to obtain a copy of the handbook.

3.2.2. MORTAR BED BONDED TO CONCRETE SUBFLOOR. This method is used where the concrete sub-floor is not subject to excessive movement or deflection (Recommended for installation of larger pieces [slabs]).

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

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

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

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

3.2.2.5. Concrete that requires additional work to achieve these requirements such as grinding, feathering, patching or scarifying are considered to be non-compliant with Industry Standards for stonework until remedial work is completed.

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

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

3.2.2.8. A mortar bed consisting of one part portland cement to three to four parts clean washed sand by volume is laid over the concrete subfloor to a nominal thickness of 1¼" (30 mm). Stone is back-buttered uniformly with a cement paste bond coat, laid over the mortar bed and tamped into a true and level plane. Joints are grouted with a portland cement based grout or other approved material. (See Detail at the close of this section).

3.2.3. MORTAR BED SEPARATED FROM CONCRETE SUBFLOOR. This method is used where the concrete slab may be problematic such as anticipated differential movement between the slab and the stone assembly. Other factors that would favor the selection of this installation system include:

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

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

3.2.3.3. Capillary moisture issues exist.

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

3.2.3.5. Where an unbondable membrane exists.

3.2.3.6. In these situations, the slab will require remedial treatment commensurate with the severity of the problem. These options usually involve a membrane of some type and as such the mortar bed cannot be bonded to the substrate. The requirement for unbonded mortar beds is that they be reinforced as specified by the design professional; usually with wire at the approximate center of the bed. As with the bonded mortar bed systems, slope and tolerance of the slab shall be such as to maintain an even thickness of the bed. Movement joint requirements will also remain the same; however, the membrane may remain continuous.

3.2.4. MORTAR BED SEPARATED FROM WOOD SUBFLOOR. This method is used where subfloor is subject to movement and deflection.

3.2.4.1. The mortar bed floats over subfloor and minimizes possibility of stone cracking from structural movement. An isolation membrane is laid over the sub-floor. A mortar bed consisting of one part portland cement to three to four parts clean washed sand by volume with reinforcement specified by the design professional. Stone tiles are laid over the mortar bed and tamped into proper plane. Joints are later grouted with a portland cement-based grout or other approved material.

3.2.5. THIN BED OVER PLYWOOD SUBFLOOR

3.2.5.1. This method should be used only in residential construction. The subfloor must be adequately designed to carry loads without excessive deflection. Subfloor must be level with a maximum variation of ⅛" in 10'-0" (3 mm in 3 m), with a deflection not exceeding L/720. Strongbacks, cross-bridging or other reinforcement shall be used to limit differential deflection between adjacent framing members. Comply with all manufacturers' written installation instructions. Apply mortar with flat side of trowel over an area that can be covered with tile while mortar remains plastic. Within ten minutes and using a notched trowel sized to facilitate the proper coverage, comb mortar to obtain an even setting bed without scraping the backing material. Key the mortar into the substrate with the flat side of the trowel. Back butter the stone tiles to ensure 95% contact with no voids exceeding 2 in² (1300 mm²) and no voids within 2" (50 mm) of tile corners on ⅜" (10 mm) tile. Back butter the stone tiles to ensure 80% contact with no voids exceeding 4 in² (2600 mm²) and no voids within 2" (50 mm) of tile corners on ¾" (20 mm) or thicker material. All corners and edges of stone tiles must be fully supported and contact area shall always be 95% or greater in water-susceptible conditions. Joints are later grouted with a portland cement-based grout or other approved material.

3.2.6. THIN-BED PORTLAND CEMENT MORTAR OVER CONCRETE SUBSTRATE

3.2.6.1. This method is used when space for full mortar bed is not possible. Concrete subfloor should not be subject to excessive movement or excessive deflection. Subfloor must be level with maximum variation of ¼" in 10'-0" (6 mm in 3 m). Mortar bed is laid using a notched trowel over subfloor to a thickness of not greater than 3/32" (2.5 mm) . Apply mortar with flat side of trowel over an area that can be covered with tile while mortar remains plastic. Within ten minutes and using a notched trowel sized to facilitate the proper coverage, comb mortar to obtain an even setting bed without scraping the backing material. Key the mortar into the substrate with the flat side of the trowel. Back butter the stone tiles to ensure a minimum of 95% contact with no voids exceeding 2 in² (1300 mm²) and no voids within 2" (50 mm) of tile corners on ⅜" (10 mm) tile. Back butter the stone tiles to ensure a minimum of 80% contact with no voids exceeding 4 in² (2600 mm²) and no voids within 2" (50 mm) of tile corners on ¾" (20 mm) or thicker material. All corners and edges of stone tiles must be fully supported and contact shall be a minimum of 95% in water-susceptible conditions. Joints are later grouted with a portland cement-based grout or other approved material. (See Detail at the close of this section).

3.2.7. THIN-BED MORTAR OVER CEMENTITIOUS BACKER UNITS

3.2.7.1. This method should be used only in residential construction and per manufacturers' instructions. The subfloor must be adequately designed to carry loads without excessive deflection. The cementitious backer unit is considered to be a bonding layer only and provides negligible structural contribution to the flooring system. Subfloor must be level with a maximum variation of 1/16" in 3'-0" (1.5 mm in 1 m), with a deflection not exceeding L/720. Cross-bridging or other reinforcement shall be used to limit differential deflection between adjacent framing members. Apply mortar with flat side of trowel over an area that can be covered with tile while mortar remains plastic. Within ten minutes and using a notched trowel sized to facilitate the proper coverage, comb mortar to obtain an even setting bed without scraping the backing material. Key the mortar into the substrate with the flat side of the trowel. Back butter the stone tiles to ensure a minimum of 95% contact with no voids exceeding 2 in² (1300 mm²) and no voids within 2" (50 mm) of tile corners on ⅜" (10 mm) tile. Back butter the stone tiles to ensure a minimum of 80% contact with no voids exceeding 4 in² (2600 mm²) and no voids within 2" (50 mm) of tile corners on ¾" (20 mm) or thicker material. All corners and edges of stone tiles must be fully supported and contact shall always be a minimum of 95% in water-susceptible conditions. Joints are later grouted with a portland cement-based grout or other approved material.

3.3. HEATED FLOOR SYSTEMS

3.3.1. In frame construction, the plywood portion of the substrate must be a minimum of 1½" (40 mm) exterior glue plywood. Leave a gap between the plywood sheets for expansion. Install a cleavage membrane over the plywood.

3.3.2. Frame and Mortar Bed. Heated floor systems are generally proprietary in nature, and the manufacturer's installation guidelines shall be closely followed. Consider using a heat deflector on top of the membrane. The heating contractor should install the heating system per manufacturer's recommendation. Fill cavity with a wire or portland mix so that the mortar bed covers pipes and is at least ¾" (20 mm) over the top of heating pipes, with a minimum bed thickness of 2½" (65 mm). Allow to cure for at least 30 days. This mortar bed thickness is necessary to dissipate heat to avoid damaging the stone by uneven heating.

3.4. THRESHOLDS

3.4.1. Exposed edges may be eased, rounded, arrised or beveled. If instructions are not given as to type of edge required, Supplier will furnish according to industry standards.

3.4.2. Thicknesses of ½", ¾", and 1¼" (12, 20, and 30 mm), or as specified.

3.5. STAIRS

3.5.1. SIZES: Tread thicknesses of ¾", 1¼", and 1½" (20, 30, or 40 mm) are commonly used for interior stairs. Thicknesses of 1¼", 2" (30, 50 mm) and cubic (greater than 2" [50 mm]) are commonly used for exterior stairs. Risers may be ¾" or 1¼" (20 or 30 mm) thick, or in the case of cubic treads, the riser face is integral with the tread surface stone.

3.5.1.1. In residential applications, thin stone (less than ¾" [20 mm] treads and risers may be installed using a thin-set portland cement mortar bed over clean and level concrete subtreads or double layers of ¾" (20 mm) plywood installed in opposite directions with ⅛" (3 mm) gaps between sheets. These types of applications will not withstand high impact or wheel loads. Overhang is not permitted when stones of this thickness are used.

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

3.5.3. 100% coverage of mortar bed material between tread and subtread is desirable.

3.5.4. Risers ¾" (20 mm) or thicker must be anchored with wire or stainless steel strap anchors. If risers thinner than ¾" are used, they may be adhered using the thin-bed portland cement mortar method.

4. TROUBLESHOOTING AND CAUTIONS

4.1. INSTALLATION METHODS

Stone paving can be installed by several methods. Consideration should be given to the various features of each method in making a selection for a specific installation. See illustrations of installation examples at the close of this section.

4.2. GEOGRAPHIC METHODS

Some installation methods and materials are not recognized and may not be suitable in some geographic areas because of local trade practices, building codes, climatic conditions, or construction methods. Therefore, while every effort has been made to produce accurate guidelines, they should be used only with the independent approval of technically qualified persons. Some installation methods and materials are not recognized and may not be suitable in some geographical areas because of local trade practices, building codes, climatic conditions, or construction methods. Therefore, while every effort has been made to produce accurate guidelines, they should be used only with the independent approval of technically qualified persons.

4.3. PROTECTION OF FINISHED WORK

During construction, the General Contractor shall protect all stone from staining and damage. After the stone paving has been installed, the General Contractor must keep all traffic off the floors for at least 48 hours. No rolling or heavy (greater than pedestrian) traffic should be permitted on newly installed stone surfaces for at least two weeks after the floor has been grouted or caulked.

4.4. PREPARATION OF STONE UNITS

Wash and dry backs and edges of all pavers prior to installation in any installation method other than pedestal supported pavers.

4.5. MOISTURE AND ALKALINITY SENSITIVITY

Stone suppliers shall identify stones that are adversely affected by moisture and alkalinity.

4.6. SETTING BEDS FOR LIGHT COLORED STONES

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

4.7. TRANSITIONS FROM STONE TO SOFT FLOORING

Where stone abuts softer flooring materials, a stone threshold or metal edge protection strip is recommended. This will help prevent edge chipping caused by impact.

4.8. HOLLOW SOUND

Because of the weight and consequent difficulties in handling large-sized pavers, it is impossible to avoid an occasional "hollow" sound found in some stone units after installation. Reasons for hollow sounds include:

4.8.1. A hollow sound may indicate that insufficient bonding of the paver exists, although it is not necessarily a reliable test. Other influences can cause a hollow sound from a properly bonded paver.

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

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

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

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

4.9. MOISTURE PENETRATION

The performance of a properly installed stone installation is dependent upon the durability and dimensional stability of the substrate to which it is bonded. The user is cautioned that certain substrate materials used in wet areas may be subject to deterioration from moisture penetration.

4.10. WET AREAS

"Wet areas" are stone surfaces that are either soaked, saturated, or subjected to moisture or liquids (usually water), e.g., gang showers, tub enclosures, showers, laundries, saunas, steam rooms, swimming pools, hot tubs, and exterior areas.

4.11. FIBERGLASS MESH BACKING

Producers frequently apply a fiber mesh reinforcement to the back surfaces of stone tiles and slabs to reduce breakage and also to increase safety when handling large slabs. Caution should be used when using a stone that has a fiberglass mesh backing applied on the back face. The fiberglass, having been bonded to the stone with a resinous (commonly epoxy, although sometimes polyester or other adhesive chemistries) adhesive, will not bond adequately with cementitious products. Only epoxy products, or products specifically made for fiberglass by the manufacture should be used when installing stone with fiberglass mesh backing.

4.12. GREEN COLORED STONE

Avoid the use of water-based adhesive when installing certain green marbles and/or serpentines. Some of these stones may warp through absorption of water from the setting bed. (Water drawn into the stone is held to the crystals by surface energy. This force tends to widen the intercrystalline space and thereby expand the wet side.)

4.13. VOIDS IN TRAVERTINE
Travertine flooring, particularly fleuri cut (also called "cross-cut) will have voids occurring just below the finished surface of the material. Since these voids are concealed by a thin shell of stone material, they do not get filled in the factory filling process. Once in service, concentrated loads (e.g., loads from wheels or spike heels) will fracture the thin shell of stone, exposing the void below. Several iterations of re-filling travertine floors in place can be expected until these voids are all discovered. This is essentially a "break-in" process for this particular material and is not considered a defect in the stone.

4.14. SEALANT STAINING
Some elastomeric sealants contain oil-based plasticizers to reduce their modulus and increase their extension/compression capability. The plasticizers can wick into stone perimeters, causing darkening of the edge (picture framing) and accelerated dirt collection on the stone face. Caution should be used in specifying sealants to ensure compatibility with stone. It is recommended that either an exemplar project be identified using the same stone and sealant components with satisfactory results, or a testing regimen (per ASTM C1248 or ASTM D2203) be employed to verify compatibility.

4.14.1. Some sealant manufactures maintain a database of stone projects using joint sealers from that manufacturer to aid in identifying exemplar projects for evaluation.

4.15. EFFLORESCENCE
Efflorescence is a salt deposit, usually white in color that appears on exterior surfaces of stone walls and floors. The efflorescence is produced by salts leached to the surface of the stone by water percolating through the stone backup and joints. The most feasible means of prevention is to stop the entrance of large amounts of water. If the conditions bringing about the efflorescence continue, scaling may occur and flake off successive layers. For this to happen, large amounts of water must continue to enter behind the stone and must contain large amounts of salts.

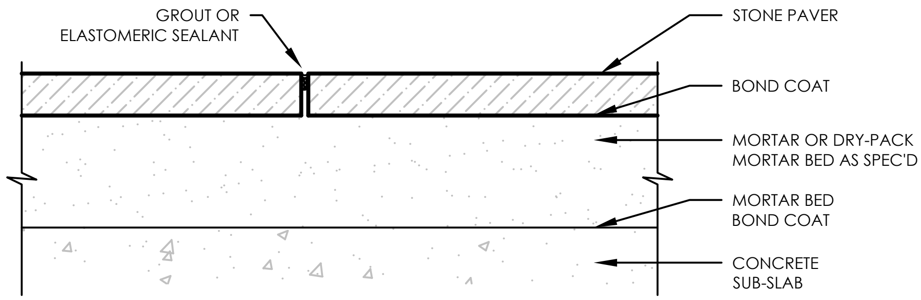
4.16. LIGHTING OF HIGH ANGLES OF INCIDENCE
Lighting with a high angle of incidence, in which the path of light is nearly parallel to the face of the wall surface, is a popular choice in both interior and exterior designs. This lighting style will exaggerate lippage, textural surface variation, and even warpage due to the extremely elongated shadow lines caused by the angle of incidence. Material and installation which are within industry tolerances may appear to be outside of tolerances due to the accentuation of the lighting technique. Inspection of areas receiving such lighting shall be done with the lighting turned off or otherwise blocked.

4.17. VARIATION IN GLOSS
It is almost impossible to uniformly read light reflection on a polished or high-honed-finish installation due to the natural characteristics of dimension stone. Due to the heterogeneous composition of natural stones, variable mineral hardness exists within the stone, producing variable reflectivity of light energy. Most stones, especially travertine marbles and limestones, will appear to reflect light unevenly.

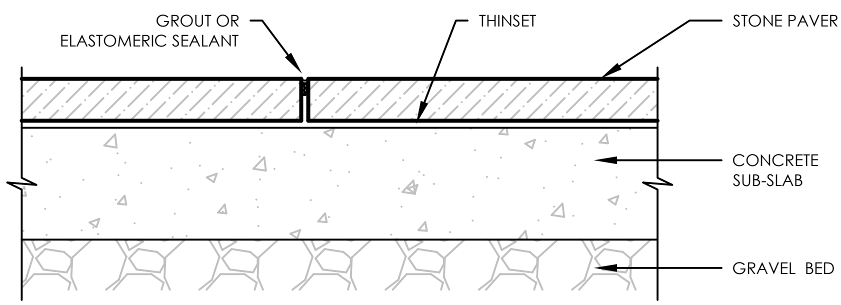
4.18. POLISHING WHEEL MARKS
Polishing wheel marks or other scratches caused during fabrication are unacceptable on honed or polished stone.

4.19. SNOW MELTING CHEMICALS
Many stones, especially limestones, are vulnerable to attack from snow melting chemicals, particularly salt. The attack is actually mechanical, rather than chemical. In solution, the salt can penetrate the pores of the stone, but when the water evaporates, the salt recrystallizes within the pore. The resultant recrystallization pressure can exfoliate the surface of the stone.

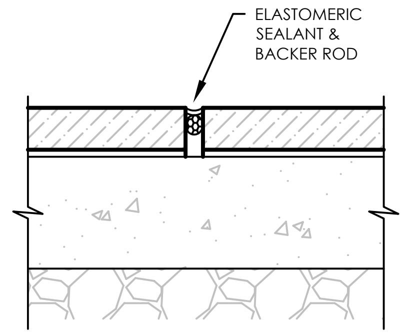
NOTES:



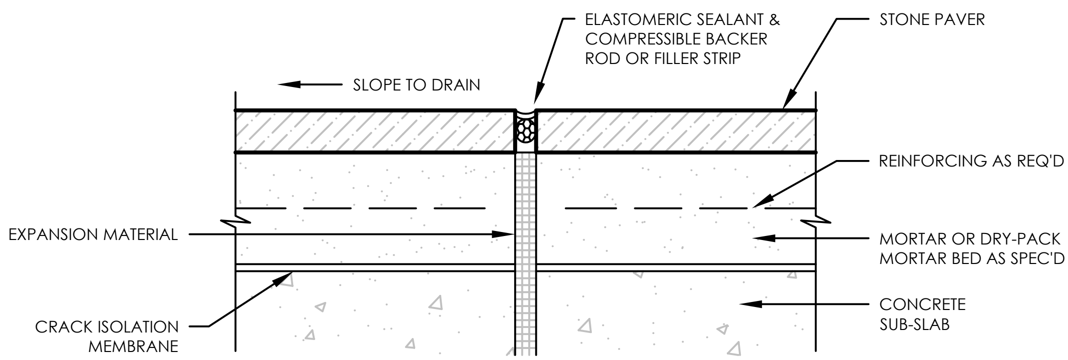
1 MORTAR BED WITH BOND COAT



2 MORTAR BED WITH THINSET



2A MOVEMENT JOINT



3 FULL MORTAR BED WITH MEMBRANE AND EXPANSION JOINT

NOTE: IT IS NOT THE INTENT OF THIS MANUAL TO MAKE EXPANSION, CONTROL, OR MOVEMENT JOINT RECOMMENDATIONS FOR A SPECIFIC PROJECT. THE SPECIFYING AUTHORITY MUST DESIGN AND LOCATE EXPANSION, CONTROL, AND MOVEMENT JOINTS ON THE CONSTRUCTION DOCUMENTS.

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www.naturalstoneinstitute.org

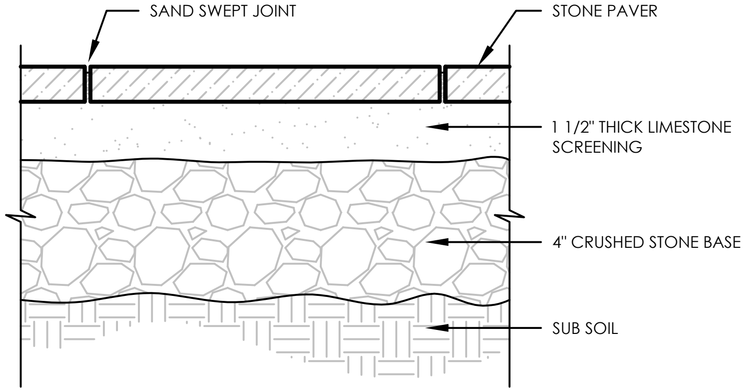
REV	DATE
0	MAR 2022

EXTERIOR STONE PAVING

DIMENSION STONE DESIGN MANUAL 2022

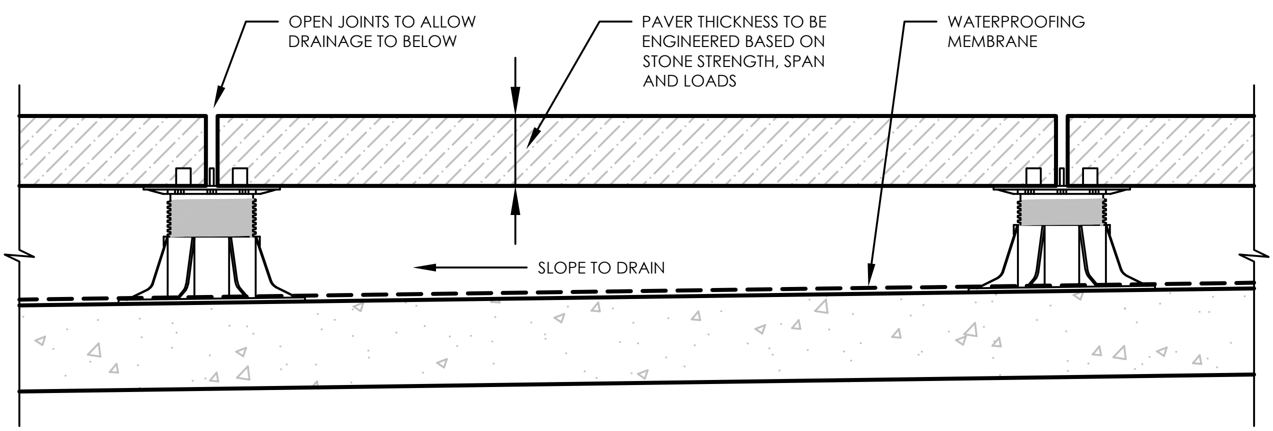
DRWG NO: 13-D-1

SCALE: 3" = 1'-0"



1 STONE PAVERS SET IN SAND BED

Scale: 3" = 1'-0"



2 PEDESTAL SUPPORTED STONE PAVERS

Scale: 1½" = 1'-0"

(GRAPHIC COURTESY OF BISON INNOVATIVE PRODUCTS)

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EXTERIOR STONE PAVING

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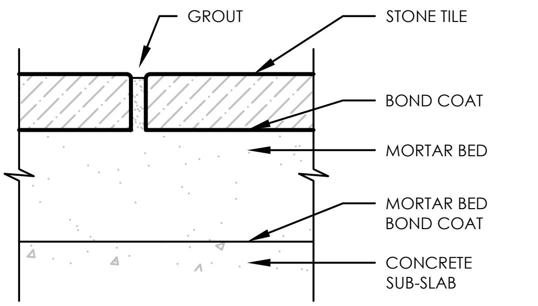
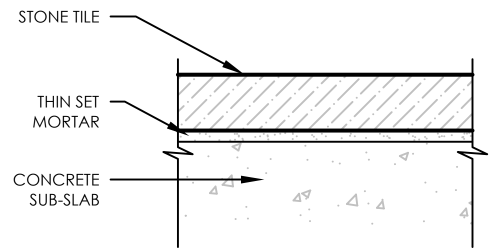
DRWG NO: 13-D-2

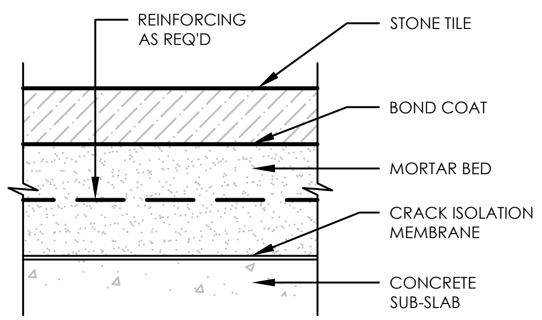
SCALE: As Noted



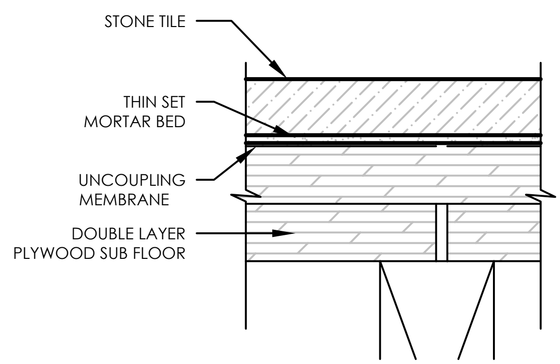
1 STONE TILE SET IN MORTAR BED



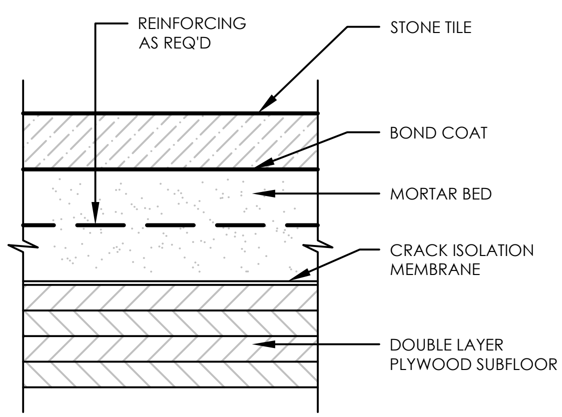
4 STONE TILE SET IN THIN-SET BED OVER CONCRETE SLAB



2 STONE TILE SET IN REINFORCED MORTAR BED



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



3 STONE TILE SET IN REINFORCED MORTAR BED OVER WOOD FRAME

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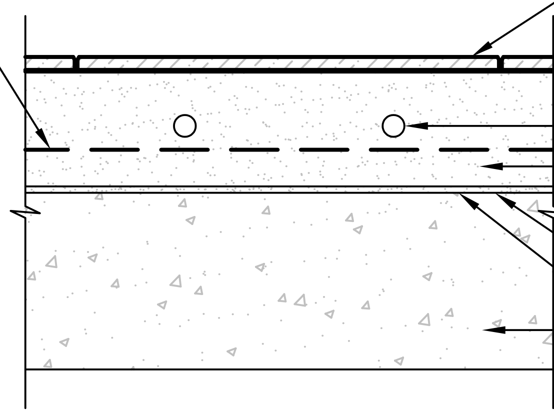
INTERIOR STONE FLOORING

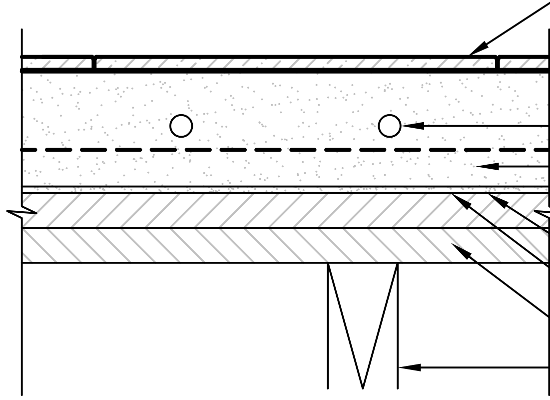
DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 13-D-3

SCALE: 3" = 1'-0"



1 STONE TILE OVER HYDRONIC RADIANT HEAT SYSTEM WITH CONCRETE SUBSTRATE



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

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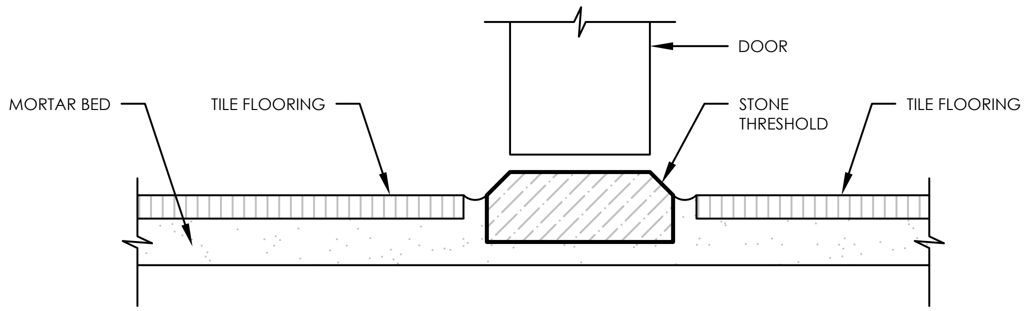
INTERIOR STONE FLOORING
RADIANT HEAT DETAILS

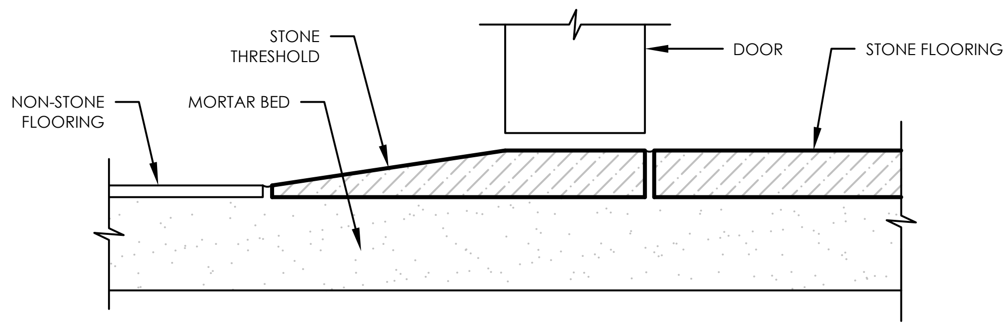
DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 13-D-4

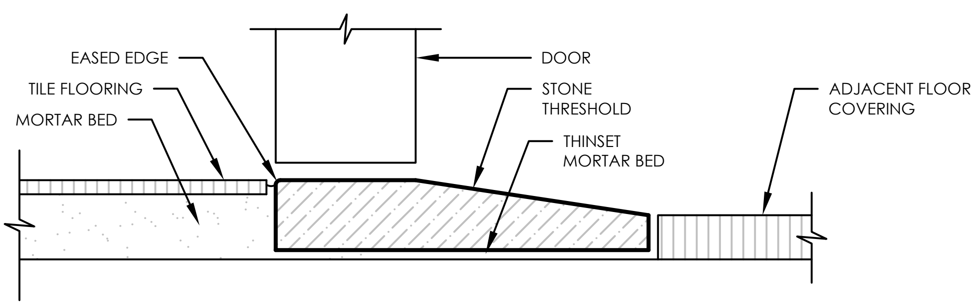
SCALE: 3" = 1'-0"



1 VARYING BED DEPTH MORTAR METHOD



2 FULL MORTAR BED METHOD



3 THIN-SET METHOD

NOTES: 1. USE 100% COVERAGE OF BOND COAT MATERIAL BETWEEN THRESHOLD AND SUB-SLAB
2. MINIMUM ABRASIVE HARDNESS OF THRESHOLD MATERIAL SHOULD BE 12.0 (ASTM C241 OR C1353)

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STONE THRESHOLDS

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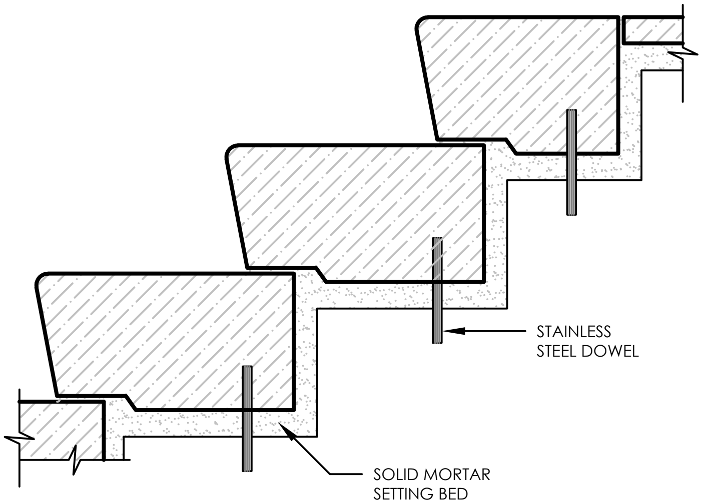
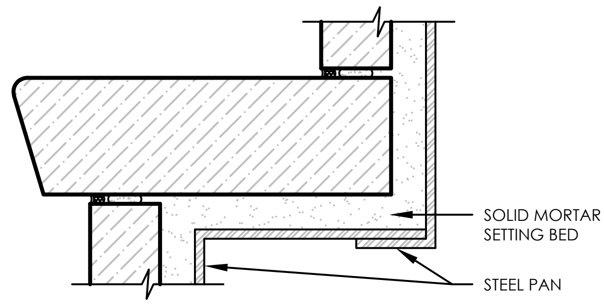
DRWG NO: 13-D-5

SCALE: 3" = 1'-0"



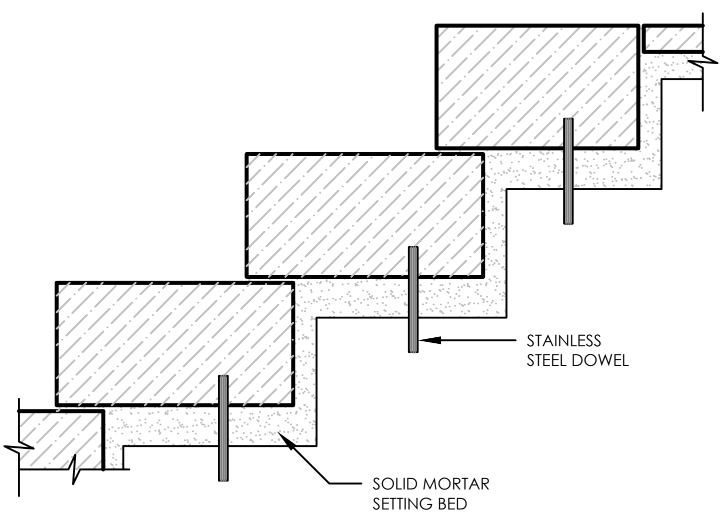
1 CUBIC STEP DETAIL

SCALE: 1½" = 1'-0"



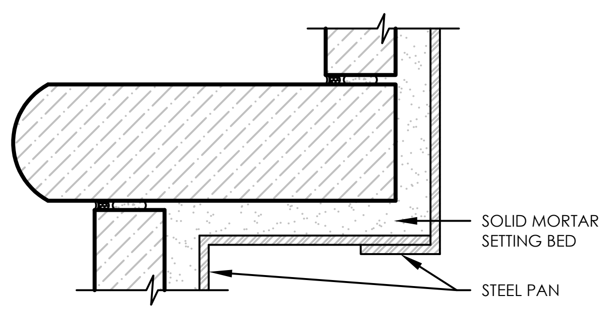
2 STEP DETAIL ON METAL PAN

SCALE: 3" = 1'-0"



3 CUBIC STEP DETAIL

SCALE: 1½" = 1'-0"



4 STEP DETAIL ON METAL PAN

SCALE: 3" = 1'-0"

NOTES: 1. USE 100% COVERAGE OF BOND COAT MATERIAL BETWEEN THRESHOLD AND SUB-SLAB
2. MINIMUM ABRASIVE HARDNESS OF THRESHOLD MATERIAL SHOULD BE 12.0 (ASTM C241 OR C1353)

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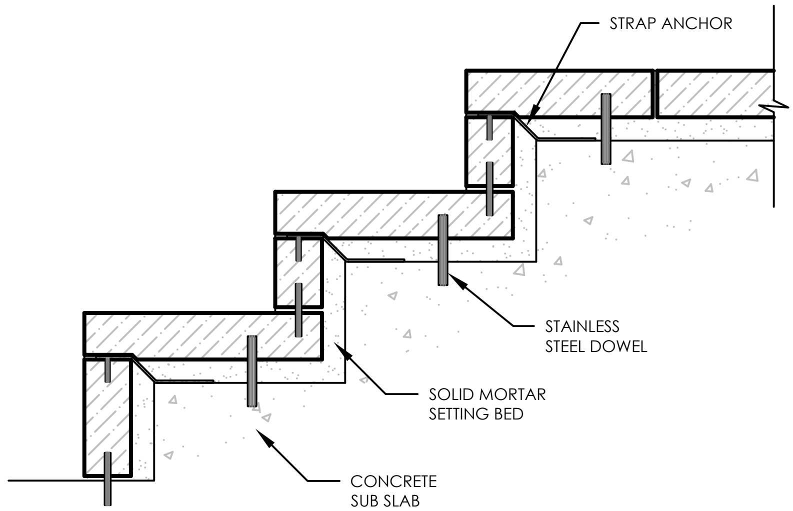
STONE STAIR DETAILS

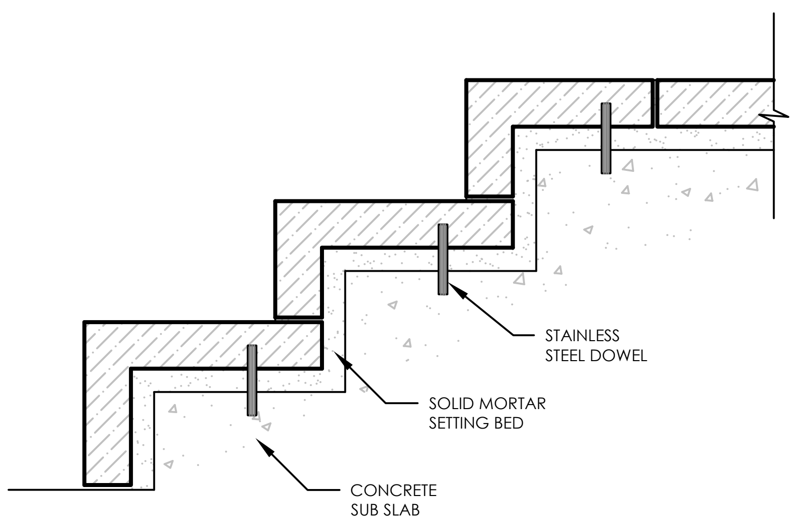
DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 13-D-6

SCALE: As Noted



5 VENEERED STEP DETAIL



6 HOOKED STEP DETAIL

NOTES: 1. A ROUGH OR TEXTURED FINISH IS RECOMMENDED FOR EXTERIOR USAGE
2. MINIMUM ABRASIVE RESISTANCE OF STONE TREAD MATERIAL SHOULD BE 12.0 (ASTM C241 OR C1353)
3. FABRICATION LABOR REQUIREMENTS COMMONLY MAKE DETAIL 6 A HIGHER COST ALTERNATIVE

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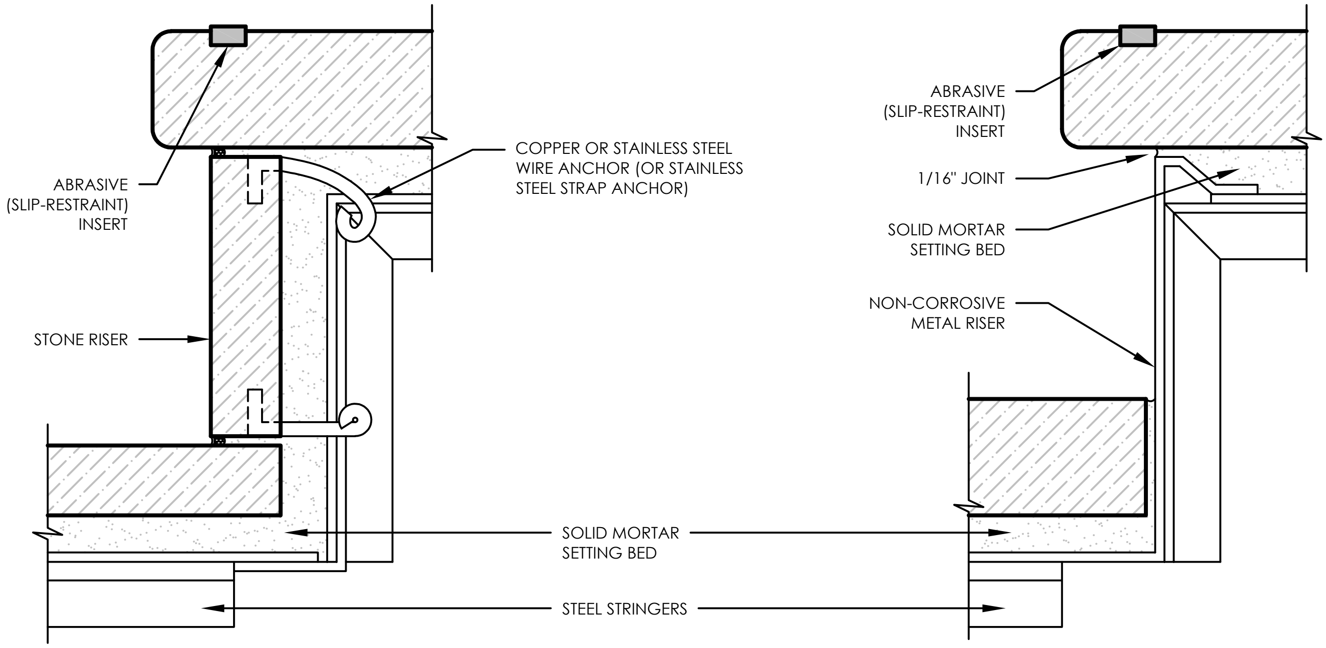
STONE STAIR DETAILS

DIMENSION STONE DESIGN MANUAL 2022

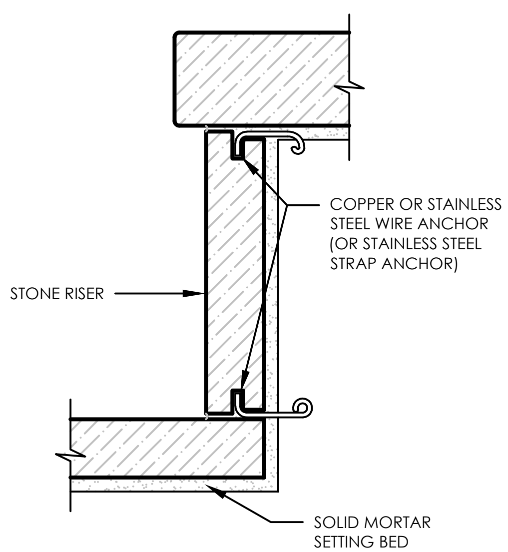
DRWG NO: 13-D-7

SCALE: 1 1/2" = 1'-0"

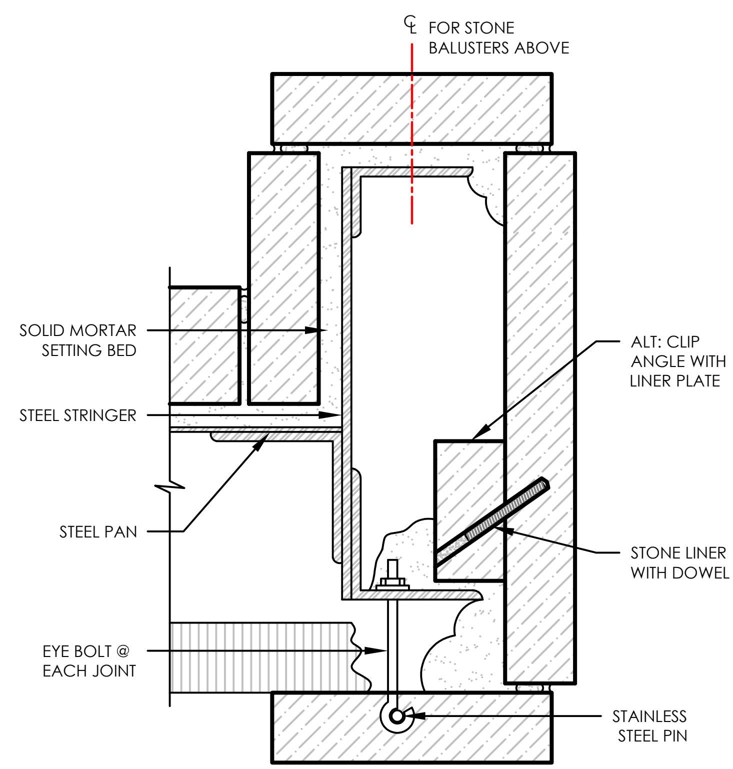


1 STEP DETAIL ON METAL PAN

2 STEP DETAIL ON METAL PAN



3 VENEERED STEP DETAIL



4 STEP DETAIL ON METAL PAN

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STONE STAIR DETAILS

DIMENSION STONE DESIGN MANUAL 2022

DRWG NO: 13-D-8

SCALE: 3" = 1'-0"

VERTICAL SURFACES

1. DESIGN CRITERIA

Design of vertical surfaces, particularly in exterior applications, require several factors to be taken into account. Amongst others, these include climatic conditions such as wind, seismic, freeze-thaw cycles; material properties of the stone selected and the structural back up provided by the building engineer. The building classification, local building codes and material selected will dictate the appropriate minimum factors of safety, preferred method of installation and optimal anchoring system. These may vary from state to state and/or specified building classification. It is for these reasons that we strongly recommend a qualified stone engineer and accredited installer be engaged from preconstruction through final construction phases to ensure a successful project delivery.

1.1. STONE SELECTION AND SUPPLY

1.1.1. STONE PRODUCT DEFINITIONS

1.1.1.1. TILE. A stone tile is a thin, flat piece of natural stone used as finishing material, with a gauged thickness ranging from ¼" to ⅝" (6 to 16 mm) inclusive and having no dimension greater than 2' 0" (610 mm). Tiles are normally supplied in typical sizes, with all atypical pieces being field cut to fit.

1.1.1.2. CUT-TO SIZE. Cut-to-size stone products, also referred to as "slab stock" stone products, are custom fabricated pieces of natural stone. Fabrication of these products normally occurs in a shop setting, where each piece is custom fabricated to specific sizes, but partial fabrication may also occur in the field at the time of installation.

1.1.2. TOLERANCES. Natural stone tiles and cut-to-size products may have different fabrication tolerances due to their different methods of fabrication. Refer to the Chapter 22 on Tolerances of this manual for fabrication and installation tolerances.

1.1.3. LABOR ASSIGNMENT: The successful installation of both dimension stone and stone tile is dependent upon the experience and craft knowledge of the firm contracted to install the stone. The Natural Stone Institute endorses the use of NSI Accredited Natural Stone companies. See www.naturalstoneinstitute.org for a directory of installation companies accredited by the NSI.

1.1.4. ASTM C119 outlines the terminology relating to dimension stone and provides a brief description of some of the stone groups. There are numerous suitable materials available for cladding in each group, however one must be aware that stone, being a natural material, may have significantly varying properties within each group. Additionally, physical and mechanical properties of the stone, panel size, panel thickness, design loads, and climatic conditions can determine whether a stone is suitable for a given application.

1.1.5. As a general rule, stone panel thickness should be a minimum of 1¼" (30 mm) for exterior installations and a minimum of ¾" (20 mm) for interior installations, but in many cases heavier thicknesses are necessitated. Panel sizes and thicknesses may also be dictated by local codes, wind load requirements, areas of usage, and material performance as determined by ASTM standard specifications. Refer to ASTM C1528 for recommendations of minimum stone thickness.

1.1.6. SHOP DRAWINGS: Detailed shop drawings shall be provided by the stone contractor. Shop drawings shall address:

1.1.6.1. Stone type and finish

1.1.6.2. Stone sizes, thicknesses, joinery and patterning

1.1.6.3. Vein and rift directions, if appropriate

1.1.6.4. Joint sizes and treatments

1.1.6.5. Identification of mortar, adhesive, and grout types.

1.1.6.6. Details of mechanical anchorage, including anchor devices and metallurgy of same.

1.1.6.7. Structural Backup

1.1.6.8. Flashing and/or other means of water management

1.1.6.9. Relationship/interface between stone and adjacent building materials

1.1.7. FABRICATION: Exterior veneer units are precut and prefinished to dimensions specified on shop drawings and are typically delivered to the job site ready to install.

1.1.7.1. All required carving shall be performed by skilled tradespeople in strict accordance with approved full-size details or models. Architectural drawings will show approximate depth and relief of carving. Carved surfaces shall be left as produced by the carving tool(s), unless otherwise specified.

1.1.8. FINISHES: Most commercially available stone finishes are suitable for exterior veneer, however, some stones, notably calcitic materials such as marbles and limestones, will not retain a polished finish in exterior environments.

1.1.8.1. Some fabricator applied treatments, such as resin, may have inadequate resistance to weathering.

1.1.9. COLORS: A wide variety of color options are available, provided they meet or exceed the necessary performance specifications of the project.

1.1.10. Panel Sizes and Thicknesses may need to be determined by engineering analyses. The following properties should be considered when determining size and thickness of stone veneer units:

1.1.10.1. Flexural Strength (Ref: ASTM C880) or Modulus of Rupture (Ref: ASTM C99) of the stone

1.1.10.2. The anticipated loads

1.1.10.3. Required factors of safety

1.1.10.4. Generally, large panel dimensions can create supply and/or anchorage difficulties. The designer is encouraged to verify obtainable dimensions with the quarrier of the material prior to finalizing the design.

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

1.1.11.1. Granite: ASTM C615, Standard Specification for Granite Dimension Stone

1.1.11.2. Limestone: ASTM C568, Standard Specification for Limestone Dimension Stone

1.1.11.3. Marble: ASTM C503, Standard Specification for Marble Dimension Stone

1.1.11.3.1. Soundness Classifications: Refer to Chapter 7 for a complete discussion of Marble Soundness Classifications.

1.1.11.4. Onyx: No ASTM Standard exists at this time.

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

1.1.11.6. Serpentine: ASTM C1526, Standard Specification for Serpentine Dimension Stone

1.1.11.7. Slate: ASTM C629, Standard Specification for Slate Dimension Stone

1.1.11.8. Soapstone: No ASTM Standard exists at this time.

1.1.11.9. Travertine: ASTM C1527, Standard Specification for Travertine Dimension Stone

1.1.12. Caution is advised when using historical test data for natural stones. It is preferable to use data obtained from test specimens from current quarry production that is representative of the actual product being supplied. Test data should be obtained from testing agencies specializing in natural stone testing.

1.2. SAMPLES AND MOCKUPS

The stone supplier shall provide samples of the various dimension stones to be used per the requirements of the project specifications. Samples shall indicate the extremes of color, veining, and marking that the stone supplied to the project will have.

1.2.1. Pending the scope of the installation and the variability of the stone product, a full-sized visual mockup may be required to adequately demonstrate the range of the material's color and character. Mockups are intended to demonstrate the full range of color tones and natural characteristics of the stone to be expected across the entire project yet condensed into the much smaller surface area of the mockup. Therefore, the effects of the variation and characteristics of the stone will be more concentrated and appear more extreme than the actual project since the actual project will have less frequent occurrences of these elements.

1.2.2. Pending the scope of the installation and the variability of the stone product, a "dry-lay" may be required to adequately demonstrate the range of the material's color character, and finish, with the advantage of predetermining the actual position and orientation of each stone panel. The dry-lay allows the design professional to see the actual blend of the finished wall, and also allows the arrangement of pieces to be adjusted per his/her desires. Since each stone panel is dedicated to a specific location, crating and handling must be skillfully executed to prevent damage as there may or may not be a suitable replacement available for a given stone. A dry lay is generally considered to be a wise investment for decorative interior office lobby, floor and wall projects. It provides a beneficial team building experience and the formal approval of all stone prior to shipment helps eliminate jobsite anxiety and rejections.

1.2.3. A performance mockup may also be required to verify the structural and/or weatherproofing capabilities of the designed system.

1.3. INSPECTION

Inspection of supplied material to evaluate compliance with approved samples or mockups shall be done at a viewing distance of not less than 6'-0" (2 m) with natural lighting, from a vantage point that is perpendicular to the face of the stone.

1.4. FIELD REPAIR

1.4.1. During the progress of construction, changes are often necessary to accommodate other trade and design revisions. These changes may require job site cutting and some finishing of stone, and this can be satisfactorily executed by qualified mechanics.

1.4.2. Repair or patching is sometimes necessary due to damage of material either on-site or in transit. By allowing these repairs to be made on-site, progress of the job can be maintained, thus aiding the successful completion of the work. Repairs should not detract from the desired appearance or strength of the completed installation.

1.5. CAVITIES

Cavities behind stone facades are commonly used to provide space for anchorage, insulation, and other components in addition to accommodating fabrication and construction tolerances of both the stone and backup system.

1.5.1. Cavities shall have weeps, commonly at intervals of 3 to 4 ft (1 to 1.5 m) at their lowest point and at any level where water cannot freely travel vertically within the cavity (such as where continuous shelf angles or flashings exist).

1.5.2. Cavities shall be vented to provide additional evacuation opportunities for water vapor and to reduce possible pressure differentials between the cavity and the ambient pressure.

1.5.3. ADDITIONAL TECHNIQUES. With today's improved construction techniques, it is possible to produce structures that are highly resistant to natural weather conditions. Joints can be sealed with resilient sealants and the building interiors can be temperature- and humidity-controlled. Venting of the cavity is recommended to prevent moisture problems. It is recommended that a vapor barrier be installed at the exterior face of the backup wall. In most cases, the back face of the stone should not be sealed.

1.5.4. VENEER CAVITIES: Solid grouting of stone veneer cavities that would permit the capillary transmission of moisture through the wall from exterior to interior, and interior to exterior, is generally considered inadvisable. However in some cases, particularly rubble stone construction, solid-filled collar joints are used.

1.6. FLASHING

Condensate is expected to form within cavities and will travel downward within the cavity until it reaches a location where it is directed out. Flashing is required at any location where water must be prevented from seeping behind attached elements and at any location where water must be prevented from contacting the area below. Flashing can be either membrane or sheet metal.

1.7. ANCHORS

Anchorage systems must be securely attached and located as shown on the approved shop drawings and shall be plumb and in true plane. Numerous types of mechanical anchorage devices have been developed over decades. Most anchors will fall under one of the following categories:

1.7.1. STRAP ANCHORS: Anchors formed from light gauge (≤ 3/16", ≤5 mm) metal, usually stainless steel, and feature a "tab" that engages a slot penetration or "kerf" in the perimeter of the stone, are commonly referred to as "strap anchors". Strap anchors carry lateral loads only, with the gravity loads carried by other means.

1.7.2. PIN ANCHORS: Pin anchors consist of a pin swaged into a strap, with the strap attached to the backup structure and the pin penetrating a drilled hole in the edge of the stone. Pin anchors are more challenging to align between successive courses than strap anchors, but are sometimes preferable to strap anchors since the penetration required in the stone removes less material and in some cases results in greater lateral capacity for the anchor.

1.7.3. DOWEL ANCHORS: Anchors consisting of a simple section of dowel, usually stainless steel, are referred to as dowel anchors. These anchors engage a drilled hole in the edge of the stone, with the opposite end of the dowel penetrating a rigid material, oftentimes concrete, to provide the necessary connection. Dowel anchors typically carry lateral loads, but in some cases (i.e.: liner blocks) are responsible for gravity loads.

1.7.4. SHELF ANCHORS: Shelf anchors are usually a section of extruded angle or bent plates, either stainless steel or corrosion protected mild steel, that carry gravity loads.

1.7.5. BENT PLATE ANCHORS: Bent plates, either formed from one metal section or welded from multiple sections, carry bidirectional loads (lateral and gravity). Essentially, they are a hybrid combination of a strap and shelf anchor. They are usually made of stainless steel since a portion of the anchor penetrates and/or is in contact with the stone.

1.7.6. BACK ANCHORS: Back anchors include any of several devices that penetrate the back surface of a stone panel with a positive, mechanical locking feature. Most back anchors are capable of providing bidirectional load carrying capacity and can therefore be used to address both lateral and gravity loads.

1.7.7. MASONRY BED ANCHORS: These anchors do not penetrate the stone but are merely embedded in the mortar joints of split-face ashlar or similar installations. They can be wire loops or corrugated metal. These types of anchors are only recommended for stone greater than 3" (75 mm) in thickness.

1.7.8. WIRE TIE ANCHORAGE: Wire tie anchorage is a historically effective method of anchoring stone panels and has been used successfully for centuries. However, this installation must be carried out by a qualified and trained marble or stone mason. Additional considerations when using wire tie anchorage are listed below:

1.7.8.1. Wire anchors are not generally recommended for installations exceeding 15'-0" (4.5 m) vertically.

1.7.8.2. Copper is the most commonly used wire, although stainless steel wire (¼ Hard Series 304 stainless steel wire is often specified as it provides a reasonable balance between workability and strength) is recommended in lieu of copper wire for exterior or wet area interior applications.

1.7.8.3. A plaster or cementitious dollop, or "spot" is used in conjunction with the wire tie. When wire tie anchorage is used for exterior or wet areas the spot material shall be of a portland cement based compound. Setting plaster, moulding plaster, or other gypsum based products are strictly limited to interior, dry environments.

1.7.8.4. When copper wire is used, it is common in some geographical regions to twist the wire to stiffen the wire via metallurgical work hardening. Excessive work hardening of the wire can lead to embrittlement of the metal. Care must be taken to ensure that the physical properties of the wire have been improved and not degraded by this process.

1.7.9. OTHER ANCHORAGE DEVICES: Standard, custom, and proprietary anchorage devices are available for stone panel attachments. A representation of many of the commonly used devices can be found in the graphics section of this chapter. Additional information can also be found in the Natural Stone Institute's Technical Bulletin on Dimension Stone Anchorage.

1.7.10. THIN STONE ANCHORAGE: Natural stone in thicknesses of less than ¾" (20 mm) are usually not capable of accommodating mechanical anchors and must be secured by adhesive attachment.

1.7.11. ANCHOR SIZE: Anchor sizing is dependent upon materials, codes, physical conditions of the structure, wind and seismic requirements, thermal properties, etc. Anchors should be engineered separately for each condition.

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

1.7.13. ANCHOR QUANTITY: Weight, size, shape, and type of stone along with loading requirements will determine the number, spacing and size of the anchors . Four anchors per panel is generally considered to be both minimum and optimum, although certain conditions may mandate additional anchor locations. IBC currently prescribes minimum anchorage quantities for non-engineered "stone veneer" and "slab type veneer" based on the surface area of the stone panels. Due to varying loads, stone properties, and anchor capacities, this may not necessarily be adequate, particularly when public or occupant safety may be compromised. It is recommended that exterior stone cladding systems be reviewed by an experienced stone cladding engineer to verify anchor and panel capacities. In all cases, anchorage shall be compliant with the project specifications, requirements of the engineer of record, and/or applicable codes.

1.7.14. ANCHOR PLACEMENT: Anchors shall be placed per the locations indicated on the approved shop drawings and engineer's calculations.

1.7.14.1. When possible, it is preferred to reduce flexural stresses in stone panels by positioning anchors at optimum locations in the panel.

1.7.14.2. In some cases, for instance anchoring highly decorative stones with limited soundness in interior installations, it is preferred to allow the field mechanics to determine the anchor placement so that unsound regions of the stone panel can be avoided.

1.7.15. FILLING OF ANCHOR PREPS: Anchor preps in stone panels shall be filled to prevent rattling of the stone panel and to prevent moisture collection in the anchor prep in wet area installations.

1.7.15.1. Fillers may be cementitious or elastomeric and must be non-expanding.

1.7.15.1.1. Only flexible filler materials are recommended for continuous kerf anchorage.

1.7.15.1.2. Cementitious fillers are generally used for stone that are fully bedded in mortar, while elastomeric fillers are commonly used for thin cladding which will have caulked joints.

1.7.15.1.3. Verify that the elastomeric material is non-staining.

1.7.15.2. Elastomeric fillers of high modulus sealants are commonly used to allow greater flexibility to accommodate building movements.

1.7.15.3. Extremely rigid fillers, such as epoxy are generally not recommended, although there are some instances where they are appropriate.

1.7.15.4. The use of gypsum plaster (molding plaster) setting spots or gypsum based compounds for anchor preps fillers for exterior stone is not an acceptable practice.

1.7.15.5. Some anchors, specifically back-anchors, are designed to be used without filler in the anchor prep. Consult the anchor manufacturer's directions regarding the use, or nonuse, of filler for these anchors.

1.8. MORTARS AND ADHESIVES

1.8.1. PORTLAND CEMENT MORTAR: Portland cement mortar is a mixture of portland cement, sand, and lime in proportions of 1:3:½ to 1:4:½ for walls. Additional additives may be included in this mortar recipe. The stone is set with this mortar while the mortar bed is still in a plastic state.

1.8.1.1. Portland cement mortars can be reinforced with metal lath or mesh, backed with membranes, and applied on metal lath over sheathed studding.

1.8.1.2. Portland cement mortars are structurally strong, generally resistant to prolonged contact with water, and can be used to plumb and square surfaces installed by others.

1.8.2. THIN-SET MORTAR: Thin-set mortar, often times called "dry-set mortar", is a mixture of portland cement (although a few are not cement-based) with sand and additives providing water retention. Thin-set mortars are used both as bedding/adhesive layers and also as a bond coat for setting stone with other mortar systems.

1.8.2.1. Thin-set mortar is available as a factory-sanded mortar to which only water need be added. Cured thin set mortar is generally tolerant of prolonged contact with water but does not form a water barrier.

1.8.2.2. Thin-set mortar is not intended to be used in trueing or leveling the substrate surfaces as tile is being installed.

1.8.2.3. Specifications for various thin-set mortar varieties can be found in ASNI A118 as below:

1.8.2.3.1. A118.1: American National Standard Specifications for Dry-Set Cement Mortar

1.8.2.3.2. A118.3: American National Standard Specifications for Chemical Resistant, Water Cleanable Tile-Setting and -Grouting Epoxy and Water Cleanable Tile-Setting Epoxy Adhesive

1.8.2.3.3. A118.4: American National Standard Specifications for Modified Dry-Set Cement Mortar

1.8.2.3.4. A118.5: American National Standard Specifications for Chemical Resistant Furan Mortars and Grouts for Tile Installation

1.8.2.3.5. A118.8: American National Standard Specifications for Modified Epoxy Emulsion Mortar/Grout

1.8.2.3.6. A118.11: American National Standard Specifications for EGP (Exterior Glue Plywood) Latex-Portland Cement Mortar

1.8.2.3.7. A118.15: American National Standard Specifications for Improved Modified Dry-Set Cement Mortar

1.8.3. Limestone (or other light-colored stones) Setting Mortar: Cement used in mortars for setting limestone and other light colored stones shall be of white portland cement per ASTM C150, or white masonry cement per ASTM C91. Nonstaining cement shall contain not more than 0.03% of water-soluble alkali when determined in accordance with procedure 15, calculation 16 of ASTM C91 or Federal Specification SS-C181C. However, if a large amount of standard cement has been used in the backup material and an effective water barrier has not been provided between the stone and the backup, the use of nonstaining cement may not prevent discoloration. Discoloration will reduce or disappear as the stone dries. The Indiana Limestone Institute recommends a 1:1:6 (portland: lime: sand) or Type N mortar be used with Indiana Limestone. At the present time, there are few masonry cement mortars produced labeled “nonstaining.”

1.9. GROUTS

Cementitious grouts used as joint fillers can be sanded or unsanded as required. Sanded grouts tend to have greater strength and durability than unsanded grouts, but can introduce the risk of surface scratching when installed in stone varieties that are softer than the aggregate in the grout, and can be difficult or impossible to install in narrow (≤⅛”, ≤3 mm) width joints.

1.9.1. Sanded portland cement grout is normally field-mixed in proportions of one part portland cement to one part clean, fine-graded sand (per ASTM C144) used for joints up to ⅛" wide; 1:2 for joints up to ½" wide; and 1:3 for joints over ½" wide. Hydrated lime may be added, not exceeding 1/5 part. Damp curing is preferable.

1.9.1.1. Sanded-portland cement grout should be applied with caution with softer varieties of stone with honed or polished finishes because it may scratch the stone surface. Masking of the stone may be necessary.

1.9.2. Unsanded portland cement grout is a commercially available mixture of portland cement and other ingredients, producing a water-resistant, dense, uniformly colored material, and is normally available in white or gray colors. Damp curing is advantageous for this material. Unsanded grout is typically used for joints of ⅛" (3 mm) or less, or when soft varieties of stone are used with polished finish which could be scratched by the aggregate in sanded grout.

1.9.3. Polymer Modified Portland Cement Grout is a mixture of any of the preceding grouts with polymer admixtures. The common polymer types are latex and acrylic. This grout is suitable for all installations subject to ordinary use and for most commercial installations. The use of polymer additives in portland cement grout increases the flexibility of the grout and reduces the permeability. Consult the grout and polymer manufacturers for specific instructions.

1.9.3.1.1. Specifications for polymer modified portland cement grouts can be found in A118.7 American National Standard Specifications for High Performance Cement Grouts for Tile Installation.

1.9.4. Coloring of Grouts: Many manufacturers offer grouting materials in colors. Architects and Designers find them pleasing for aesthetic reasons. Since some stones are more porous than others, test to determine the stability of the relationship between the colored joint filler and the stone before proceeding. Make certain pigments contained in the colored grout do not stain the stone. A mockup to test for staining and color consistency should be performed.

1.10. JOINT SEALANTS

1.10.1. Unlike grouting, which is almost always in the stone specification section, building sealants are normally covered in a separate specification section. While grouting is nearly always performed by stone setters, in most trade areas the installation of sealants is not in the trade jurisdiction of Marble Mechanics or Stonemasons.

1.10.2. Sealants should comply with the requirements documented in ASTM C920 Standard Specification for Elastomeric Joint Sealants.

1.10.3. Common joint sealant chemistries include silicone, urethane, and polysulfide.

1.10.3.1. Strict adherence to the written instructions of sealant manufacturer is required.

1.10.3.2. Primers may be required for some sealant/substrate combinations. Check manufacturer's requirements.

1.10.3.3. Some grades of silicone sealants are not recommended by their manufacturers for application on high calcite content materials. Consult the Sealant Manufacturer's technical recommendation before applying a given sealant to calcite materials.

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

1.10.3.5. Specialty sealants exist for specific in-service conditions. For example, mildew-resistant silicone sealants formulated with fungicide are often used for sealing interior joints in showers and around tubs, sinks, and plumbing fixtures.

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

1.10.3.7. It is recommended that exemplar projects of the same stone type and sealant type be reviewed, or a mockup be prepared to ensure the sealant is non-staining and compatible with the stone.

1.10.3.8. Some sealants contain plasticizers which may wick into the stone perimeter and cause staining. If exemplar applications are not available to verify that the sealant does not contain staining plasticizers, testing per ASTM C1248 or ASTM D2203 is recommended. An adhesion test may also be required.

1.10.4. BACKER RODS: An important feature in the determination of the joint sealant is the selection of the backer rod.

1.10.4.1. The backer rod performs three functions:

1.10.4.1.1. Controls the depth and shape of the sealant profile.

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

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

1.10.4.2. Backer rods are available as either "open cell" or "closed cell" type. Closed cell backer rods are generally preferred as they do not absorb water like an open cell rod. Caution is necessary when installing closed cell rods to avoid puncturing the closed cell rods. A punctured rod, during periods of increasing temperature will exhaust air as the air trapped within the rod expands. This leads to a possible bubble or breach of the sealant joint.

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

1.11. JOINTS

1.11.1. EXPANSION, AND MOVEMENT JOINTS

1.11.1.1. Expansion Joints. In exterior stone walls, expansion joints may be provided to reduce the damaging effect of building and/or veneer movements due to thermal expansion, structural live load deflection, seismic displacement, and other applicable movements based on project conditions and material properties. Because of the many conditions and structural systems in which stone can be installed, the Specifying Authority or engineer of record shall show locations and details of expansion joints on project drawings and/or calculations.

1.11.1.2. Movement Joints are also required in fields of paving. Movement joints extend through the finish layer only, and provide an interruption to the accumulation of shear stress resulting from differential in expansion between the finish layer and substrate layers of the paving assembly. Reference ANSI A108.01 section 3.7 and ANSI A108.02 section 4.4 and TCNA EJ 171 for guidance on movement joint location and design.

1.11.2. Joint Size: Typical joint widths are:

1.11.2.1. Exterior Stone Cladding: Minimum ¼" (6 mm), preferably ⅜" (10 mm). Joints of ½" (12 mm) or larger are frequently required for large unit size installation.

1.11.2.2. Interior Stone Cladding: Minimum 1/16" (1.5 mm), preferably ⅛" (3 mm). Joints of ¼" (6 mm) or larger are frequently required for large unit size installation.

1.11.2.3. Tight or "hand-butted" joints are not recommended.

1.11.3. Shims: Shims shall be stainless steel or high-impact plastic or approved equal. Shim size shall distribute the loads to ensure that point loading does not affect stones performance.

1.11.3.1. Where permanent setting pads (shims) are required, 90 durometer neoprene or high-impact plastic is recommended. Placement of setting pads (shims) shall be positioned to accommodate effective load transfer and avoid interference with joint filler materials.

1.11.3.2. Shims used in joints of "stacked" veneer systems remain in the joint permanently to transfer load from course to course. Shims may be used to temporarily maintain joint width in other joint conditions but are to be removed prior to application of joint filler material.

1.12. LIPPAGE

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

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

1.12.3. Lippage tolerances may not be attainable in flamed, cleft, or otherwise textured finishes. In those installations, joint width should be increased to limit perceived lippage, and in some cases joints as wide as ¾" (20 mm) may be required.

1.12.4. Lippage tolerances may not be achievable in extremely large stone panels, in which case larger than typical joint widths are recommended to minimize perceived lippage.

1.12.4.1. It is recommended that exposed stone edges be gauged to the precise thickness specified, particularly when the condition includes multiple pieces in a continuous run.

1.13. SURFACE SEALERS

1.13.1. Sealing the Face of the Stone: This section does not imply that sealing the face of the stone is a necessary practice. Application of sealers is a common practice in certain instances, such as when high porosity stone is installed or when the stone is installed in a food or beverage service area. If any sealer coating is specified for any natural stone material, advice should be sought in detail from qualified stone suppliers or installers (See Chapter 3, pg. 3-5, Section 5.10).

1.13.1.1. While commonly referred to as "sealers" the products used to treat stone surfaces are typically an "impregnating repellent", which when properly applied will preserve the ability of the stone to transmit water vapor ("breathe").

1.14. THERMAL INSULATION

1.14.1. Because heat is easily transmitted through stone when stone is part of a system assembly, insulation should be provided by other contractors. A minimum 1" (25 mm) cavity shall be maintained between the stone and the insulation to prevent contact between the two materials.

1.14.2. To comply with regional energy codes, stone anchorage may require a thermal isolator to reduce the conductivity of the anchorage assembly.

1.15. FIRE RATINGS

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

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

1.15.2. Fire resistance of a material does not constitute a "fire rating". Fire ratings are established for construction assemblies, of which the stone would be only one component. Because changing the stone variety would nullify the fire rating of the assembly, it is cost prohibitive to provide the testing and documentation required to include the benefit of the stone's fire resistance to a fire rated wall. Therefore, when a fire rating is required, it is normally achieved by construction of a fully fire rated wall behind the stone face, typically with multiple layers of gypsum board.

1.16. ENGINEERING

The attachment systems for many interior and low-rise stone installations of limited scope are designed by empirical methods and are not reviewed by a registered or licensed engineer. As the scope and complexity of installation increases, or the complexity of the project environment increases (e.g.: special wind or seismic regions), having the design completed and/or reviewed by a registered, licensed professional experienced in stone attachment system designs becomes necessary.

1.16.1. A knowledgeable and experienced Installer must provide an engineered and fabricated system that will satisfy functional and aesthetic requirements. However, determining which performance requirements and the criteria under each must be made by the Specifying Authority in consultation with the Structural Engineer.

2. EXTERIOR INSTALLATION SYSTEMS

Vertical Stone Surfaces are installed with a variety of conventional and proprietary systems. A brief discussion of the more common types is below:

2.1. INDEPENDENTLY SUPPORTED VENEER

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

2.1.1. The stone panels and associated anchorage are designed to accommodate vertical loads (stone unit self-weight) and lateral loads (wind and seismic forces) as required by governing codes and/or project specifications. Each of these loads is transferred directly to the backup wall substrate through the stone anchorage. Joints between each stone are designed to accommodate thermal expansion and differential movement between stone units, and therefore, must remain free of shims, mortar, or any other rigid material that would transfer load from one stone to another. The joints are typically filled with a non-staining sealant that possesses extension and compressive capacities adequate to meet the performance requirements for the project. A minimum joint width of ⅜" (10 mm) is recommended for exterior stone veneer. Larger joints may be required to accommodate specific project demands. Note: This system can also be installed as a rainscreen or open-joint façade omitting joint sealant between stone veneer units.

2.1.1.1. Concrete/CMU Substrates: Independently Supported veneer systems can be anchored directly to cast-in-pace concrete or Concrete Masonry Unit (CMU) backup walls. In most cases, the cores of CMU wall require filling to provide adequate capacity for the drilled anchors.

2.1.1.2. Metal Frame Substrates: Independently Supported veneer systems can be anchored to miscellaneous metal framework by either welding or bolting, or a combination of the two. All elements must have adequate corrosion protection.

2.1.1.3. Stud Walls: Independently Supported veneer systems can be anchored to stud frame walls.

2.1.1.3.1. Metal studs placed behind stone wall installations to support the stone must be engineered and sized to accommodate loads. Stud wall thickness must provide adequate pull-out capacity for fasteners (16 gauge or heavier is often required).

2.1.1.3.2. Continuous horizontal channels are frequently required to provide for more flexibility in attachment locations and to distribute loads uniformly over multiple studs.

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

2.1.2. Grid Systems, commonly composed of vertical and horizontal support framing of varying corrosion-resistant materials, such as aluminum, mild steel, cold-formed steel, or stainless steel. The framing is typically pre-installed in the stone setting cavity to the substrate or support wall. Stone supports are typically integrated in the system design.

2.1.3. Strut Systems are commonly composed of vertical support framing of varying corrosion-resistant materials such as aluminum, mild steel, cold-formed steel or stainless steel. The framing is typically pre-installed in the stone setting cavity to the substrate or support wall. Non-integrated stone supports are typically attached in a method similar to Independently Supported Veneer or "Stacked" Veneer with Relieving Supports.

2.1.4. Integrated Curtainwall Stone veneer installed in glazing channels of glazed curtain wall members or mechanically fastened to mullions in similar manner to metal spandrel panels in a manner similar to glass or curtainwall spandrel panels.

2.1.5. Bi-Material Composite Panels

2.1.5.1. Lightweight Natural Stone Veneer Panels Definition: This product is a bi-material panel using a thin (±5 mm) stone face adhesively bonded to a lightweight aluminum backer. Most stone varieties and finishes are available, although each manufacturer has several preferred stones available in their offerings. Attachment of these systems is commonly done with a proprietary attachment system available from the panel manufacturer.

2.1.5.2. Other backing materials are used in addition to aluminum, including carbon fiber, fiberglass, stone, and concrete.

2.2. STACKED VENEER

Restraint and relief are achieved by using a combination of lateral ties (straps, split-tail anchors, welded tees, or other positively engaged mechanical anchorage approved by a qualified design professional) and gravity relief supports.

2.2.1. Each stone panel is restrained by mechanical anchorage attached to the backup wall substrate (building structure, masonry backup, stud framing assembly, miscellaneous steel, etc.). The stone panels and associated anchorage are designed to accommodate lateral loads only (wind and seismic forces) as required by governing codes and/or project specifications. These loads are transferred directly to the backup wall substrate through the stone anchorage. Relieving supports (e.g., continuous angles or clips) are designed to accommodate the cumulative vertical load of the stone veneer units "stacked" between the relief support and expansion or control joint above, typically a live load joint at a floor/slab line. Relief supports are typically provided over all openings and at each story height (or maximum vertical spacing of 20' [6 m]). Within a "stack", vertical loads are typically transferred from one stone to another using load-bearing shims or mortar. The joints are typically filled with a non-staining sealant or mortar adequate to meet the performance requirements for the project.

2.2.2. Consideration of weeps and flashing is recommended when continuous relief angles are utilized. Relieving angles should be provided over all openings and at each story height (or maximum vertical spacing of 20' [6 m]). Angles should have ¼" (6 mm) weep holes every 2'-0" (600 mm). Refer to local codes for variance.

2.3. THICK BED, COURSED ASHLAR INSTALLATION

2.3.1. Coursed splitface ashlar veneers are anchored to the substrate wall to address lateral loads only. Dead loads (gravity loads) are carried downward through successive courses and ultimately borne by concrete corbels, shelf angles, or other means of transferring the load to the building frame.

2.3.2. The substrate wall may be cast in place concrete, concrete masonry units, or sheathed stud frame walls. In all cases appropriate waterproofing shall be applied to the substrate wall.

2.3.3. The stone product is typically split in a hydraulic guillotine, and will have irregular, cleft surfaces on both the front and back faces. The degree of this irregularity and depth of relief will vary pending the mineral structure, rift direction and intensity, and course height. The surfaces resulting from the guillotine will be both convex and concave. In many cases, the stone will be hand pitched in the field to create convex surfaces on all pieces yielding a "pillowed" look to each course of the wall.

2.3.4. When installing stone with a relatively uniform bedding thickness, an open cavity is usually maintained between the stone and the substrate wall. This cavity varies, pending construction tolerances and irregularity of the back surface of the stone, and can be anywhere from 1" to 4" (25 to 100 mm), and sometimes larger to accommodate insulation or other building envelope components. The cavity must be ventilated, and weeps must occur at the bottom course and at any course where water cannot travel vertically within the cavity (such as at a shelf angle location). Weeps must occur frequently, with lateral spacing typically every 3'-0" to 4'-0" (1.0 to 1.2 m) as joint pattern allows.

2.3.4.1. In some instances, for example field or rubble stone construction or other stone wall constructions using stone units of varying bedding thicknesses, a mortar-filled collar joint with a secondary drainage system is required in lieu of a vented cavity.

2.3.5. Dead load should be relieved at every floor line, and in no case shall the vertical dimension between relieving points exceed 20'-0" (6 m). Shelf angles used to relieve deadload may be mild steel with appropriate corrosion protection.

2.3.6. Lateral loads must be accommodated by anchors within the stone bed joints. Corrugated "brick ties" are not recommended. Masonry "loop" anchors, or anchors that penetrate the stone such as pin or bent strap anchors are preferred. These anchors shall be stainless steel. Anchor quantity and placement is governed by local codes, but typically requires one anchor for every 3 ft² (~4 anchors/m²). In some cases, for instance seismic regions, continuous rodding within the mortar bed may be required.

2.3.7. The stones shall be fully bedded in mortar. Type S mortar is typically used for harder stones (e.g., granite) and type N mortar is typically used for softer stones (e.g., limestone).

2.4. ADHERED VENEER

2.4.1. Thinset Adhered installation is generally limited to thin stone (¼" to ½" [6 to 12 mm] thickness) of heights not exceeding 15'-0" (4.5 m).

2.4.1.1. Units shall not exceed 36 inches (914 mm) in the greatest dimension nor more than 720 square inches (0.46 m²) in total area and shall not weigh more than 15 pounds per square foot (73 kg/m²) unless approved by the local governing officials and the engineer of record.

2.4.1.2. Recommended substrate materials are masonry and cementitious backer board.

2.4.1.3. Exterior Vertical Surfaces. When adhesive installation methods are used for exterior vertical surfaces, the stone shall be back buttered to achieve, as close as practical, 100% adhesive contact between the stone and the backup. Remove freshly installed tiles periodically during installation to verify adhesion level.

2.4.1.4. When thin stone tiles are installed on exterior vertical surfaces, they are fully reliant upon the backup and substrate for performance. Use of unstable backup materials should be avoided.

2.4.2. Thin-Bed Stone Adhered Systems are stone installation of ¾" to 1" (20 to 25 mm) stone units which are design to portray the look of thicker (±4" / 100 mm) stone veneers.

2.4.2.1. Thin-bed stone units shall not exceed 36 inches (914 mm) in the greatest dimension nor more than 720 square inches (0.46 m^2) in total area and shall not weigh more than 15 pounds per square foot (73 kg/m^2) unless approved by the local governing officials and the engineer of record.

2.4.2.2. Cast-in-place concrete, concrete masonry unit, and sheathed stud frame backup walls are suitable substrates for thin-bed stone installation.

2.4.2.3. An appropriate waterproofing membrane, either liquid or sheet applied, is required at the face of the substrate wall.

2.4.2.4. Thin-bed stone systems have limited adjustment capability, so concrete and CMU walls frequently require a metal lath with a scratch coat to provide for a more accurate plane to which the stone can be adhered. Sheathed stud frame walls always require metal lath with a scratch coat.

2.4.2.5. Corner units are often fabricated as an "L" shape to create the appearance of a thicker stone wythe.

2.4.2.6. Thin bed stone systems are adhered to the scratch coat with standard portland cement mortars or latex modified mortars.

2.5. STONE SOFFITS

Stone soffits may be anchored with back anchors, or edge anchors. In some cases soffits may be edge-supported.

2.5.1. When thinner stone panels are used for exterior soffits in high wind load environments and are only edge supported, additional measures to prevent uplift may be required.

2.5.2. Factors of Safety may need to be increased for soffit design to address the continuous loading condition of this application.

3. INTERIOR INSTALLATION SYSTEMS

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

3.1. ANCHORED SYSTEMS

3.1.1. Concrete/CMU Backup

3.1.1.1. Masonry Backup: May be poured-in-place concrete, hollow concrete block, brick, or other solid masonry surface. Normally, stone installation with this substrate will be set with a cavity.

3.1.2. STUD WALLS

3.1.2.1. Metal Studs: Must be engineered to accommodate all loads and be of adequate thickness to provide required fastener pullout values (16 gauge is generally recommended). Stone anchors may attach directly to the studs, or a horizontal track component may be used to carry the load of the anchor uniformly across several studs. Plywood, cementitious backer board, or gypsum board may be used as a non-loadbearing sheathing.

3.1.2.2. Wood Studs: Stone anchors may attach directly to the studs, or a horizontal track component may be used to carry the load of the anchor uniformly across several studs. Plywood, cementitious backer board, or gypsum board may be used as a non-loadbearing sheathing. The use of natural wood studs may require additional bracing, bridging, blocking or other provisions to prevent rotation or other deformation in the studs over time. When engineered studs are used, follow manufacturer's instructions for fastening and bracing requirements.

3.2. ADHERED SYSTEMS

In all conditions, the substrate must be installed sufficiently true and level so that the stone panels or tiles may be installed true and level and sufficiently rigid to ensure a satisfactory backup surface to the stone installation. (Industry standard: ⅛" in 10'-0" with no more than 1/32" between individual stones.)

3.2.1. For all applications, the stone tile shall be back buttered to achieve, as close as practical, 100% adhesive contact between the stone and the backup.

3.2.2. STONE TILE SYSTEMS

3.2.2.1. Stone Tile Installation References. The Natural Stone Institute has participated in the Tile Council of North America's (TCNA) development of the Handbook for Ceramic, Glass, and Stone Installation. This document is reprinted every year, although the handbook committee meets only biennially, so substantial revisions are likely to appear only biennially. This handbook includes a section dedicated to the installation of stone tile products. The details are not duplicated in the Natural Stone Institute publications. Contact the TCNA (www.tcnatile.com) or the Natural Stone Institute's Book Store to obtain a copy of the handbook.

3.2.2.2. Tile patterns shall be laid out so that no perimeter tile is less than ½ the width of the typical stone tile, except at the front of cutouts.

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

3.3. STONE BASE

Stone Base not exceeding 1-0" (300 mm) in height is most often adhesively attached. Stone base of greater heights generally requires mechanical anchorage.

3.4. STONE SOFFITS

Stone soffits are either edge supported, anchored with back anchors, or anchored with edge anchors. In some cases, thin (≤½", ≤12 mm) stone soffits in interior applications can be adhesively attached without mechanical anchorage. Consult the adhesive manufacturer for guidance in installation methodology and substrate recommendations.

3.4.1. Factors of Safety may need to be increased for soffit design to address the continuous loading condition of this application.

3.5. STONE FIREPLACE FACES

Anchorage of stone fireplace surrounds is accomplished similarly to other interior installations.

3.5.1. Provide adequate accommodations for expansion due to thermal effects, including absolute temperature and thermal gradients.

3.5.2. Caution is required in selecting joint sealer, anchor fillers, and/or adhesive materials that may be exposed to elevated temperatures. Consult the product manufacturer for recommendations.

4. TROUBLESHOOTING AND CAUTIONS

4.1. WET AREAS

Avoid the use of plywood or gypsum board as substrate materials. Provide a moisture barrier. Suitable substrates are masonry backup and cementitious backer board on metal or wood studs. Apply appropriate water proofing membranes to all substrates.

4.2. PROTECTION OF FINISHED WORK: During construction, the General Contractor shall protect all stone from staining and damage.

4.3. TOLERANCES

Fabrication and installation tolerances can be found is a separate chapter of this manual.

4.4. HYSTERESIS

Hysteresis is a phenomenon that affects certain "true" marbles. Unlike most stones, which return to their original volume after exposure to higher or lower temperatures, these marbles show small permanent increases in volume after each thermal cycle. This can result in differential expansion within the stone, which is more likely to be accommodated or restrained in thick veneers than in thin ones. If it is not restrained, bowing of the marble panels ensues. Bowing also stretches the face, which makes stones more porous and increases the vulnerability to corrosion from acids in the atmosphere and deterioration from freezing and thawing effects. If marbles with this tendency are selected, research shall be performed to determine the minimum thickness needed to overcome effects of hysteresis.

4.5. GYPSUM

The use of gypsum-based products as fillers in anchor preparations is not recommended in any environment and is specifically prohibited for any wet or potentially wet environment.

4.5.1. Ettringite: Ettringite can be formed by the combination of gypsum and portland cement. Ettringite has a volume that is greater than the sum of the volumes of the two parent components. Therefore, if portland cement and gypsum are mixed in a confined space (as in an anchor slot), extreme expansive forces will occur as the ettringite is formed, typically causing rupture of the anchor slot.

4.6. FIBERGLASS MESH BACKING

Producers frequently apply a fiber mesh reinforcement to the back surfaces of stone tiles and slabs to reduce breakage and also increase safety when handling large slabs. Caution should be used when using a stone that has a fiberglass mesh backing applied on the back face. The fiberglass, having been bonded to the stone with a resinous (commonly epoxy) adhesive, will not bond adequately with cementitious products. Only epoxy products, or products specifically made for fiberglass by the manufacture, should be used when installing stone with fiberglass mesh backing.

4.6.1. Regardless of the tenacity of the bond of the installation adhesive to the fiberglass mesh, the overall performance of the attachment system can be no greater than the bond between the fiberglass and the stone, of which the installer has no control. Testing of the bond at this interface is recommended.

4.7. GREEN COLORED STONE

Avoid the use of water-based adhesive when installing certain green marbles and/or serpentines. Some of these stones may warp through absorption of water from the setting bed. (Water drawn into the stone is held to the crystals by surface energy. This force tends to widen the intercrystalline space and thereby expand the wet side.)

4.8. SEALANT STAINING

Some elastomeric sealants contain oil-based plasticizers to reduce their modulus and increase their extension/compression capability. The plasticizers can wick into stone perimeters, causing darkening of the edge (picture framing) and accelerated dirt collection on the stone face. Caution should be used in specifying sealants to ensure compatibility with stone. It is recommended that either an exemplar project be identified using the same stone and sealant components with satisfactory results, or a testing regimen per ASTM C1248 or ASTM D2203 be performed.

4.9. EFFLORESCENCE

Efflorescence is a salt deposit, usually white in color that appears on exterior surfaces of stone walls and floors. The efflorescence is produced by salts leached to the surface of the stone by water percolating through the stone backup and joints. The most feasible means of prevention is to stop the entrance of large amounts of water. If the conditions bringing about the efflorescence continue, scaling may occur and flake off successive layers. For this to happen, large amounts of water must continue to enter behind the stone and must contain large amounts of salts.

4.10. DOWN WASHED LIGHTING

The use of down washed lighting and/or lighting of high angles of incidence, in which the path of light is nearly parallel to the face of the wall surface, is a popular choice in both interior and exterior designs. This lighting style will exaggerate lippage, textural surface variation, and even warpage due to the extremely elongated shadow lines caused by the slight angle of incidence. Material and installation which are within industry tolerances may appear to be outside of tolerances due to the accentuation of the lighting technique. Inspection of areas receiving down washed lighting shall be done with the down washed lighting turned off.

4.11. VARIATION IN GLOSS

It is almost impossible to uniformly read light reflection on a polished or high-honed-finish installation due to the natural characteristics of dimension stone. Due to the heterogeneous composition of natural stones, variable mineral hardness exists within the stone, producing variable reflectivity of light energy. Most stones, and especially travertine marbles and honed-finish surfaces, will appear to reflect light unevenly.

4.12. POLISHING WHEEL MARKS

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

4.13. GEOGRAPHICAL VARIATION IN PRACTICE

Some installation methods and materials are not recognized and may not be suitable in some geographic areas because of local trade practices, building codes, climatic conditions, or construction methods. Therefore, while every effort has been made to produce accurate guidelines, they should be used only with the independent approval of technically qualified persons.

NOTES: