Stone Testing

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STONE TESTING

1.0 INTRODUCTION

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

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

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

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

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

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

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

1.5.1 Instrumental Neutron Activation Analysis (INAA)

1.5.2 Atomic Absorption Spectroscopy (AA)

1.5.3 Inductively Coupled Plasma Emission Spectroscopy (ICP-OES)

1.5.4 X-ray Fluorescence Spectroscopy (XFS)

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

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

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

2.0 ASTM STANDARD TEST METHODS AND SPECIFICATIONS

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

2.2 Current Standards. ASTM standards are revised from time to time. A revised version is indicated with a hyphen followed by a two-digit number after the basic designation of the standard, e.g., ASTM C119-11, showing that it was revised in 2011. An additional number in parentheses, e.g., ASTM C97-92(1994), indicates that the 1992 edition was formally reaffirmed without change in 1994. The latest edition should be used. Copies of ASTM standards can be obtained from ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959 U.S.A. Telephone 610.832.9585. Copies can also be ordered through ASTM's web site and downloaded electronically. The Internet address is www.astm.org.

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

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

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

3.0 OVERVIEW OF STANDARD TEST METHODS

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

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

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

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

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

4.0 ABSORPTION AND BULK SPECIFIC GRAVITY TESTING OF DIMENSION STONE

4.1 Water absorption is a measure of the porosity of a stone and can be an indicator of its susceptibility to damage during freezing. A stone that has greater water absorption will also tend to absorb liquid stains more readily. In general, the lowest water absorption is desired. The absorption is expressed as the percent weight change due to absorbed water. The maximum allowable water absorption for each type of stone is prescribed in the standard specifications for that specific stone. The required values range from 0.20% for marble to 12% for low-density limestone. According to ASTM C97, at least 3 specimens, as described for the density determination, are dried and weighed. It is important that the surface not be fractured by the cutting process because these fractures will increase water absorption. The specimens are then soaked in water for 48 hours, wiped dry, and weighed again. The difference in weights is divided by the dry weight and multiplied by 100 to give the percentage of water absorption. Variations in the wiping of the wet specimen before weighing will cause variations in the result. The standard test method describes removing the specimens from the water and surface drying with a damp cloth, but this is still somewhat subjective. A dryer wet specimen will result in a lower absorption number.

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

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

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

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

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

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

5.0 STRENGTH TESTING OF DIMENSION STONE

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

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

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

5.3 Compressive Strength of Dimension Stone. Compressive strength is a measure of the resistance to crushing loads. If one were to build a stone wall, for example, the stone at the bottom would have to withstand the compressive load of the weight of the stones above. A stone floor must be able to bear the crushing loads of people, furniture, and other objects on the floor. The compressive strength is the maximum load per unit area that the stone can bear without crushing. A higher compressive strength indicates that the stone can withstand a higher crushing load. The required values range from 1,800 psi (12.45 MPa) for marble to 19,000 psi (131 MPa) for granite. To determine the compressive strength, at least 5 specimens are tested in ASTM 170. They should be cubes at least 2" to 3" on each side. Each face must be perfectly flat and they must be parallel or perpendicular with each other. Faces must be smooth with no tool marks and there should be no nicks at the corners. The faces must be honed or polished with no saw marks or other tool marks remaining. Any flaws in the specimens can result in a lower compressive strength. In some instances, the testing laboratory may have to refinish the specimens to produce surfaces sufficiently flat for testing.

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

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

5.5 Modulus of Rupture of Dimension Stone. ASTM C99 requires a minimum of 3 specimens that are 4"x 8"x 2¼" thick. All of the faces, except the ends, must be flat and be parallel or perpendicular with each other. The faces must be smooth with no tool marks and there should be no nicks at the corners. The faces should be honed or polished with no saw marks or other tool marks remaining. Any flaws in the specimens can result in an apparent low modulus of rupture strength. The flexural (bending) strength may be tested in a dry or wet condition and with the load parallel or perpendicular to the rift. The specimens must be dried or soaked for 48 hours. For the modulus of rupture test, the stone specimen is laid flat on two crosswise parallel steel edges 7" apart. The 7" span allows the 8" long specimen to overhang the supports by ½” at each end. The supports of the fixture are gimbaled to accommodate any warp of the test specimen and prevent the introduction of torsional stresses applied to the stone. The test load, or force, is applied to the center of the top of the specimen through another crosswise edge. The load is increased until the specimen breaks. The flexural strength is then calculated from a formula based on the geometry of the test condition.

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

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

5.6 Flexure Testing of Slate. The modulus of rupture testing for slate, specified in ASTM C120, is somewhat different than C99. The specimens are 12" x 1½" x 1" thick. Rubbing or sanding the cleft faces achieves the specified 1" thickness. Six specimens are required: 3 with length parallel to the rift, and 3 with length perpendicular to the rift. For the test, the span between the supporting knife edges is 10".

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

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

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

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

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

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

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

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

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

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

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

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

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

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

5.11 Coefficient of Friction Testing. Slippery floors are a safety hazard, thus some measure of slip resistance is needed to evaluate stone and its finish as a floor material. Traditionally in the stone industry, slip resistance was evaluated by measuring the static coefficient of friction (the force required to initiate slipping divided by the normal force) per the ASTM C1028 method. This test method was withdrawn in 2014 and no replacement method was offered.

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

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

5.12 Other Stone Selection Considerations.

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

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

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

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

6.0 OTHER ASSOCIATIONS FOR ADDITIONAL INFORMATION

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

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

American Concrete Institute (ACI)
www.concrete.org

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

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

Construction Specifications Institute (CSI)
www.csinet.org

International Masonry Institute (IMI)
www.imiweb.org

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

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

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

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

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

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

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