Limestone

An excerpt from the *Dimension Stone Design Manual*, Version VIII (May 2016)

Produced and Published by the
Marble Institute of America
380 East Lorain St. Oberlin, Ohio 44074
Telephone: 440-250-9222
Fax: 440-774-9222
www.naturalstoneinstitute.org

© 2016
All rights reserved. No part of this document may be reproduced or transmitted in any form or by means electronic or mechanical, including photocopy, recording, or by an information storage and retrieval system, without written permission from the Natural Stone Institute.

LIMESTONE

1.0 GENERAL

1.1 Related Documents

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

1.2 Applicable Publications

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

1.2.2 ASTM International (ASTM):

1.2.2.1 C568, Standard Specification for Limestone Dimension Stone

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

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

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

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

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

1.2.3 Marble Institute of America (MIA):

1.2.3.1 Membership, Products, and Services Directory

1.2.3.2 Dimension Stone Design Manual

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

1.2.4 Indiana Limestone Institute of America (ILI)

1.2.4.1 Indiana Limestone Handbook

1.3 Scope of Included Work

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

1.4 Definition of Terms

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

1.5 Source of Supply

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

1.6 Samples

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

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

1.7 Shop Drawings

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

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

1.8 Defective Work

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

1.9 Repairing Damaged Stone

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

 © 2016 Marble Institute of America

2.0 MATERIALS

2.1 Limestone

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

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

2.1.3 Schedule: Limestone shall be provided as follows:

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

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

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

2.2 Setting Mortar

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

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

2.2.3 Sand should comply with ASTM C144.

2.2.4 Mixing water must be potable quality.

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

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

2.3 Pointing Mortar

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

2.4 Sealants and Backup Material (If Applicable)

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

2.5 Anchors, Cramps, and Dowels

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

2.6 Stain Prevention

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

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

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

2.7 Adjacent To Water

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

(See Horizontal Surfaces chapter for more information.)

3.0 FABRICATION

3.1 Beds and Joints

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

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

3.2 Backs of Pieces

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

3.3 Moldings, Washes, and Drips

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

3.4 Back-checking and Fitting to Structure or Frame

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

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

3.5 Cutting for Anchoring, Supporting, and Lifting Devices

3.5.1 Holes and sinkages shall be cut in stones for all anchors, cramps, dowels, and other tieback and support devices per industry standard practice or approved shop drawings. However, additional anchor holes may be

 © 2016 Marble Institute of America

drilled at job site by Limestone Contractor to facilitate alignment.

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

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

3.6 Cutting and Drilling for Other Trades

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

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

3.7 Carving and Models

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

4.0 SHIPPING AND HANDLING

4.1 Packing and Loading

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

4.2 Unloading and Storage at Job Site

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

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

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

5.0 INSTALLATION

5.1 General Installation

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

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

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

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

5.2 Mortar Setting

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

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

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

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

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

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

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

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

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

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

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

5.3 Anchorage

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

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

5.3.3 All anchorage devices and anchor hole/slot fillers shall be in accordance with

© 2016 Marble Institute of America

ASTM C1242. Care must be taken to ensure that any holes capable of retaining water are filled after use to prevent water collection and freezing.

5.4 Sealant Joints

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

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

5.5 Expansion Joints

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

5.5.2 Filler material for these joints shall be nonstaining.

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

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

5.6 Caulking

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

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

5.7 Weep Tubes

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

6.0 CLEANING AND PROTECTION

6.1 Cleaning

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

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

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

6.2 Protection of Finished Work

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

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

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

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

PRODUCT DESCRIPTION – Limestone

1.0 GEOLOGICAL CLASSIFICATION

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

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

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

1.4 Since limestone by definition must be at least 50% calcium carbonate, the other 50% can be one of various clasts or minerals of other kinds of stone. These include clay, silt, quartz or other sands, pebbles, and especially fossils–

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

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

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

© 2016 Marble Institute of America

usually calcite or aragonite (a mineral with the same chemistry as calcite ($CaCO_3$), but with an unstable atomic geometry unlike calcite, which has a stable atomic geometry.

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

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

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

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

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

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

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

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

2.0 COLOR AND VEINING

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

3.0 TEXTURE

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

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

4.0 FINISHES

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

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

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

4.1.3 Plucked: A rough texture.

4.1.4 Abrasive: A flat, nonreflective surface.

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

4.1.6 Polished: Mirror gloss, with sharp reflections.

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

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

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

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

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

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

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

5.0 THICKNESS

5.1 Standard nominal thicknesses for limestone are generally 3/8", ¾", 1¼", 1½", 2", 2¼", 2½", 3", 3½", and 4". The

© 2016 Marble Institute of America

recommended thicknesses vary depending on the type of limestone used.

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

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

6.0 SIZES

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

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

7.0 PRODUCT SAMPLING

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

8.0 PROPER USAGE TIPS

8.1 Recommendation for commercial floors:

8.1.1 Minimum ¾" thickness.

8.1.2 A honed finish.

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

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

9.0 VENEER CUTTING

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

10.0 DAMPPROOFING

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

TECHNICAL DATA – Limestone

1.0 PROPERTIES OF LIMESTONE DIMENSION STONE

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

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

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

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

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

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

Property — **Range of Values**

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

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

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

Density, lb/ft^3 (C97) 110-185
Recommended (min):
110 (low density),
135 (medium density),
160 (high density)

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

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

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

Abrasion Resistance (H_a) (C241) ...3.0-33.0
Recommended (min): 10

2.0 STRENGTH (ASTM C99, C170, C880)

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

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

[4] Test methods described in current ASTM standards.

[5] Also known as Young's Modulus.

© 2016 Marble Institute of America

be two or more inches thick. The Flexural Strength (C880) test is recommended when the stone thickness will be less than two inches.

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

3.0 FIRE RESISTANCE

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

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

4.0 ABRASION RESISTANCE (ASTM C241)

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

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

5.0 FACTORS AFFECTING PROPERTIES

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

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

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

6.0 SAFETY FACTORS

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

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

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

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

7.0 SEISMIC CONSIDERATIONS

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

8.0 EFFLORESCENCE AND STAINING

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

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

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

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

© 2016 Marble Institute of America

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

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

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

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

9.0 THERMAL EXPANSION

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

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

© 2016 Marble Institute of America

NOTES:

© 2016 Marble Institute of America