~~Designation:C1528–08~~ Designation: C1528 – 09

Standard Guide for Selection of Dimension Stone for Exterior Use[1]

This standard is issued under the fixed designation C1528; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

Natural stone, while being perhaps the oldest building material known to man, can also be one of the most difficult of all building materials to properly evaluate, select, and specify. Every natural stone product is unique, having its own physical properties and performance capabilities. Responsible stone selection involves extensive and objective evaluation of both the stone material and the application in which it is required to perform.

This guide presents a cursory review of the different stone types commonly used in construction, common applications, available finishes, and factors affecting product costs. It is intended to be used in combination with good judgment, responsible engineering analysis, local building codes, and any other available resources. It is not a "how-to" or a "step-by-step" guide, and has been prepared with the assumption that the user has some familiarity in the use of natural stone prior to utilizing this guide.

Past performance is the best test of a dimension stone's durability. Yet because the physical properties of a natural stone can vary within a single deposit, even stones with a history of satisfactory performance may need to be tested to ascertain the quality of the current production stock. Common physical property tests include absorption, density, compressive strength, modulus of rupture, flexural strength, abrasion resistance, and anchor strength. Additional tests may also be required depending on the material and application.

In a high proportion of the cases, failure of a natural stone in service is a result of improper application, rather than the inherent properties of the stone. Placing stones in unsuitable environments, faulty fabrication, installation, or construction practices, and incompatible associated materials are frequent causes of stone system failures (for example, high-porosity stones in subgrade applications, inadequate anchorage or expansion space, mortars leaching alkalis, inappropriate strength mortars, staining grouts, voids in setting beds, and pavement stones with inadequate resistance to abrasion).

In selection of natural dimension stone products, the application as well as the aesthetic appeal must be considered. While aesthetics are important to the design, the selection of the proper stone material, thickness, anchorage, and related components is necessary to ensure meeting the performance and durability requirements of the design.

1. Scope

1.1 This guide is intended to be used by architects, engineers, specifiers, contractors, and material suppliers who design, select, specify, install, purchase, fabricate, or supply natural stone products for construction applications.

1.2 *Consensus Standard*—This guide is an industry consensus standard drafted in a cooperative effort among engineers, architects, geologists, producers, and installers of natural stone.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

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

[1] This guide is under the jurisdiction of ASTM Committee C18 on Dimension Stone and is the direct responsibility of Subcommittee C18.08 on Selection of Exterior Dimension Stone.

~~Current edition approved May 15, 2008. Published July 2008. DOI: 10.1520/C1528-08.~~

Current edition approved Aug. 1, 2009. Published November 2009. Originally approved in 2002. Last previous edition approved in 2002 as C1528–02. DOI: 10.1520/C1528-09_WIP_#852046.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

C99 Test Method for Modulus of Rupture of Dimension Stone
C119 Terminology Relating to Dimension Stone
C120 Test Methods of Flexure Testing of Slate (Breaking Load, Modulus of Rupture, Modulus of Elasticity)
C121 Test Method for Water Absorption of Slate
C170 Test Method for Compressive Strength of Dimension Stone
C217 Test Method for Weather Resistance of Slate
C241 Test Method for Abrasion Resistance of Stone Subjected to Foot Traffic
C503 Specification for Marble Dimension Stone
C568 Specification for Limestone Dimension Stone
C615 Specification for Granite Dimension Stone
C616 Specification for Quartz-Based Dimension Stone
C880 Test Method for Flexural Strength of Dimension Stone
C1201 Test Method for Structural Performance of Exterior Dimension Stone Cladding Systems by Uniform Static Air Pressure Difference
C1242 Guide for Selection, Design, and Installation of Dimension Stone Anchoring Systems
C1352 Test Method for Flexural Modulus of Elasticity of Dimension Stone
C1353 Test Method for Abrasion Resistance of Dimension Stone Subjected to Foot Traffic Using a Rotary Platform, Double-Head Abraser
C1354 ~~Test Method for Strength of Individual Stone Anchorages in Dimension Stone~~ Test Method for Strength of Individual Stone Anchorages in Dimension Stone
C1526 Specification for Serpentine Dimension Stone
C1527 Specification for Travertine Dimension Stone

2.2 Provisions of dimension stone handbooks, manuals, and specifications should be reviewed for compatibility with the principles outlined in this guide.

3. Terminology

3.1 *Definitions*—For definitions of terms used in this guide, refer to Terminology C119.

4. Significance and Use

4.1 *Related Components*—Natural stone is only one component of a building's construction. All related materials and assemblies need to be evaluated to ensure compatible interactive behavior with the stone product.

4.2 *Applicable Codes*—Every stone application shall comply with applicable building codes.

EXTERIOR APPLICATIONS OF DIMENSION STONES

5. Introduction

5.1 Natural stones have long been used and admired for their beauty and permanence. As a natural material, each piece of stone has features and physical characteristics that make it unique. The rich variation in color and texture, as well as its ability to age gracefully in the exterior environment, has made stone one of the most popular materials for construction, sculpture, and monuments.

5.2 Varieties of stone possess certain properties making it suitable for a specific application. Stone geology (mineral content and structure), compressive strength, flexural strength, resistance to absorption and erosion, as well as its ability to be worked, vary widely by stone type. These are all key characteristics that dictate the best use of the material and must be considered during the process of stone selection.

6. Exterior Applications

6.1 This guide is limited to the discussion of exterior applications of stone. Of these, there are several major categories, which are introduced briefly as follows:

7. Load-Bearing Masonry

7.1 Load-bearing masonry is perhaps the oldest form of stone construction. Its defining feature is the transferring of structural load vertically by relying on the compressive strength of the stone to support itself and other imposed loads. Due to the weight of the stone itself, structures built in this manner tend to be of limited height. As the height of the structure increases, the wall thickness at the structure's base must increase, thus requiring large individual stones, or multiple wythes of stone. The costs of such walls are typically higher than other systems, due to the large amount of stone and labor involved.

8. Cladding

8.1 In response to the limitations and expense of load-bearing masonry, stone cladding systems were developed. Cladding systems can offer the appearance of load-bearing masonry but without the mass and expense. Cladding systems also offer a wide variety of applications, allowing greater architectural innovation.

8.2 When stone is used as cladding, it is exposed to unique loading characteristics that can require complex structural analysis and detailing in order to be used successfully. Materials other than stone are also often integrated into cladding systems, requiring consideration of their material properties as well as compatibility with the stone components.

9. Building Trim

9.1 Stone has been and continues to be used in architecture to accent other building materials, or to perform a specific purpose. Stone is often integrated into wall systems as decorative belt courses, window sills, lintels, arches, or water tables. Stone can add an element of interest to buildings, in addition to performing as a durable wall component with a specific and well-defined purpose.

10. Pavements

10.1 From cobblestone streets to modern plazas, stone is used to carry vehicle and pedestrian traffic. Modern systems include those bearing on pedestals and traditional sand or cement-based setting bed systems.

10.2 Materials used for steps must have a high resistance to abrasion and provide a surface with adequate slip resistance for public safety. Many varieties of dimension stones, with appropriate finish, will satisfy both of these requirements.

11. Steps

11.1 Materials used for steps must have a high resistance to abrasion and provide a surface with adequate slip resistance for public safety. Many varieties of dimension stones, with appropriate finish, will satisfy both of these requirements.

11.2 Steps are manufactured from dimension stones as "cubic," in which the tread and riser faces are of one piece of stone, and also "veneered" in which multiple pieces of thin stone material are placed over a concrete or steel frame to form the tread and riser surfaces.

12. Coping

12.1 Wall systems that are fully exposed to the environment, such as roof parapet walls, balcony and terrace enclosure walls, and planter walls, are particularly susceptible to water penetration. Stone coping and wall caps are often used to help protect the underlying wall system from excessive moisture penetration and associated distress.

12.2 Copings and wall caps can also add a visual accent to the wall system, improving the appearance of the wall system by defining changes in the wall configuration.

12.3 Stone copings and wall caps are typically jointed, therefore, protection of the wall system is also reliant on proper treatment of the joints.

13. Roofing

13.1 Roofing applications for natural stone are typically limited to slate, a variety of stone that can be quarried and fabricated into thin, shingle-shaped elements. Dense, nonporous stones can provide a durable, water-resistant roof system that effectively utilizes the unique physical characteristics of the material.

14. Ornamental, Sculpture, and Monumental Elements

14.1 Many varieties of stone possess characteristics that make them a desirable material for sculpting and carving. Most stone varieties can be worked by hand or power tools into unique shapes and representations, including engravings and reliefs. Properly selected stones can demonstrate resistance to environmental effects, thereby providing a sense of permanence to monuments and decorative sculpted items.

COMMON DIMENSION STONE ~~TYPES—GRANITE~~ TYPES

15. ~~Mineralogy, Appearance, and Texture~~

~~15.1The term "granite" has both geological and commercial definitions. There are many rock types that are not classified as granites by true geological definition, yet they are included in the commercial classification of granite because they exhibit similar performance and behavioral characteristics as true granites. For the purpose of this guide, "granite" is used in its commercial sense. This includes any visibly granular, igneous rock consisting mostly of feldspars and quartz accompanied by one or more dark minerals.~~

~~15.2Typically, feldspar is the most abundant mineral found in granites, and because of this, the color of the granite is largely governed by the color of this mineral. The color can be modified by the quartz, hornblende, mica or any other mineral present in significant quantity. Dark granular igneous rocks, classified petrographically as anorthosite, basalt, diabase, diorite, or gabbro, are often referred to as "black granites." Using the rather broad commercial definition of granite, granites are available in a wide array of colors including pink, gray, white, red, black, brown, buff, green, and blue.~~

~~15.3The majority of granites found in the industry are granular or crystalline in appearance, with the grain size varying anywhere between 2 or 3 mm up to 25 mm or larger. Some of the materials included in this definition will show a layered or plate-like structure due to recrystallization, folding, or other changes while the rock was in a plastic or semi-molten state. Such metamorphic rocks are called granite gneisses.~~

~~15.4A granite with uniform distribution of the minerals is desirable for the supply of a large application with minimal color variation. Many commercial deposits exhibit remarkable homogeneity across vertical and lateral distances, while other deposits will display considerable variation between adjacent blocks or even within one block.~~

~~15.5Many granites are "anisotropic," or "directionally specific" in either appearance or performance, and as such, dictate attention to the direction that they are quarried and sawn to achieve the desired visual and performance requirements. Other granites are nearly "isotropic," with similar appearance and performance characteristics regardless of the direction the material is cut.~~ General

15.1 By strict geological definitions, hundreds of rock types are used as dimension stones. The commercial definitions of these rock types are much broader, allowing materials with similar performance and behavioral characteristics to be grouped together. Therefore, stones of different scientific geological definitions will be included in the same commercially-defined group. Using these broad commercial definitions, most materials used as dimension stone will fall under one of seven classifications: Granite, Marble, Limestone, Quartz-Based, Slate, Serpentine, or Travertine.

15.2 The finish applied to a stone may have more bearing on its suitability for use than the type of stone. While polished or honed surfaces are often used for cladding materials, these finishes are not recommended for walking surfaces because they do not demonstrate the frictional properties necessary for safe pedestrian ambulation. Refer to Section 36 for more detailed discussions of finish types.

15.3 Most dimension stones are known by an industry trade name. In many cases, a particular stone will be given different trade names by different fabricators or brokers. Therefore, the trade name alone my not be adequate to identify the selected material. Including the origin (quarry location) and quarry owner in the specification will help minimize confusion in material identification.

15.4 For major projects, sufficient inventory of block material is rarely available at any one fabricator's facility. Supply of raw block material from the quarry to the fabricator will usually occur concurrently with fabrication throughout the duration of the project. The production capacity of the quarry, in addition to any transportation difficulties must be carefully evaluated to ensure uninterrupted delivery of material throughout the project's construction.

15.5 Quarries of all dimension stone types will have unique capabilities and limitations. Natural fissures and fracture planes in the quarry will limit available piece size and yield. The supplier of the material must be consulted during the design phase of the project to ensure that the project requirements can be satisfied by the specified material. Specific grades (for example, select, monumental, structural, architectural, quarry-run, clear, variegated) may be identified in the material to further define the color range or clarity of the stock quality.

15.6 Fabricators of natural stone products use a variety of machinery from worldwide sources. The stone products themselves exhibit vastly different strength and workability properties, as well as widely varying availability of raw stock sizes and qualities. As a result of these variables in product and machinery, there is less standardization of stone product offerings and sizes than are typically found in the supply of other construction components. The thicknesses of the stone slabs will generally adhere to standard offerings, and detailing materials to correspond with recognized industry standard slab thicknesses will benefit the project in both economy and delivery. Table 1 lists common slab thickness found in the dimension stone industry, with a brief description of the applications in which they are typically employed.

SPECIFIC DIMENSION STONE TYPES

16. ~~Suitability for Use~~

~~16.1Granite materials have one of the widest ranges of applications of any natural stone type. Architectural use of granite includes exterior and interior cladding, exterior and interior paving, furniture tops, and landscape applications such as curbs, retaining walls, or copings. Granite is frequently used in monument or memorial applications where permanence and weather resistance are primary considerations. The chemical resistance and dimensional stability of granite allow limited industrial applications such as pickling tanks, surface plates, precision machine bases, and paper machine press-rolls.~~

~~16.2The particular finish specified for the granite may have a greater bearing on its suitability for use than the granite itself. Polished and honed finishes are popular for vertical surfaces because of their refined appearance and low maintenance requirements. These finishes are not recommended for walking surfaces as they have relatively poor slip resistance. Textured surfaces such as thermal, tooled, or sanded are commonly used in pedestrian traffic areas due to their favorable frictional properties.~~

~~16.3*Physical Strength*—Physical strength properties of granite are determined by laboratory testing in accordance with ASTM standard test procedures for each physical property to be evaluated. Minimum or maximum values for each physical property, to aid in determination of a specific granite's suitability for exterior exposure, are in accordance with Specification~~ Granite

16.1 Commercially, "granite" includes any visibly granular, igneous rock consisting mostly of feldspars and quartz, and accompanied by one or mare dark minerals. Typically, feldspar is the most abundant mineral found in granites and, because of this, the color of the granite is largely governed by the color of this mineral. The color can be modified by quartz, hornblende, mica, or any other mineral in significant quantity. Granites are available in a wide array of colors including pink, gray, white, red, black, brown, buff, green, and blue. Dark granular igneous rocks, classified petrographically as gabbro, anorthosite, basalt, or diabase, are also included in the granite group and often referred to as "black granites".

16.2 The majority of materials in the granite group are granular or crystalline in appearance, with the grain size varying between 2 or 3 mm up to 25 mm or larger. Some of the materials included in the granite group will show a layering, or plate-like structure,

TABLE *Continued*

Thickness	Granite	Marble	Limestone	Quartz-Based	Slate	Serpentine	Travertine
5 mm (3⁄16 in.)	Not offered, except as veneers with a reinforced backer	Not offered, except as veneers with a reinforced backer	Not offered, except as veneers with a reinforced backer	Not offered, except as veneers with a reinforced backer	Used as roofing slate, also some thin-set tiles supplied in 6 mm (1⁄4 in.) thicknesses.	Not offered, except as veneers with a reinforced backer	Not offered, except as veneers with a reinforced backer
10 mm (3⁄8 in.) 13 mm (1⁄2 in.)	"Thin-set" tiles for interior use only	"Thin-set" tiles for interior use only	Thin-set" tiles for interior use only	"Thin-set" tiles for interior use only	"Thin-set" tiles for interior use only. Also commonly used for blackboards and countertop inserts. 13 mm & 15 mm materials are also used as flooring, baseboard, thresholds, and furniture applications	"Thin-set" tiles for interior use only	"Thin-set" tiles for interior use only
20 mm (3⁄4 in.)	Interior flooring, Interior walls, countertops	Interior flooring, Interior walls, countertops	Interior flooring, Interior walls, countertops	Interior flooring, Interior walls	Used as interior flooring, baseboard, window stools, hearths, interior wall veneer, and countertops	Interior flooring, Interior walls, countertops	Interior flooring, Interior walls, countertops
25 mm (1 in.)	Not generally used	Not generally used	Not generally used	Not generally used	Common thickness for flooring, window stools/sills, treads & risers, wall caps, hearths & mantels, countertops, and sanitary partitions.	Not generally used	Not generally used
30 mm (11⁄4 in.)	Interior Walls and Countertops. Considered the minimum thickness for exterior applications, horizontal or vertical, although design loads may require thicker material.	Interior Walls and Countertops. Considered the minimum thickness for exterior applications, horizontal or vertical, although design loads may require thicker material.	Used in interior flooring applications or limited vertical application in higher density limestones, countertops	Generally the minimum thickness available for interior flooring or exterior pavement.	Interior Walls and Countertops. Considered the minimum thickness for exterior applications, horizontal or vertical, although design loads may require thicker material.	Interior Walls and Countertops. Considered the minimum thickness for exterior applications, horizontal or vertical, although design loads may require thicker material.	Interior Walls and Countertops. Considered the minimum thickness for exterior applications, horizontal or vertical, although design loads may require thicker material.
40 mm (15⁄8 in.)	Used in exterior cladding applications when design loads marginally exceed capacity of 30 mm	Used in exterior walls & pavements	Commonly used thickness for interior flooring & wall veneer in high-density limestones.	Not commonly used	Exterior cladding	Used in exterior walls & pavements	Used in exterior walls & pavements

TABLE *Continued*

Thickness	Granite	Marble	Limestone	Quartz-Based	Slate	Serpentine	Travertine
50 mm (2 in.)	Used in Exterior cladding applications when necessitated by design loads, spans, or flexural strengths. Also used when reveals are machined into stone face.	Commonly used in exterior walls or pavement.	Generally the minimum thickness used for any application of low or medium density limestone. Also the minimum thickness for exterior applications of high-density limestone.	Used in flooring & pavement applications. Used in limited cladding applications with small panel sizes and modest design loads.	Slate slabs are generally available in several increments in this range – Thickness of 38, 45, 50, 57, 63, & 70 mm (1½ in., 1¾ in., 2 in., 2¼ in., 2½ in., & 2¾ in.) can be obtained from most fabricators. These thickness are used for exterior cladding, treads, & coping.	Commonly used in exterior walls or pavement.	Commonly used in exterior walls or pavement.
80 mm (3 in.)	Used in exterior cladding when extremely large piece sizes are used, or when deep reveals are cut into stone face. Also used in exterior pavement subjected to passenger vehicle traffic. Commonly used in exterior window sill applications.	Thickness greater than 50 mm in Marble are referred to as "cubic" material. These thicknesses are generally applied in monument, sculpture, or decorative work, and are not normally offered as a "standard" thickness	Common thickness for exterior cladding applications, although design loads, spans, or material strengths may dictate thicker panels. Also commonly used in coping & sill applications	Common exterior cladding thickness	Used for copings, and also for cemetery markers.	Thickness greater than 50 mm in Serpentine are referred to as "cubic" material. These thicknesses are generally applied in monument, sculpture, or decorative work, and are not normally offered as a "standard" thickness	Thickness greater than 50 mm in Travertine are referred to as "cubic" material. These thicknesses are generally applied in monument, sculpture, or decorative work, and are not normally offered as a "standard" thickness
100 mm (4 in.)	Used in Landscape or Sitework applications such as copings & fountains		Used in exterior cladding when required to meet design loads or because of decorative reveals machined into stone face.	Used as coping, water tables, and belt courses – often will be supplied as 125 mm (5 in.).	Cubic material is available from slate producers, although not frequently used.		
150 mm (6 in.)	Used in Landscape or Sitework applications such as curbs, copings, steps, & fountains		Slab thickness greater than 100 mm are not considered "standard", but are available on a project-specific basis for ornamental or sculpture type work. Also found in classical architectural detailing.	Used as coping, water tables, belt courses, steps, & curbs			
200 mm (8 in.)	Used in Landscape or Sitework applications such as curbs, copings, steps, & fountains			Referred to as "Cubic" material, these thicknesses are available on a job-specific basis for ornamental, landscape, and rustic applications.			
Greater than 200 mm (8 in.)	These thicknesses are not considered "standards", but are available on a project-specific basis for sculpture, ornamental or monumental typ e applications						

due to recrystallization, folding, or other changes while the rock was in a plastic or semi-molten state. Such metamorphic rocks are called granite gneisses.

16.3 Granites with uniform mineral distribution will show remarkable homogeneity within the quarry and will have minimal variation of color, texture, or veining pattern from block to block. Other granites will display considerable color variation between blocks, or even within one block.

16.4 Some granites are nearly isotropic, meaning that they have similar appearance and performance characteristics regardless of the direction the material is cut. More commonly, a granite will demonstrate some degree of anisotropic behavior, ranging from mild to pronounced. Such granites frequently require sawing in a specific direction in which to obtain the required visual and performance properties.

16.5 Granite materials are used in a variety of architectural, memorial, and industrial dimension stone applications. A list of common applications follows:

Architectural:
Exterior cladding/curtainwall
Interior cladding
Exterior paving
Interior flooring
Furniture & countertops
Curbs
Steps
Retaining walls
Coping
Window sills/stools
Memorial:
Monuments/Markers
Mausoleums
Industrial:
Picking tanks
Surface plates/Precision machine bases
Paper press rolls

16.6 The physical properties of granite are determined in accordance with a variety of ASTM test procedures. Minimum and maximum values for the material's physical requirements are listed in Specification C615.

17. Standard Thicknesses

17.1Most granite products are custom made to the designer's specifications. The slab thickness however, is best kept to the dimensional standards of the industry to benefit both delivery and economy. Standard nominal thicknesses of granite offered by major fabricators are listed as follows:

10 mm (⅜ in.)	This is primarily a "thinset" floor tile thickness, and is limited to interior applications only.
20 mm (¾ in.)	The 20 mm (¾ in.) thickness is very common for interior clad- ding, interior flooring, or furniture applications. Exterior use of this thickness is not recommended.
30/32 mm (1¼ in.)	The 30 mm (1¼ in.) thickness is generally considered to be the minimum thickness suitable for exterior applications, although specific design criteria may dictate the use of thicker material.
40 mm (1⅝ in.)	The most typical usage of this thickness is exterior cladding panels when design loads marginally exceed the capacity of 30 mm (1¼ in.) material.
50 mm (2 in.)	Predominantly an exterior cladding material, 50 mm (2 in.) panels are used when necessitated by high design loads or large panel sizes. The machining of decorative reveals in the granite panel may also require that this thickness be used.
80 mm (3 in.)	Occasionally used in exterior cladding applications when extremely large panels are required or when deep re- cesses are cut into the stone. This thickness is also common in pavement applications that are subjected to vehicular traffic.
100 mm (4 in.), 150 mm (6 in.), and 200 mm (8 in.)	These thicknesses are generally found in landscape and site applications such as curbs, coping, steps, or fountains. Granite of these thicknesses or thicker is usually referred to as "cubic" material.

18.Availability

18.1Granites are found throughout the world, and most are known by a unique trade name in the industry. In many cases, a particular granite will be given additional trade names by different fabricators or brokers. There are extreme examples of stone types that are known by a half dozen or more names in the industry, therefore, the trade name alone may not adequately identify the selected material. Including the origin (quarry location) and quarry operator of the material in the specification will help to minimize confusion.

~~18.2For major projects, there is usually insufficient inventory of block material available at any one fabricator's facility to supply the project. Supply of raw block material from the quarry to the fabricator will occur concurrently with fabrication throughout the duration of the project construction. The production capacity of the quarry must be carefully considered to ensure uninterrupted delivery of material to the fabricator at the required rate. This is further complicated when the source of the granite is distant from the fabrication facility.~~

~~18.3The size of blocks obtainable from a granite quarry is unique to the specific quarry. Natural fissures and fracture planes existing in the rock formation will dictate the available block size and block shape. Some granite materials have been supplied in monolithic forms approaching 15 m (ft) in length, while other granites will not be available in panels larger than 1 m^2. The supplier of the material must be consulted during design phases to ensure that the design requirements can be satisfied by the specified material.~~

~~18.4Many granites are sold in varying "grades" or "selections." Oftentimes, terms such as "monumental," "structural," "architectural," "quarry-run," "select," "clear," or "variegated" are used with the tradename of the granite to further clarify the material specified.~~

~~COMMON DIMENSION STONE TYPES—MARBLE~~

~~19.Mineralogy, Appearance, and Texture~~

~~19.1Geologically, marble is a metamorphic rock resulting from the recrystallization of limestone. Marble has both geological and commercial definitions. Geologically, the name marble is applied to rocks comprising crystallized grains of calcite (calcium carbonate) or dolomite (calcium magnesium carbonate), or both. Commercially, the name marble has come to be applied not only to rocks meeting the geological definition but also to rocks ranging from pure carbonate to those containing very little carbonate, yet having compositions and textures that permit them to be polished. The commercial marble group includes geologically true marbles; compact, dense limestones capable of being polished (limestone marbles); serpentine rocks (mostly or entirely hydrated magnesium silicate); and travertine (porous or cellularly layered, partly crystalline calcite).~~

~~19.2Commercial marbles come in an almost unlimited palette of colors. They may be uniformly colored or a mixture of two or more colors. They may have bands or streaks in varying colors, called veining, contributing to any number of patterns. Geologic marbles of almost pure calcite or dolomite, or both, are white although trace minerals may contribute off-white background shadings and colorful veining. The color, veining, clouds, mottling, and shading in marbles are caused by substances included in minor amounts during formation. Iron oxides make the pink, yellows, browns, and reds. Most grays, blue-grays, and blacks are of carbonaceous origin. Greens are caused by micas, chlorites, and silicates.~~

~~20.Suitability for Use~~

~~20.1Marble has been used architecturally for centuries. It is one of man's oldest building materials, as a dimension stone. Yet, not all marbles are suitable for use as exterior dimension stone.~~

~~20.2Some of the basic considerations to be addressed in selecting a suitable marble for exterior use are as follows:~~

~~20.2.1*Texture*—Texture is defined as that aspect of the physical appearance of a rock that is determined by size, shape, and mutual relations of the component grains or crystals. Texture plays a very important part in the physical strength and resistance to exterior exposures of marble. Marbles with a fine-grained, equigranular texture (grains of uniform size) tend to be less resistant to the effects of exterior exposure than those with a medium- to large-grained, inequigranular texture (grains of markedly varying sizes). The latter usually have an interlocking texture (grains with irregular boundaries, which interlock by mutual penetration).~~

~~20.2.2*Physical Strength*—Physical strength properties of marble are determined by laboratory testing in accordance with ASTM standard test procedures for each physical property to be evaluated. Minimum or maximum values for each physical property, to aid in determination of a specific marble's suitability for exterior exposure, are in accordance with Specification~~ Marble

17.1 Geologically, marble is a metamorphic rock resulting from recrystallization of limestone. Within this geological definition, the term marble is correctly applied only to rocks comprising crystallized grains of calcite (calcium carbonate) or dolomite (calcium magnesium carbonate), or both. Commercially, the term "marble" is applied not only to rocks meeting this definition, but also to rocks ranging from pure carbonate to those containing little carbonate, yet having compositions and textures that allow them to be polished. While sometimes loosely included in the definition of commercial marble, polishable limestones, travertines, and serpentines can be better evaluated under their correct stone type definition and appropriate specifications.

17.2 A geologic marble of pure calcite or dolomite would be white in color. Marble colors, veining, clouds, mottling, and shading are caused by substances included in minor amounts during formation. Iron oxides make the pinks, yellows, browns, and reds. Most grays, blue-grays, and blacks are of carbonaceous origin. Greens are the results of micas, chlorites, and silicates.

17.3 While marble has been used architecturally for many centuries and is one of man's oldest building materials, not all marbles are suitable for exterior use. The marble's texture is governed by the size, shape, and mutual relations of the component grains or crystals. Texture is often a factor in the material's ability to resist weathering effects. Marbles with a fine-grained, equigranular texture tend to be less weather-resistant than those with a medium to large grained, inequigranular texture, because the latter usually has an interlocking texture (grains with irregular boundaries, that interlock by mutual penetration).

17.4 Marble materials are used in a variety of architectural and memorial dimension stone applications. A list of common applications follows:

Architectural:
Exterior cladding/curtainwall
Interior cladding
Exterior paving
Interior flooring
Furniture & countertops
Steps
Coping
Window sills/stools
Memorial:
Monuments/markers
Mausoleums
Civic memorials

17.5 The physical properties of marble are determined in accordance with variety of ASTM test procedures. Minimum and maximum values for the material's physical requirements are listed in Specification C503.

~~20.2.3*Soundness*—Marbles have been classified~~ 17.6 The Marble Institute of America classifies marbles into four soundness groups. The basis of this classification is simply the usual fabrication and handling practices involved in working with the material. Practical experience with each material has deemed such practices to be both necessary and acceptable. The classification has no bearing on the cost of the material. The four groups are listed ~~as follows:~~ below:

~~20.2.3.1~~17.6.1 *Group A*—Sound marbles with uniform and favorable working qualities; containing no geological flaws or voids.

~~20.2.3.2~~

17.6.2 *Group B*—Marbles similar ~~to~~ in character to Group A marbles, but with less favorable working qualities; may have natural faults; a limited amount of waxing, sticking, and filling may be required.

~~20.2.3.3~~17.6.3 *Group C*—Marbles with some variations in working qualities; geological flaws, voids, veins, and lines of separation are common. It is standard practice to repair these variations by waxing, sticking, filling, or cementing. Liners and other types of reinforcement are used when necessary.

~~20.2.3.4~~17.6.4 *Group D*—~~Marbles similar to Group C marbles, but containing a larger proportion of natural faults, maximum variations of working qualities, and requiring more of the same methods of finishing and reinforcing. This group comprises many of the highly colored marbles prized for their decorative values.~~

~~20.2.3.5*Hysteresis*—Most dimension stones return to their original volume after exposure to high or low temperatures. Some marbles exhibit a phenomenon known as "hysteresis," or a permanent volume change after exposure to thermal cycling. Hysteresis typically manifests itself as a bowing of the marble panels, often suggesting a pillowed effect. In addition to the bowing, the face of the panels will become more porous, making the surface more vulnerable to attack by corrosive agents and freeze/thaw deterioration. If a marble which is subject to hysteresis is selected, careful research is required to determine the minimum thickness required to prevent failure of the cladding system.~~

~~20.3Marble is a suitable and durable material for exterior dimension stone when properly selected, designed, and installed. The ultimate test for any specific marble is its past historical performance on existing structures. Some marbles, particularly those included in the Group C and D classifications, are not suitable for exterior use.~~ —Marbles similar to Group C marbles, but containing a larger proportion of natural faults, maximum variations of working qualities, and requiring more of the same methods of finishing and reinforcing. This group comprises many of the highly-colored marbles prized for their decorative values.

17.7 Most dimension stones return to their original volume after exposure to high or low temperatures. However, some marbles exhibit a phenomenon know as 'hysteresis", or a permanent volume change after exposure to thermal and moisture cycling. Hysteresis typically manifests itself as a bowing of the marble panels, often suggesting a pillowed effect. In addition to the bowing, the face of the panels becomes more porous, making the surface more vulnerable to attack by corrosive agents and freeze/thaw deterioration. Before selecting marble that is subject to hysteresis for a project, careful research should be conducted to determine the minimum thickness required to prevent failure of the cladding system.

17.8 Marble is a suitable and durable material for use when properly selected, designed, and installed. The ultimate test for any specific marble is its past historical performance on existing structures. Some marbles, particularly those included in the groups B, C and D classifications, are not suitable for exterior use.

18. Limestone

18.1 Limestone is a commercial rock term embracing both limestone and dolomite. It is a sedimentary rock composed principally of calcium carbonate (the mineral calcite) or the double carbonate of calcium and magnesium (the mineral dolomite), or a mixture of the two. Limestones, like all sedimentary rocks, contain organic matter and other natural characteristics that affect their appearance and properties. The amount, kind, and distribution of these natural characteristics may affect the suitability of the rock for commercial use. Limestones are known to exist in all geologic time periods and on all continents of the earth, but those that have properties of superior dimension stones are relatively rare.

18.2 Limestones are found in hues of white, brown, gray, yellow, red, or black, but those used commercially are commonly light earth tones of gray, buff, reddish or yellowish buff, or mixtures of these colors. The appearance of the stone is affected not only

by color, but also by its texture, stratification, and finish. Texture is determined by the size, shape, and arrangement of component grains, skeletal minerals, and crystals. Stratification refers to the composition, thickness, and arrangement of component beds. Finish is brought about by milling or fabrication. Limestones range in texture from those so fine-grained that they lack visible particles, to coarse-grained, in which individual fossil shells may be apparent.

18.3 Some limestones are "anisotropic", or directionally specific in their physical and visual properties, and have a preferred splitting direction. However, many widely-used limestones do not display a preferential direction of splitting, and are referred to as "freestones".

18.4 Limestone materials have been used for hundreds of years in a variety of architectural dimension stone applications in all climates. A list of common applications follows:

Exterior cladding
Paving and steps
Window lintels and sills
Wall copings
Interior cladding, base and mouldings
Interior flooring
Hearths, mantels, fireplace surrounds
Columns
Balustrades
Carvings, decorative trim

18.5 The physical properties of limestone are determined in accordance with a variety of ASTM test procedures. Minimum and maximum values for the material' physical requirements are listed in Specification C568. This specification classifies dimension limestones into three separate categories according to density.

18.6 Because of the varying physical properties found within limestones, a single variety may not be suitable for all applications. As with all materials, specifiers should verify that the stone under consideration is suitable for the intended application. For large projects, availability of stone type, dimensional capability, production, and historical performance of the limestone should be checked to ensure that project requirements can be met. Limestone used in older buildings may no longer be quarried today, but stone of similar color and texture may be found.

19. Quartz-Based

19.1 The term "Quartz-Based" is a general commercial term including a variety of rocks, all of which consist of high contents of quartz and silica. The grains of quartz are commonly cemented together by silica or calcium carbonate. This dimension stone classification includes an extremely wide variety of materials, with a wide range of physical and mechanical properties. Sandstone, bluestone, brownstone, quartzite, and meta-quartzite are examples of materials included in this group.

19.2 Quartz-based stones of sedimentary origin will typically have pronounced bedding planes producing considerable anisotropic properties. This will generally affect both the appearance and performance of the material. Quarrying methods will be tailored to take advantage of this feature, using the natural separation planes, or rift, of the stone to determine the separation planes of the blocks.

19.3 Composition varies widely within this group, from materials that feature coarse, well-defined visible grains of quartz, to those having very fine, tightly-bonded particles appearing nearly homogeneous in structure. The grain size controls the degree of finish that can be obtained, with the finer grain sizes allowing more refined, smoother finishes.

19.4 Quartz-based stones are found in a variety of colors. Shades of light buff to dark blue gray are most common. Quartz-Based materials are used in a variety of architectural dimension stone applications. A list of common applications follows:

Exterior cladding/curtainwall
Interior cladding
Interior flooring & steps
Exterior paving & steps
Coping
Window sills
Water tables/belt courses

19.5 The physical properties of quartz-based stones are determined in accordance with a variety of ASTM test procedures. Minimum and maximum values for the material's physical requirements are listed in Specification C616. In this specification, three sub-categories of Sandstone, Quartzitic Sandstone, and Quartzite are listed with separate sets of properties for each.

20. Slate

20.1 Slate is a microcrystalline, metamorphic rock commonly derived from shale. The shales from which slates originate were deposited previously as clay beds. Slates are composed mostly of micas, chlorite, and quartz.

20.2 Slates are always "anisotropic" or "directionally specific" in their properties. The micaeous minerals have a subparallel orientation resulting in very pronounced cleavage planes within the rock. This enables most slates to be split into thin, strong sheets. As a result of this property, slate is the only dimension stone type to be commonly used as roofing.