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Standard Guide for Selection of Dimension Stone[1]

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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.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be

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used independently of the other, and values from the two systems shall not be combined.

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C97 Test Methods for Absorption and Bulk Specific Gravity of Dimension Stone
C99 Test Method for Modulus of Rupture of Dimension Stone
C119 Terminology Relating to Dimension Stone
C120 Test Methods for Flexure Testing of Structural and Roofing Slate
C121/C121M 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
C295 Guide for Petrographic Examination of Aggregates for Concrete
C406 Specification for Roofing Slate
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
C629 Specification for Slate Dimension Stone
C880 Test Method for Flexural Strength of Dimension Stone
C856 Practice for Petrographic Examination of Hardened Concrete
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 Attachment 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 Abraser
C1354 Test Method for Strength of Individual Stone Anchorages in Dimension Stone
C1526 Specification for Serpentine Dimension Stone
C1527 Specification for Travertine Dimension Stone
C1721 Guide for Petrographic Examination of Dimension Stone
D2203 Test Method for Staining from Sealants

[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.

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 STONE

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, have 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 There are several major categories of exterior applications for stone; each of these is introduced below.

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.

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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.

INTERIOR APPLICATIONS OF DIMENSION STONE

15. Interior Applications

15.1 Stone is often used at the interior of buildings due to its exceptional durability, beauty, and classical appearance. Due to the lack of environmental exposure, these applications are usually more forgiving of the material and allow for a broader range of stone varieties to be used. The major categories of interior use are discussed briefly below.

16. Flooring

16.1 Stone floors are typically highly durable, low maintenance, and aesthetically pleasing. When using stone as flooring, one must make sure that the finish is appropriate for its intended use; stone used for flooring should be abrasion resistant and have a finish that is not slippery to foot traffic when wet.

16.2 Joint conditions in floor installations are also critical; while interior flooring is not subject to the same temperature fluctuations as exterior installations, the joint system should include expansion joints that will accommodate cyclic variations in the stone dimensions over time, particularly if there is a substantial heat load from sunlight exposure or below floor-heating elements.

16.3 Stone flooring and the joint materials should also be relatively impervious to moisture; it is not unusual for interior floors to be cleaned with water and detergents on a daily basis. Excessive moisture in the flooring system can lead to discoloration of the joint materials and the stone, particularly if the stone flooring material is absorptive. Moisture can become trapped below highly polished finishes and appear as a stain. Some stone types used as flooring may need to be treated at the edges and bottom surface as well as the top surface to limit absorption-related concerns. However, component compatibility should be researched or tested prior to treating these surfaces to inhibit bond performance between the stone, adhesive, and grout. Only cleaning procedures and products (including waxes and cleaning agents) that are approved for use by the stone supplier should be used. Unapproved methods may stain or damage the stone or damage the stone finish.

17. Stairs

17.1 The use of stone for stair treads and risers leads to an attractive, durable, and low maintenance way to address interior elevation changes. Stone selected for stairs should be able to withstand constant foot traffic with minimal surface abrasion, erosion or damage. It should also be naturally slip-resistant due to the stone type or the finish selected.

18. Cladding

18.1 Stone used as interior wall cladding should be designed and installed in a similar manner to exterior wall cladding; however, loading considerations are different with an interior application. When considering stone anchorage options for an interior application, one should include (at a minimum) a nominal differential pressure on interior stone resulting from variations in building pressurization due to mechanical system performance and air loss through the building enclosure; however, it is likely that seismic requirements will control an interior application when compared to the comparatively low lateral loads generated from building pressurization.

19. Ornament and Sculpture

19.1 Stone used as decorative elements in an interior application have the distinct advantage of not being exposed to environmental forces such as temperature fluctuations, wind, water, and atmospheric pollutants. Therefore, the variety of stone suitable for interior applications can include many stone types that would otherwise not be appropriate due to their reduced resistance to environmental forces.

20. Wet Areas

20.1 Stone panels and tiles are commonly used for shower stall linings, urinal screens, and toilet partitions. Proper attention to water flow, waterproofing, corrosion resistance of attachment hardware, and base material is as critical in these applications as it would be in an exterior application.

21. Furnishings

21.1 Stone is widely used for countertops in kitchens, wet bars, and bathrooms. Normally, stone with lower absorption properties are recommended, though virtually any stone can be used if properly treated with impregnating repellents for exposure to moisture. Such repellents may alter the color or gloss levels of the stone surface, and typically have a reapplication interval specified by the manufacturer. While repellents will offer some degree of protection against moisture and staining, they will not protect acid sensitive stones against etching due to acid exposure.

21.2 Stone can also be used for table tops and table supports. Flexural strength is critical in these applications, along with consideration of the additional load to the floor structure from stone furniture when compared to other materials commonly used.

COMMON DIMENSION STONE TYPES

22. General

22.1 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.

22.2 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 43 for more detailed discussions of finish types.

22.3 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.

22.4 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.

22.5 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.

22.6 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

23. Granite

23.1 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,

TABLE 1 Common Thickness and Application Chart

Applications	Granite	Marble	Limestone	Quartz-Based	Slate	Serpentine	Travertine
Tile[A]	10-13 mm [⅜-½ in.]	10-13 mm [⅜-½ in.]	10-13 mm [⅜-½ in.]	10-13 mm [⅜-½ in.]	6-10 mm [¼-⅜ in.]	10-13 mm [⅜-½ in.]	10-13 mm [⅜-½ in.]
Roofing	NA[B]	NA	NA	NA	6-10 mm [¼-⅜ in.]	NA	NA
Interior Flooring	20 mm [¾ in.]	20 mm [¾ in.]	20 mm [¾ in.]	30 mm [1¼ in.]	10-25 mm [⅜-1 in.]	20 mm [¾ in.]	20 mm [¾ in.]
Interior Cladding	20 mm [¾ in.]	20 mm [¾ in.]	20 mm [¾ in.]	30 mm [1¼ in.]	25 mm [1 in.]	20 mm [¾ in.]	20 mm [¾ in.]
Countertops	20-30 mm [¾-1¼ in.]	20-30 mm [¾-1¼ in.]	20-30 mm [¾-1¼ in.]	20-30 mm [¾-1¼ in.]	20-30 mm [¾-1¼ in.]	20-30 mm [¾-1¼ in.]	20-30 mm [¾-1¼ in.]
Exterior Cladding[C]	30-80 mm [1¼-3 in.]	30-80 mm [1¼-3 in.]	50-80 mm [2-3 in.]	30-80 mm [1¼-3 in.]	30-80 mm [1¼-3 in.]	30-80 mm [1¼-3 in.]	30-80 mm [1¼-3 in.]
Exterior Paving (pedestrian)	30-50 mm [1¼-2 in.]	30-50 mm [1¼-2 in.]	30-50 mm [1¼-2 in.]	30-50 mm [1¼-2 in.]	30-50 mm [1¼-2 in.]	30-50 mm [1¼-2 in.]	30-50 mm [1¼-2 in.]
Exterior Paving (vehicular)	80 mm [3 in.]	80 mm [3 in.]	80 mm [3 in.]	80 mm [3 in.]	80 mm [3 in.]	80 mm [3 in.]	80 mm [3 in.]
Window sills	80 mm [3 in.]	80 mm [3 in.]	80 mm [3 in.]	80 mm [3 in.]	80 mm [3 in.]	80 mm [3 in.]	80 mm [3 in.]
Copings	100-200 mm [4-8 in.]	100-200 mm [4-8 in.]	100-200 mm [4-8 in.]	100-200 mm [4-8 in.]	80 mm [3 in.]	100-200 mm [4-8 in.]	100-200 mm [4-8 in.]
Curbs	100-200 mm [4-8 in.]	100-200 mm [4-8 in.]	100-200 mm [4-8 in.]	100-200 mm [4-8 in.]	NA	100-200 mm [4-8 in.]	100-200 mm [4-8 in.]
Steps	100-200 mm [4-8 in.]	100-200 mm [4-8 in.]	100-200 mm [4-8 in.]	100-200 mm [4-8 in.]	NA	100-200 mm [4-8 in.]	100-200 mm [4-8 in.]
Monuments/ Cubic[D]	> 200 mm [8 in.]	> 200 mm [8 in.]	> 200 mm [8 in.]	> 200 mm [8 in.]	NA	> 200 mm [8 in.]	> 200 mm [8 in.]

[A] For interior use with “thin-set” adhesives.
[B] Not applicable or generally not used.
[C] 30 mm is generally considered the minimum thickness for exterior application without a structural backing. Design loads may require thicker material or when stone contains deep reveals, generally produced at thickness increments of 10 mm.
[D] For units that are highly articulated, or other applications as necessary based on design loads or spans.

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”.

23.2 The majority of materials in the granite group are granular or crystalline in appearance, with the grain size varying between 2 or 3 mm [1⁄16 or ⅛ in.] up to 25 mm [1 in.] or larger. Some of the materials included in the granite group will show a layering, 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.

23.3 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.

23.4 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.

23.5 Granite materials are used in a variety of architectural, memorial, and industrial dimension stone applications. Memorial applications include monuments, markers, and mausoleums. Industrial applications include pickling tanks, surface plate, precision machine bases, and paper press rolls.

23.6 Nominal thicknesses of granite offered by fabricators are as follows:

10 mm [3/8 in.]	Tile for interior use only with "thin-set" adhesives or as part of a panelized system with structural backing.
20 mm [3/4 in.]	Interior cladding, interior flooring, furniture, and countertops. Occasionally used as exterior cladding on mausoleums when panel sizes are sufficiently small to resist design loads.
30 mm [1 ¼ in.]	Generally considered the minimum thickness for exterior cladding without a structural backing. Design loads may require thicker material.
40-50 mm [1 ⅝-3 in.]	Exterior cladding when design loads marginally exceed the capacity of material supplied at 30 mm [1¼ in.] or when reveals are machined into the face of the panel.
80 mm [3 in.]	Exterior cladding when extremely large panels are required or when deep reveals are cut into the face of the panel. Also, exterior window sills, copings, and exterior paving units subject to vehicle traffic.
100-200 mm [4-8 in.]	Landscape or site work applications such as curbs, steps, copings, and fountains.
>200 mm [8 in.]	Sculpture, ornamental, or monumental applications.

24. Marble

24.1 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.

24.2 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.

24.3 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).

24.4 Marble materials are used in a variety of architectural and memorial dimension stone applications. Memorial applications include monuments, markers, mausoleums, and civic memorials.

24.5 Nominal thicknesses of marble offered by fabricators are as follows:

10 mm [⅜ in.]	Tile for interior use only with "thin-set" adhesives or as part of a panelized system with structural backing.
13 mm [½ in.]	Tile for interior use only with "thin-set" adhesives where heavier pedestrian traffic is anticipated.
20 mm [¾ in.]	Interior cladding, interior flooring, furniture, and countertops.
30 mm [1¼ in.]	Generally considered the minimum thickness for exterior application without a structural backing. Design loads may require thicker material.
40-50 mm [1⅝-2 in.]	Exterior cladding when design loads marginally exceed the capacity of material supplied at 30 mm [11/4 in.] or when reveals are machined into the face of the panel.
80 mm [3 in.]	Exterior cladding when extremely large panels are required or when deep reveals are cut into the face of the panel. Exterior window sills, copings, and exterior paving units subject to vehicle traffic.
100-200 mm [4-8 in.]	Landscape or site work applications such as curbs, steps, copings, and fountains.
>200 mm [8 in.]	Sculpture, ornamental, or monumental applications.

24.6 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.

24.7 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 below:

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

24.7.2 *Group B*—Marbles similar 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.

24.7.3 *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.

24.7.4 *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.

24.8 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.

24.9 Marble is a suitable and durable material for use when properly selected, designed, and installed. The ultimate test for