Serpentine

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SERPENTINE

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 C1526, Standard Specification for Serpentine 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.

1.3 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 serpentine 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 or ASTM International.

1.5 Source of Supply

1.5.1 All serpentine shall be obtained from quarries having adequate capacity and facilities to meet the specified requirements, and by 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 Serpentine Contractor shall submit through the General Contractor, for approval by the Specifying Authority, at least two sets of samples of the various kinds of serpentine specified. The sample size shall be 1'-0" x 1'-0" and shall represent approximately the finish, texture, and anticipated range of colors to be supplied. Where necessary to show variations in color and markings, larger samples or range sets of samples should be submitted. If serpentine is to be matched, a minimum of two sets each containing four matched samples showing proposed veining and range of colors

in each set must be supplied. Samples designating finished face shall be clearly labeled on the back with the name of the serpentine, and the use for which the serpentine is intended. One set of samples shall be retained by the Specifying Authority, and one set shall be returned to the Serpentine Supplier for their record and guidance. It is noted herein that serpentine is a natural material and will have intrinsic variations in color, markings, and other characteristics. Depending on the serpentine 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 the finished slabs is recommended to understand the finish and full range of the material.

1.7 Shop Drawings

1.7.1 The Serpentine Contractor shall submit through the General Contractor, for approval by the Specifying Authority, sufficient sets of shop drawings showing general layout, jointing, anchoring, stock thickness, and such other pertinent information. These drawings shall show all bedding, bonding, jointing and anchoring details along with the net piece dimensions of each serpentine unit. One copy of approved drawings shall be retained by the Specifying Authority, one copy shall be retained by the General Contractor, and one copy returned to the Serpentine Contractor for fabrication. NO FABRICATION OF SERPENTINE SHALL BE STARTED UNTIL SUCH DRAWINGS HAVE BEEN FULLY APPROVED AND MARKED AS SUCH. The General Contractor shall furnish all field dimensions necessary for fabrication. If measurements are not established and guaranteed in advance, the Serpentine Contractor shall obtain and verify measurements at the building. The General Contractor shall be responsible for all reasonable assistance to the Serpentine Contractor, including the services of an Engineer, if required, for the establishment of levels, bench marks, and the like. The Serpentine 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 serpentine 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 Patching during fabrication. Serpentines have some variation in working qualities. Veins and lines of separation are common. It is standard practice to repair these variations by use of reinforcing, liners, sticking[1] together, filling with resin or terrazzo, and doing all other work necessary to hold the stone together to yield a finished product that is usable for architectural purposes. On completion, most repair is visible, with differences in light reflection. Unlike other dimension stones, many varieties of serpentine that have been reinforced and repaired are suitable for use in exterior environments, though not in all situations. Where questions of suitability for use are encountered, the MIA recommends that reliance on past performance is the best guide for making decisions as to future performance.

[1] *Sticking* describes the butt edge repair of a broken piece, now generally done with dowels, cements, or epoxies. The pieces are "stuck" together; thus "sticking."

1.9.2 Patching during installation. Small chips at the edges and corners of serpentine may be patched, provided the structural integrity of the stone is not affected and the patch matches the color and finish of the stone so that it does not detract from the appearance.

2.0 MATERIALS

2.1 Serpentine

2.1.1 General: All serpentine shall be of kind or kinds shown on the Specifying Authority's drawing or as specified herein, conforming to or within the range of approved samples and in accordance with the characteristics and working qualities. Care shall be taken in selection to produce as harmonious effects as possible. Patching and waxing[2], where permitted under the Marble Institute of America Group Classifications, shall be carefully done to conform to the serpentine's general character and finish. Texture and finish shall be within the range of sample(s) approved by the Specifying Authority.

2.1.2 ASTM C1526 [C97] [C99] [C170] [C241] [C880] See the chart of applicable ASTM standards and tests in the Appendix.

2.1.3 Schedule: Serpentine shall be provided as follows:

2.1.3.1 For (*state location on building*) (*state name and color*) serpentine 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 serpentine/finish combination on the project.

2.1.4 Asbestos Content. Most serpentine stone contains a minor quantity of asbestos fibers as a constituent to the white calcite veining common to the variety, and as such, should be worked "wet" only. The asbestic content has no effect on the stone's use and/or maintenance. (Refer also to the Geological Classification section within this chapter).

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

2.1.6 Polished: A mirrorlike, glossy surface which brings out the full color and character of the stone. This finish is not recommended for exterior or commercial floor use.

2.1.7 Honed: A velvety smooth surface with little or no gloss.

2.2 Setting Mortar (And Adhesives)

2.2.1 Portland cement shall conform to the requirements of the Standard Specification for Portland Cement, ASTM C150. White portland cement is recommended for white or light colored serpentine. Nonstaining cement shall conform to the requirements of the Standard Specification for Masonry Cement, ASTM C91. Molding Plaster (plaster of paris) shall conform to the requirements of the Standard Specification for Gypsum Casting Plaster and Gypsum Molding Plaster, ASTM C59/C59M.

2.2.2 Sand. All sand shall be clean, free from organic and other deleterious matter likely to stain the finished work, and shall be screened as required for the desired results.

2.2.3 Portland cement shrinkage-reducing accelerator used with portland cement to give it the quick-setting characteristics of plaster of paris, shall be a

[2] *Waxing* refers to the practice of filling minor surface imperfections such as voids or sand holds with melted shellac, cabinetmaker's wax or certain polyester compounds. It does not refer to the application of past wax to make surfaces shinier.

nonstaining admixture that will not corrode anchors or dowels.

2.2.4 Nonstaining adhesive shall be of a type that will not stain the serpentine, is not affected by temperature changes or moisture, and adheres firmly to all clean surfaces.

2.3 Pointing Mortar

2.3.1 Mortar for pointing shall be Type N, as defined in ASTM C270 (Standard Specification for Mortar for Unit Masonry). All mixing, handling, and pacing procedures shall be in accordance with ASTM C270.

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).

2.4.2 Sealants used for pointing to exclude moisture and to provide a joint that will remain plastic for many years, shall be nonstaining.

2.5 Anchors, Cramps, and Dowels

2.5.1 Anchors, cramps, and dowels shall be made of corrosion-resistant metals. Special cramps, dowels, and the like shall be used where shown on shop drawings, but elsewhere, #8 copper or stainless steel wire anchors shall be used. It shall be the responsibility of the Serpentine Contractor to anchor all serpentine securely. For standing serpentine, the following practices usually prevail:

2.5.1.2 A minimum of four anchors should be provided for pieces up to 12 square feet, with two additional anchors for each additional 8 square feet of surface area. Shims used to maintain joints shall be plastic.

2.5.1.3 Use of copper wire for anchors to be installed over 12' off the ground is not recommended.

3.0 FABRICATION

3.1 Beds and Joints

3.1.1 Bed and joint width shall be determined by analysis of anticipated building movements and designed to accommodate such movements without inducing undue stresses in the stone panels or joint filler materials. Expansion joints shall be designed and located to accommodate larger movements.

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 shall be drilled at job site by Serpentine Contractor to facilitate alignment.

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

3.7 Carving and Models

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

Finished serpentine shall be carefully packed and loaded for shipment using all reasonable and customary precautions against damage in transit. No material which may cause staining or discoloration shall be used for blocking or packing.

4.2 Site Storage

It shall be the responsibility of the Serpentine Contractor to receive, store, and protect the serpentine from damage by others after it is delivered to the job site and prior to its erection in the building. All serpentine shall be received and unloaded at the site with care in handling to avoid damage or soiling. If serpentine is stored outside, it 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 serpentine 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 Serpentine 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 stone 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 Caution with Serpentine Setting Beds. Water expands the intercrystalline space in serpentine dimension stone. When it is being installed in a mortar bed, techniques should be employed that minimize the amount of water at the back face of the stone, and/or employment of fogging on the face (to increase the intercrystalline space at both surfaces uniformly) should be considered. Absent of this, the stone could expand at the back face temporarily to a larger dimension than the top face, causing warping and/or twisting. The warped stone is difficult, if not impossible, to return to its original dimensions.

5.2.2 Other methodologies suggest employment of installation material that is not water-soluble to avoid this potential problem.

5.2.3 This is an installation condition, and should not be construed as a limitation of the stone's range of application. Most serpentine varieties perform well in wet work applications.

5.3 Floor Serpentine

5.3.1 Floor Preparation. It is the General Contractor's responsibility to clean all subfloor surfaces to remove dirt, dust, debris, and loose particles immediately prior to setting serpentine floor and to ensure that the area to receive the stone flooring meets the deflection standards of the industry.

5.3.2 Curing compounds of any kind shall not be used on the slab on which floor serpentine is to be directly set. If a curing compound is present, it is the General Contractor's responsibility to remove it by scarifying the slab.

5.3.3 Before being set, all serpentine shall be clean and free of foreign matter of any kind.

5.3.4 Cement Bed. The cement bed to receive the serpentine tile shall consist of 1 part portland cement to not more than 3 to 5 parts of clean, sharp sand mixed quite dry for tamping. White Portland cement is recommended for light-colored serpentines.

5.3.5 Serpentine Tamped. The serpentine shall be tamped with a suitable mallet until firmly bedded to the proper level of the floor.

5.3.6 Serpentine Removed. The serpentine shall then be removed and the back parged with wet cement or the bed sprinkled with water and cement. In the latter procedure, the back of the serpentine shall be wet. The method of fully buttering edges of the serpentine as it is laid is equally approved.

5.3.7 Joints between the serpentine pieces shall show an even width when laid and finished.

5.3.8 Traffic after Installation. The floor shall be roped off for 24 hours after installation and then grouted with water and white portland cement grout or nonstaining dry set portland cement grout.

5.3.9 Timeline for Additional Cleaning. Cleaning or additional surfacing, if required, shall not be undertaken until the new floor is at least seven days old.

5.3.10 Thin-Set Method. The thin set method of installing serpentine tile employing the use of dry set portland cement mortars is recommended for thin serpentine tiles (nominal 3/8" thick) where optimum setting space is not available. Subfloor shall be clean, smooth finished, and level.

5.3.11 Stone dust must be washed off the back face of stone pavers prior to installation. Apply mortar with flat side of trowel over an area that can be covered with tile while mortar remains plastic. Within ten minutes, and using a notched trowel sized to facilitate the proper coverage, comb mortar to obtain an even-setting bed without scraping the backing material. Key the mortar into the substrate

with the flat side of the trowel. Comb with the notched side of the trowel in one direction. Firmly press stone tiles into the mortar and move them perpendicularly across the ridges, forward and back approximately 1/8" to ¼" to flatten the ridges and fill the valleys. Ensure a maximum mortar thickness of 3/32" between stone tile and backing after stone tile has been tamped into place. Stone tile shall not be applied to skinned-over mortar. Or alternatively, back butter the stone tiles to ensure 100% contact. In either method, ensure 100% contact on 3/8" tile; not less than 80% contact on ¾" or thicker material, excepting that all corners and edges of stone tiles must always be fully supported, and contact shall always be 100% in exterior and/or water-susceptible conditions.

5.4 Interior Veneer Serpentine

5.4.1 The serpentine shall be set by spotting with gypsum molding plaster or cement mortar and the use of concealed anchors secured in the wall backing.

5.5 Serpentine Wall Tile

5.5.1 Individually set thin tile (nominal 3/8" thick) on vertical surfaces exceeding 8' is not recommended. Where thin serpentine tile is installed, nonstaining adhesives or dry set mortars may be used as setting beds.

5.6 Toilet and Shower Compartments

5.6.1 Stiles and partitions shall be assembled with concealed dowel fastenings or corrosion resistant angles, three in height of stall.

5.6.2 For ceiling-hung units, metal supporting members in ceiling are to be furnished and installed by the General Contractor.

5.7 Mortar Joints

5.7.1 Mortar joints shall be raked out to a depth of ½" to ¾". Apply pointing mortar in layers not exceeding 3/8" and allow each layer to get hard to the touch before the next layer is applied. Tool finished joints with a concave tool having a diameter approximately 1/8" greater than the joint width.

5.7.2 Care shall be taken to keep expansion joints free of mortar, which would compromise their function.

5.8 Anchorage

5.8.1 All serpentine shall be anchored or doweled in accordance with the approved shop drawings.

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

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

5.9 Sealant Joints

5.9.1 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.

5.9.2 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.

5.10 Expansion Joints

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

5.11 Caulking

5.11.1 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.

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

5.12 Weep Tubes

5.12.1 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 Serpentine shall be shop-cleaned at the time of final fabrication. It shall also be cleaned after installation and all pointing or caulking is completed. All dirt, excess mortar, weld splatter, stains, and other defacements shall be removed.

6.1.2 All cleaning methods shall be in accordance with ASTM C1515.

6.1.3 Stiff bristle fiber brushes may be used, but the use of wire brushes or of acid type cleaning agents and other solutions that may cause discoloration is expressly prohibited. Fabricator should be contacted before cleaners other than neutral detergents are used.

6.2 Protection of Finished Work

6.2.1 After the serpentine work is installed, it shall be the responsibility of the General Contractor to see that it is properly and adequately protected from damage and stains until all trades are finished. This responsibility includes the stone cleaning costs prior to the final inspection. The Serpentine Contractor will outline the needs for protection, in writing, to the General Contractor. For the protection of projecting members, corners, window stools and saddles, wood guards using lumber that will not stain or deface serpentine shall be supplied, installed, and maintained by the General Contractor. All nails used shall be galvanized or nonrusting. Damage to finished serpentine by other trades shall be repaired or replaced at the expense of the General Contractor. Serpentine flooring shall be adequately protected by the General Contractor against traffic and other damage with nonstaining materials, without cost to the Serpentine Contractor.

6.2.2 All serpentine work in progress shall be protected at all times during construction by use of a suitably strong, impervious film or fabric securely held in place.

PRODUCT DESCRIPTION – Serpentine

1.0 GEOLOGICAL CLASSIFICATION

1.1 Serpentine. These beautiful and elegant green stones traditionally have been grouped in the commercial marble category. However, they are not true marbles. Marble is by geologic definition metamorphic limestone, calcium carbonate ($CaCO_3$), and dolomite

$CaMg(CO_3)_2$. Geologically, the "green marbles," as they are informally known, are the low-level metamorphic stone "serpentinite," of which the dominant mineral is serpentine. When the mineral name is altered to end with the suffix "ite," it becomes the name of the stone in which it is the main chemical constituent. Serpentinite is sometimes confused with "green schist," an entirely different rock generally not suitable as dimension stone and rarely seen in the market in part because large, nonfractured blocks are difficult to obtain and loose mineral grains often preclude achieving suitably polished and durable surfaces.

1.2 The major parent rock of the serpentine mineral is dark, iron- and magnesium-rich igneous rock of the oceanic type, with a lesser amount of lighter, continental-type rock admixed. When these are intruded with hot, chemical-rich fluids, the mineral serpentine is formed in beltlike rinds around larger blocks of oceanic-type, seafloor rock bodies. This action takes place when two large segments of Earth's crust crash together, causing regional scale metamorphism with injection of chemical-rich fluids[3]. Serpentines are thought to be formed very deep, at temperatures up to around 500°C at a depth called the "Moho," [4] the border marking the transition between the outer crust of the Earth and the underlying upper mantle, at depths of less than 10 to more than 60 km.

1.3 Slight variations of parent rock mineral content, the condition of the parent rock, variations in chemistry of the invading fluids, and changes in temperature, pressure, and time plus subsequent geologic history, all influence the formation of serpentine stone. Frequently asked questions are: Why the great differences between different shades of green? Why does one fade and others do not? Why is one very dark green and others light- or yellowish-green? Why is one provided with reinforcing net epoxied to the back and another is not? The complex differences are all in the chemistry of rocks, fluids, and variations in parameters of the metamorphic process.

1.4 A wide range in apparent quality and performance of these beautiful stones reflects the diversity of mineral content and consequent variations in the physical properties and durability between the many "green marbles" or serpentinites on today's market. This clearly points up the exceptional value of the experience and knowledge attained by skilled stone technicians.

1.5 The geochemistry involved with these rocks is complex; however, knowing something about a few of the important chemical components of serpentine and their properties greatly aids understanding this often perplexing stone group.

1.6 Serpentine ($Mg_3Si_2O_5(OH)_4$) is only formed as a metamorphic mineral. It has the sheeting habit of mica in that it is composed of thin sheets loosely bound together like pages in a poorly manufactured book. Unlike the well-known micas, biotite and muscovite, serpentine sheets are not elastic, but they are flexible. Large chunks of the mineral have a "soapy" appearance and luster, and feel slippery or "greasy." The slippery surfaces act as a lubricant in faulting of the stone. Serpentinites often occur in contorted and complex shapes because of the flexibility of the sheets, and that is part of the attraction of the stone. Serpentine hardness varies from about H=2.5 to 5 on the Mohs Scale[5], depending on specific parameters of its geologic history and other admixed minerals. Serpentine does not react to cold, dilute acid.

1.7 Asbestos. The normal, sheet-like "habit" or occurrence of serpentine has been

[3] Skinner, B. J. and S. C. Porter, 1992, *The Dynamic Earth*, 2nd ed., John Wiley & Sons, New York, p. 455.

[4] *Moho* is the accepted slang term for Mohorovicić Discontinuity, or the crust/mantle boundary identified by a contrast in the velocity of sound through the two chemically different rock compositions.

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

described, but another form of serpentine is fibrous, and when found in this form it is the potentially dangerous mineral asbestos. Properly known as chrysotile serpentine or chrysotile asbestos, it has a slightly different chemistry than normal serpentine. Additional meta-morphism, and again slight changes in chemistry, produce the familiar mineral talc. Since the three forms of serpentine often occur together, avoid cutting serpentinites dry and maintain absolutely meticulous dust control in the shop.

1.8 Chrysotile and Talc. The transformation of serpentine to chrysotile (asbestos) to talc is a continuously variable chemical series and the members are chemically quite similar, but have differing molecular geometry. Since they form in response to slight differences in metamorphic pressures and chemistry, all three minerals may be found together. Talc is the softest of minerals and used as the example for H=1 on the Mohs Scale. Talc does not polish. Chrysotile may polish if highly compacted and cut normal to the fibers. Sometimes chrysotile may become highly siliceous; that is, the mineral is replaced by silica but retains a "ghost" of its fibrous structure. This altered variant is known in the semiprecious gem trade as "tiger's eye" for its striking optical characteristics. Since both talc and asbestos can be considered undesirable admixtures to a commercial-grade "green marble," they are not generally found in more than small or trace amounts in the better-known serpentines used for decades. Their occurrence tends to weaken the stone, allows moisture penetration, weathers faster, and should be considered detrimental in some exterior applications where moisture control is difficult. White veins in serpentine indicate the presence of talc or asbestos; consequently, the use of such stone should be minimized in external applications.

1.9 Calcite and magnesite (calcium and magnesium carbonates, ($CaCO_3$) and ($MgCo_3$) occur in serpentinites, usually as white to off-white discrete masses or veins of varying thickness in the figure of the stone. Both carbonate minerals have several properties in common: they are both H=3 (soft), break in perfect little rhombohedrons due to inherent weakness in molecular structure, and both are generally white or sometimes slightly iron-stained.

1.10 The only characteristic that can be used to differentiate the two is their reaction to cold, dilute acid: calcite will effervesce vigorously while magnesite does not. Is this important in dimension stone? Yes, if used as a tabletop, one of the traditional uses of highly figured "green marbles." It will not be easily etched by salad vinegar or wine if the carbonate mineral is magnesite. The simple dilute acid test can be done by anyone; however, if a surface-masking sealer is used, the acid may not reach the calcite and produce the typical reaction. If the sealing agent is trustworthy over an extended time, the occurrence of one or the other of these carbonates stones should not matter. Consulting with Sealing Professionals is recommended.

1.11 Carbonate minerals soluble in dilute acids should be used with extreme care in exterior applications where an acid-polluted atmosphere exists. Likewise, magnesite-rich "green marbles" should not be used in exterior applications where atmospheric sulfate pollution occurs. Magnesite will react to very dilute sulfuric acid in the moisture and recrystallize to water-soluble magnesium sulfate (milk of magnesia).

1.12 Note: Thin-set, cementitious compounds will probably react with any carbonate mineral in the serpertinite stones yielding a failure in attaching thin sheets of some green marble.

1.13 Siderite ($FeCO_3$) is a semi-hard iron carbonate (H=3.5 to 4.5 on the Mohs Scale) not uncommon in serpentinites as pale- to dark-brown masses or veins. It breaks easily into parallelogram-shaped fragments, as do other carbonates, and does not react with cold,

dilute acids. It will effervesce in hot, dilute acids, but trying to perform that test is strongly discouraged due to the danger of eye damage when attempting to heat any acid.

1.14 Brucite (magnesium hydroxide or $Mg(OH)_2$) commonly occurs with serpentine, greenschists, chlorite schists, and with talc and other low-grade metamorphic stone formed from dark, high iron- and magnesium-rich igneous rock. Brucite is very soft, about H=2.5 – the same hardness as a human fingernail – thus it is not desirable to have large accumulations or veins of brucite in "green marbles." Brucite is very soluble in cold, dilute acids, but will not effervesce, becoming instead a mud-like slurry.

1.15 Note that since serpentine is formed in part from iron- and magnesium-rich parent rock, the occurrence of other high-Mg minerals such as brucite or magnesite and the carbonates of iron, Fe, Ca, and Mg are to be expected as minor constituents in serpentinites.

1.16 Chlorite [$(Mg,Fe)_5(Al,Fe)_2Si_3O_{10}(OH)_8$] is another green, very soft, sheet-like, metamorphic mineral. Chlorite, like serpentine, brucite, and magnesite, has flexible but not elastic sheets loosely bound together. It has a greasy-feeling surface that facilitates internal slippage in the serpentinite and greenstone belts. Its color ranges from medium green to a light, yellowish-green, and light to medium yellow. Chlorite hardness is H=2 to 2.5, or very soft. Although chlorite may polish, it does not retain polish and is prone to rapid surface dulling. Veins of chlorite weaken the stone when sliced thin and may be a likely reason to reinforce some slabs with backup netting and epoxy. Chlorite's sheeting habit acts as a plane of weakness along which faulting, slippage, and fracturing will occur, further weakening a thinly sawn piece.

1.17 Chlorite may be almost impossible to distinguish from serpentine except by hardness, a very difficult distinction to make, and these two minerals do occur together. Rapid weathering or loss of the well-polished surface of some "green marbles" may in fact be due to undetected chlorite that occurs as finely disseminated or small pockets in the serpentine that are obscure except to close inspection by experienced Stone Technicians.

1.18 Albite ($NaAlSi_3O_8$). This plagioclase feldspar composed of sodium aluminum silicate is found in some serpentinites, an expectation given the dark, oceanic-type parent of serpentine. Albite is hard (H=6) and durable, thus a vein of albite is in no way a detriment unless incipient fractures accompany the vein – probably when the vein happens to be bordered by a very thin chlorite rind.

1.19 Magnetite (Fe_3O_4) iron oxide is often present in serpentinites due to mineral segregation that occurs in metamorphic processes. Magnetite is very hard (H=5.5 to 6.5), harder than common glass. It is magnetic, black, and when polished, has a metallic luster.

1.20 Limitations. As a final note to this section regarding the use of serpentine in building applications, remember that failures with the "green marbles" can occur in some projects from the physical limitations of accessory minerals in the stone's chemical composition. In addition, serpentine's sheet-like, crystalline habits and slippery texture can sometimes cause weakness in slabs, or allow accelerated surface oxidation in exterior uses where water, temperature extremes, and sunlight will rapidly degrade some minerals. The degree of compaction should always be examined in any stone selection.

2.0 COLOR AND VEINING

2.1 The color, veining, clouds, mottlings, and shadings in serpentine are caused by minor inclusions during the formation or some prior degradation or weathering of the stone to release staining color. Iron oxides make the pinks, yellows, browns, and reds. Most grays, blue grays, and blacks are of bituminous origin.

Greens are caused by micas, chlorites, and silicates.

3.0 TEXTURE

3.1 The term "texture," as applied to serpentine, means size, degree of uniformity, and arrangement of constituent minerals. Grains of calcite and other carbonates, the chief accessory mineral of most serpentines, are crystalline and have definite rhombohedral cleavage which shows bright, reflecting faces on a broken surface. In most serpentines, however, the grains are elongated in one direction by the plication (folding) of the beds.

4.0 FINISHES

4.1 Serpentine's surface may be finished in a number of ways. In general, smooth finishes tend to emphasize color and veining, whereas rough finishes tend to subdue the veining or markings.

4.2 Typical Finishes for Serpentine Are:

4.2.1 Polished: A glossy surface that brings out the full color and character of the serpentine. It is not generally recommended for exterior use or commercial floors.

4.2.2 Honed: A satin-smooth surface with little or no gloss, recommended for commercial floors.

5.0 THICKNESS

5.1 Standard nominal thicknesses for serpentine veneer are ¾", 7/8", 1¼", 1½", and 2". When a serpentine thinner than ¾" is specified, the ratio between thickness and overall size and the use of reinforcing backup materials must be considered. Serpentine thicker than 2" is usually regarded as cubic stock.

6.0 SIZES

6.1 Serpentine is a product of nature with hundreds of varieties available, each possessing distinct 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 serpentine. Check with the Stone Supplier as to the sizes that are available for the specific serpentine.

6.2 Selection and delivery can be greatly facilitated by a jointing scheme which permits the use of smaller sizes. A final jointing scheme should be agreed upon after the serpentine has been selected and the Serpentine Contractor has been consulted.

7.0 PRODUCT SAMPLING

7.1 Serpentine is formed by nature; thus, there are variations in the tonal qualities of the stones. However, it is these natural variations that make serpentines unique, valuable, and highly desirable. Because of these variations, selection of serpentine 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 complete range of colors of the desired stone.

8.0 PROPER USAGE TIPS

Recommendation for commercial floors:

1) Minimum ¾" thickness.
2) A honed finish.
3) A minimum hardness value of 10 as measured by ASTM C241.

Avoid the use of gypsum or molding plaster setting spots for the installation of exterior stone.

9.0 VENEER CUTTING

9.1 Quarry blocks are reduced to slabs by a gang saw. The gang saw consists of a series of steel blades set parallel in a frame that moves forward and backward. The most productive and precision gang saws have diamond-tipped blades with individual hydraulic blade tensioners.

9.2 Serpentine blocks can be sawn either perpendicular or parallel to the bedding plane. The perpendicular cut is referred to as an across-the-bed or vein cut. The parallel cut is with-the-bed or fleuri cut. Some serpentines produce a pleasing surface when sawed in either direction, and are available as either vein or fleuri. Other serpentines produce a pleasing surface only when sawed in one direction, and are generally available only in that variety.

TECHNICAL DATA - Serpentine

1.0 PROPERTIES OF SERPENTINE 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.
In present-day construction, however, this is far from being true. Performance requirements are daily becoming 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.

1.2 Serpentine is a product of nature and not always subject to the rules of consistent behavior that may apply to manufactured building materials. It may not be proper for certain applications.

1.3 Physical property values of serpentine may, however, be measured using the standard test methods approved by the Dimension Stone Committee C 18 of ASTM International. The values found when stone is tested for absorption, density, compressive strength, abrasion resistance, and flexural strength should be useful for the Designer and Engineer when preliminary construction calculations are being made. However, these tests should be made before the project specifications are written, not after. Member companies of the Marble Institute of America are represented on this committee and are active in its technical work of establishing proper test methods and specifications consistent with the latest technology.

1.4 Physical Properties of Serpentine
(This historical data and information is provided only as a guideline. Recommended minimums or maximums are established and provided by ASTM International.)*

Property	**Range of Values**
Compressive Strength (C170) lbs/in²	9,000 27,000
Recommended (min): 10,000	
Flexural Strength (C880) lbs/in²	900-5,000
Recommended (min): 1,000	
Modulus of Elasticity** (in millions) lbs/in²	2.0-15.0
Density, lb/ft³ (C97)	155-180
Recommended (min): 168	
Modulus of Rupture (C99) lbs/in².	500-2,500
Recommended (min): 1,000	
Absorption, by weight % (C97).	0.09-1.2
Recommended (max): 0.20 exterior, 0.60 interior	
Abrasion Resistance (H_a) (C241)	25-110
Recommended (min): 10	

* Test methods described in current ASTM standards.
** Also known as Young's Modulus.

2.0 STRENGTH (ASTM C170, ASTM C880)

2.1 The strength of a serpentine is a measure of its ability to resist stresses. This strength depends on several factors: the rift and cleavage of the crystals, the degree of cohesion, the interlocking of the crystals, and the nature of any cementing materials present.

3.0 FIRE RESISTANCE

3.1 Serpentine is not combustible according to underwriters' ratings, and so is considered a fire-resistant material. Because of its thermal conductivity, however, the heat transfer through serpentine is fairly rapid. Serpentine 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. Pilot plant tests at The Ohio State University Pyrotechnics Laboratory indicate that a 10 minute rating could be expected from 7/8"-thick serpentine.

3.3 The use of an insulating material with serpentine substantially improves the fire rating, as shown in the following:

7/8" serpentine with 1" core of:
Paper Honeycomb……½ hour
Cement-Bonded Wood Excelsior……1 hour
Autoclaved Cellular Concrete……1½ hour

3.4 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 serpentine varieties make them extremely desirable and economically practical for floors and stairs. Varieties with an ASTM C241 abrasive hardness rating (H_a) of 10 or more are recommended for use as flooring. A minimum abrasive hardness of 12.0 is recommended for commercial floors, stair treads, and platforms subject to heavy foot traffic. Surfaces of floors constructed with two or more varieties, with H_a differences more than 5, will not wear evenly and uniformly.

5.0 FACTORS AFFECTING PHYSICAL 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 serpentine meets this test as few other building materials can.

5.2 Illinois Institute of Technology Research Institute's studies have shown that the durability of serpentine is little affected by cycles of weather. This is because of serpentine's low rate of absorption. The rates of moisture absorption of all the serpentines studied were less than 1 percent by weight. Other masonry materials range upward from 4 to 12 percent.

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 Within the accepted limits of safe design practice, the closer the allowable load is to the ultimate failure load in a structure, the more efficient is the use of the material and the less the cost of the construction.

6.3 Contemporary design of buildings, exclusive of the monumental type, does not usually employ serpentine 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 load, and a safety factor of 5.0 is recommended. Where the serpentine 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.

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.

6.5 To determine the thickness and size of panel required:

6.5.1 Determine the design and wind load.

6.5.2 Obtain the flexural strength of the serpentine under consideration using the ASTM C880 test method. This information may be available from the Serpentine Supplier.

6.5.3 Select the unsupported span for each thickness for which the stress is below the flexural strength of the serpentine from the appropriate table.

6.6 This span for each thickness is the maximum for panels that are supported on two sides only.

6.7 If the panel is supported on all four sides and the long side of the panel exceeds twice the short side, use the short span from the table.

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.

7.2 Additional Readings:

7.2.1 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.

7.2.2 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 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 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 Serpentine is not 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 Research indicates that staining or discoloration occurring on new buildings is caused by the action of water percolating through cement from which soluble alkali salts are leached. The salts are then carried by the water through the serpentine, 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 the water evaporates.

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 the back.

8.7 Stains sometimes appear on the base course when serpentine is in contact with soil, or on interior and exterior horizontal surfaces, 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 and most of the veining in serpentine contain soluble salts. Therefore, this staining phenomenon is similar to the discoloration described previously, and will disappear when the source of moisture is eliminated. However, materials from the veining may remain on the stone's surface. In walls, provide venting so that moisture can escape through the vents rather than through the stone. On horizontal surfaces, the use of a vapor barrier between the setting bed and the concrete slab, or between the setting bed and the ground, is recommended.

Additional Resources: Refer to Veneer Cutting and Veneer Patterns drawings at the close of Chapter 7 (Marble and Onyx).