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DIRECT ADHERED EXTERIOR MARBLE CLADDING

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There are a wide variety of marbles used in building construction, both natural and synthetic, which are suitable as direct adhered cladding materials for exterior walls. However, determining suitability of marble as a direct adhered external cladding requires more careful analysis than manufactured materials like ceramic tile or thin brick because it is a heterogeneous natural material, and even different pieces of the same type of stone will exhibit varying properties.

The most important physical characteristic in assessing suitability of marble for cladding, aside from aesthetic characteristics of color and texture, is the porosity of marble. Porosity, also known as the material's water absorption, is one of the key physical characteristics which determines the durability and suitability of marble as a direct adhered external cladding material. The effects of moisture on direct adhered marble are varied. Moisture absorbed in a marble may be heated by solar radiation or frozen by cold temperatures and exert pressure in excess of the stone tensile strength (water increases 9% in volume when frozen !). Moisture will act also as a vehicle for transport of salts and contamination from other surfaces, from pollutants, or from weathering of the stone. Moisture absorption can also affect the dimensional stability of some marbles.

Moisture sensitivity of stones

Modern stone fabrication technology now allows production of marble tiles a thin as 1/4-1/2 inch / 6-10 mm. While this technology has made exterior direct adhered natural marble walls technically feasible and affordable, it presents problems of moisture permeability and sensitivity that previously, were of little concern with traditional thick (2-4 inches / 50-100 mm) stable slabs of marble. Known by the term "hysteresis", thin stones (primarily marbles) can bow or warp from crystal growth as a result of differential temperature or moisture change through its thickness.

Some stones, especially dark and highly colored marbles, contain minerals such as serpentine which are reactive with water; that means that crystal growth occurs when exposed to water, and the volume of stone literally expands. This results in two problems that may occur if thin, moisture sensitive stones are installed on facades

using the direct adhered method:

Progress of installation - if water based cement or latex cement adhesive mortars are used, the side in contact with the adhesive will expand, and the outer surface will remain dry, resulting differential movement with enough pressure to cause a thin marble to warp or distort from a flat plane. A thick section of marble would not be affected because the high ratio of unaffected or dry cross section to wet setting surface would not generate enough expansive force to overcome the resistance of the mass of stone.

The solution to this problem has been to either use accelerated latex cement adhesive mortars which mechanically lock the surface of the marble before distortion by the expansive forces begin, or in highly sensitive stones, to use 100% chemically reactive epoxy adhesives which contain no water. However, these types of adhesives, and the labor techniques required for exterior use, are typically more costly.

Post Installation - Even if moisture sensitive marble is installed successfully on an exterior wall, the marble may still be subject to cracking and spalling or adhesive bond failure from excessive volume expansion after exposure to constant humidity or repeated cycles of rain.

Cladding temperature & color

A dark colored marble tile can become extremely hot from absorption of solar radiation. Color selection of a cladding material requires special consideration for expansion and contraction, as well as differential movement between the cooler underlying substrate. Dark colored marble can easily reach a temperature of 170-190^{o} F / 80-90 o C within 3-4 hours exposure to sun in hot, arid desert climates. When the sun sets, the ambient air temperature can drop to 60-70^{o} F / 15-20^{o}C in 1-2 hours, resulting in a temperature drop of about 90^{o}F / 50^{o}C in the cladding material n 2 hours. A dark marble, with an average coefficient of linear expansion of 7.3 x 10 $^{-6}$ inch / ^{o} F could expand and contract up to 7/8 inch / 20 mm over a distance of 100 feet / 30 m in as little as 2 hours !! This is not only a graphic example on the importance of movement joints, but also the importance of using a flexible, low modulus adhesive that can accommodate differential thermal movement between the marble cladding and the substrate.

Rupture or breaking strength of marble is also an important characteristic for use in direct adhered exterior walls to resist reflection of thermal or moisture (shrinkage) movement in the underlying wall assembly and structure.

In order to select the most suitable type of marble for an application, or to understand the technical requirements for adhesive installation of a particular marble, the logical sequence of consideration is to first have a general understanding of the classifications and physical properties of marble.

Marble - geologic & commercial classification

Marble is geologically classified as a metamorphic stone with a primary mineral composition of calcite and dolomite. Geologically, marble is actually a limestone that has been re-crystallized by heat, pressure, and intrusion of other minerals (thus the term "metamorphic"). The term "marble" is a commercial category of natural stone. Geologically, marble is a metamorphic limestone of sufficient hardness capable of taking a polish.

Commercially, there are over 8000 varieties of marble, based on mineral content, color and geographic origin. According to American Society for Testing and Materials standard ASTM C 503, there are four classifications of marble building stone for exterior cladding:

Marble classification

- Class I - Calcite
- Class II - Dolomite
- Class III - Serpentine
- Class IV - Travertine

The percentage of magnesium carbonate in marble generally determines its strength, color, texture and variety. Calcite marbles have < 5 % of magnesium carbonate, and dolomite marbles have > 40 % magnesium carbonate. Travertine is geologically a limestone, and serpentine is geologically an igneous stone, both capable of taking a polish, and therefore commercially classified as a marble.

Stone industry organizations such as the Marble Institute of America further classify marble according to fabrication, handling and working qualities according to the following categories:

Marble - fabrication & working quality Classification

- *Group A* - sound stone with uniform characteristics and favorable working qualities
- *Group B* - stone similar to group A; may have some natural faults
- *Group C* - stone with variations in working qualities, containing geological flaws, voids and veins.
- *Group D* - contains many of the most highly colored, veined, and decorative marbles with substantial natural cleavage faults.

While fabrication classifications are not necessarily an indication of the physical properties or durability of stone, it is generally recommended that only Group A marble is suitable for use as external cladding, especially due to the thinner sections typical to the direct adhered method of installation. However, one of the advantages of the direct adhesion of marble is that the entire surface of the stone is adhered, which allows marbles that may normally be structurally too fragile for mechanical anchorage to be considered for direct adhesion, as long as the marble can be fabricated and handled safely prior to adhesive installation, and that the marble can be proven to have weathering durability to prevent spalling or exfoliation even if fully adhered.