

BY DAREN KNEEZEL

Wiss, Janney, Elstner Associates, Inc.

Given sufficient time and certain exposure conditions, any stone is vulnerable to some degree of deterioration when exposed to environmental weathering.

Evaluating Stone Durability

Stone, in general, is considered a durable material; however, not all stones are as durable as one might anticipate.

Stone durability is dependent on its composition, which can affect strength and appearance, and environmental exposure factors. Even though a particular stone may be thought of as uniform, it is still a natural material with varying composition and physical properties. These properties can vary significantly, even for stone removed from slightly different areas of a single quarry or formation. Small variations in some stone types can result in significant differences in durability performance in service.

Stone durability is greatly influenced by its use and exposure. A stone that performs well in one application or geographic location will not necessarily perform well in all applications and locations. Factors that contribute to accelerated deterioration of stone include exposure to moisture, freeze/thaw cycles, temperature extremes, rain acidity, and crystallization of salts. While all of these factors are influenced by project location and

local climate, several of these factors are further influenced by application or location on the building. For instance, horizontal applications such as paving or coping units that are exposed to standing water or snow/ice are typically considered more severe exposures than vertical applications. Severe exposures that are influenced by location on the building include panels near grade that are exposed to deicing salts; locations with greater frequency of freezing and thawing, such as southern exposures where surface temperatures are significantly greater during the day than at night; and locations that are not moderated by the interior building temperature such as parapet walls. The color and thickness of the stone may, in certain situations, affect its durability, as a dark colored stone will experience greater temperature extremes than light colored stone, and a thin stone will not moderate temperature extremes through its thickness as much as a thicker stone. See Figures 1–2.

Location:

Northbrook Main Office
330 Pfingsten Road
Northbrook, IL 60062

Contact:

T: 847.272.7400
E: dkneezel@wje.com

www.wje.com

WJE ENGINEERS
ARCHITECTS
MATERIALS SCIENTISTS

Wiss, Janney, Elstner Associates, Inc.



FIGURE 1
Examples of deterioration that are influenced by location on a building. Marble deterioration at the base of a building due to deicing salts.



FIGURE 2
Typical freeze/thaw damage to a travertine coping stone.

Evaluating Stone Durability (CONTINUED)

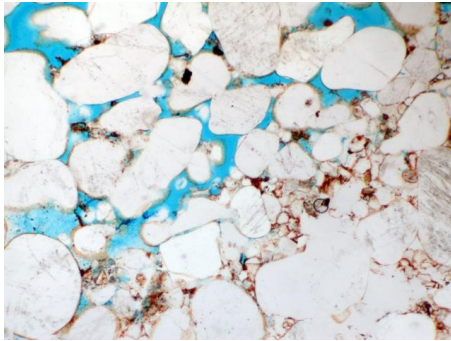


FIGURE 3
Thin-section view of stone with adjacent porous (upper left; void space filled with blue epoxy) and non-porous (lower right) layers. Variable absorption presents a potential concern under cyclic freezing and thawing.



FIGURE 4
Effusive igneous rock formation showing several layers from which material is being quarried.

Given sufficient time and certain exposure conditions, any stone is vulnerable to some degree of deterioration when exposed to environmental weathering. Test methods and evaluations that provide a better understanding of the potential for poor in-service durability are a critical part of the stone selection process. The following is a systematic approach for evaluating a stone type for durability. Each task provides a progressively rigorous review; however, if one of the first tasks indicates a marginal or poor quality stone, it is likely time/cost effective to consider an alternative stone.

Task 1 – Project Review

Where a stone has an established history of use (20-plus years) in an environment and application similar to that being considered, the long-term durability of the stone is most accurately assessed by previous performance of the stone in similar applications. The applicability of this evaluation (and testing summarized below) depends on whether the material is representative of the range of material to be provided.

Task 2 – Petrographic Evaluation

Petrographic evaluation is a qualitative review of stone features or constituents that may affect stone strength and durability. Petrographic evaluation of representative specimens provides detailed information on the stone mineralogy and structure of the stone for identification of minerals that may cause spalling, staining, or other serviceability issues (e.g., iron inclusions or poor weathering minerals such as clay). Petrographic evaluation can also identify mineral sizes, grain structure,

susceptibility to cleaving, orientation of bedding/foliation/rift, or other variations in the stone fabric that may contribute to strength variations, bowing, or low durability. It can also be used to help determine the cause of distress in an existing application. Petrographic evaluation is typically performed in accordance with the pertinent sections of ASTM C1721, *Standard Guide for Petrographic Examination of Dimension Stone*. See Figure 3.

Task 3 – Quarry Evaluation

Petrographic evaluation of a quarry is performed to provide a broad overview of the uniformity of the exposed stone or blocks within the quarry and presence of visible features or textures that may cause serviceability issues for use in establishing quality control measures or determination of where material is to be removed. Quarry evaluation can also help to ensure that test specimens are representative of project material. See Figure 4.

Task 4 – Physical/Mechanical Testing

Physical/mechanical properties of dimension stone are typically assessed through testing in accordance with the following ASTM procedures: absorption and specific gravity (C97), modulus of rupture (C99), compressive strength (C170), and flexural strength (C880) testing. Testing may also include abrasion resistance (C1353) testing if the stone is to be used in a flooring or paving application.

ASTM publishes material specifications for granite, limestone, marble, sandstone, serpentine, slate, and travertine. Minimum values listed in these specifications are

Evaluating Stone Durability (CONTINUED)

based on stone that has traditionally performed well in service for general building and structural purposes. Stone with absorption and density values that meet ASTM requirements are typically considered to have properties that are consistent with and compare favorably to other stones of that type that have been shown to perform satisfactorily in weathering environments. However, this testing is not comprehensive, as the composition and void structure of the stone are not assessed through this testing; factors that can significantly affect durability. Because of this, simulated weathering testing or other durability testing is more predictive of weathering durability.

Task 5 – Durability Testing

Durability testing is particularly useful for a stone with unknown or limited performance history, or for stone that does not meet the minimum specified physical properties for that stone type, to reduce the risk of using a poor durability stone on a project. These tests are greater cost and longer duration than the standard physical/mechanical tests but provide the most accurate durability assessment of a stone with limited historical precedent in severe weathering applications. While durability tests may not be of great value on a new project when using a stone that has an established history of use in the environment similar to that being considered, they may be appropriate for large or high-profile projects in which testing represents a small percentage of the total project cost regardless of the stone type. See Figures 5–8.



FIGURE 5
Varying degrees of deterioration exhibited by specimens after accelerated weathering exposure. Heavily deteriorated and cracked marble specimen.



FIGURE 6
Surface spalling of sandstone specimen.

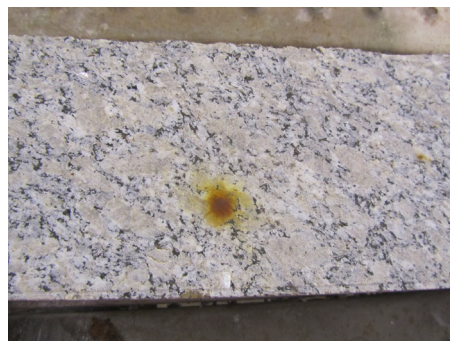


FIGURE 7
Stain spot in granite specimen.



FIGURE 8
More advanced surface spalling of limestone specimen.

Simulated weathering testing that is most often performed is used to evaluate the effect of temperature extremes and freeze/thaw cycles in the presence of moisture on stone durability. For some stone types, durability can be assessed to a certain degree using procedures for evaluating concrete durability outlined in ASTM C666, *Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing*.

However, the temperature range in this test (0 to 40 degrees Fahrenheit) does not represent service temperature ranges known to affect some stone types (particularly marble) or the potential effects of acid rain (particularly for marble and limestone).

While there is no ASTM test method for simulated weathering of dimension stone,

Evaluating Stone Durability (CONTINUED)

an “accelerated weathering” test method has been used to evaluate durability of stone proposed for use in severe weathering environments for more than thirty years and employs procedures similar to those outlined in ASTM C666. This testing involves cyclical exposure of stone specimens to extreme temperatures (typically -10 to 170 degrees Fahrenheit) while they are partially immersed in water or a 4pH acid solution to simulate acid rain exposure. The flexural strength of specimens tested after exposure to 100 (or in some cases 300) temperature cycles is compared to the strength of specimens not exposed. Dynamic modulus of elasticity testing is also often performed to nondestructively evaluate rate of deterioration at periodic intervals in accordance with ASTM C215, *Test Method for Fundamental Transverse, Longitudinal, and Torsional Frequencies of Concrete Specimens*.

Other durability tests include salt crystallization to evaluate resistance of a stone to crystallization of salts within its pore structure (EN 12370 - Determination of resistance to salt crystallization) and bow testing to evaluate the potential for marble bowing (EN 16306 - Determination of resistance of marble to thermal and moisture cycles).

Summary

A poor durability stone can result in diminished building appearance, may require supplemental repairs to address deterioration, or in extreme cases may require replacement of panels or entire facades. While durability assessment of stone may seem like an unnecessary expense during the stone selection process, identification of poorly performing stone or features within a stone early in a project can result in significant savings down the road.

www.wje.com

WJE | ENGINEERS
ARCHITECTS
MATERIALS SCIENTISTS
Wiss, Janney, Elstner Associates, Inc.

Location:
Northbrook Main Office
330 Pfingsten Road
Northbrook, IL 60062

Contact:
T: 847.272.7400
E: dkneezel@wje.com
W: www.wje.com