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Standard Guide for Selection and Use of Stone Consolidants¹

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1. Scope

1.1 This guide covers procedures for the selection and use of consolidants for preservation of stone.

1.2 When considering the use of stone consolidants, guidance from specialists experienced in stone conservation should be sought. Where work on features of artistic, architectural, cultural or historical importance is being considered, guidance from specialists in these fields should be sought. Historic preservation guidelines should be considered in planning the work.

1.3 This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this guide may be applicable in all circumstances. This ASTM guide is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects.

1.4 Limited description of tests are provided for informational purposes only. See the referenced standard for complete description.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user to consult appropriate safety and health practices and determine the applicability of regulatory limitation prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

C 88 Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate²

C 97 Test Method for Water Absorption and Bulk Specific Gravity of Natural Building Stone³

C 99 Test Method for Modulus of Rupture of Natural Building Stone³

C 170 Test Method for Compressive Strength of Natural Building Stone³

C 295 Petrographic Examination of Aggregates for Concrete²

C 418 Test Method for Abrasion Resistance of Concrete by Sandblasting²

C 779 Test Method for Abrasion Resistance of Horizontal Concrete Surfaces²

C 880 Test Method for Flexural Strength of Natural Building Stone³

C 1352 Test Method for Flexural Modules of Elasticity of Dimension Stone³

C 1353 Test Method Using the Tabor Abrasor for Abrasion Resistance of Dimension Stone Subjected to Foot Traffic³

D 2244 Test Method for Calculation of Color Differences from Instrumentally Measured Color Coordinates⁴

D 3960 Practice for Determining Volatile Organic Compound (VOC) Content of Paints and Related Coatings⁴

E 96 Test Method for Water Vapor Transmission of Materials⁵

E 179 Guide for Selection of Geometric Conditions for Measurement of Reflection and Transmission Properties of Materials⁴

E 284 Definitions of Terms Relating to Appearance of Materials⁴

E 632 Recommended Practice for Developing Short-Term Accelerated Tests for Prediction of the Service Life of Building Components and Materials⁶

G 26 Practice for Operating Light Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Non-Metallic Materials⁶

G 53 Practice for Operating Light—and Water—Exposure Apparatus (Fluorescent UV-Condensation Type) for Exposure of Non-Metallic Materials⁶

2.2 Other Documents:

The Secretary of the Interior's Standards for the Treatment of Historic Properties with Guidelines for Preserving, Rehabilitating, Restoring and Reconstructing Historic Buildings⁷

UNESCO, 1978 International Charter for the Conservation

¹ This guide is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.24 on Building Preservation and Rehabilitation Technology.

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² Annual Book of ASTM Standards, Vol 04.02.

³ Annual Book of ASTM Standards, Vol 04.07.

⁴ Annual Book of ASTM Standards, Vol 06.01.

⁵ Annual Book of ASTM Standards, Vol 04.06.

⁶ Annual Book of ASTM Standards, Vol 14.04.

and Restoration of Monuments and Sites (Venice Charter). 1964, 1986⁸

AIC. 1979, Code of Ethics and Standards of Practice. 1976, Revised 1994⁹

RILEM. Test No. 11.4, Water absorption under low pressure (pipe method), RILEM Commission 25-PEM, Tentative Recommendations, 1980¹⁰

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 *consolidant*—a consolidant is a material applied to stone to re-establish the bond between particles that may have been lost through weathering or other decay mechanisms. The consolidant treatment aims to reduce the rate of decay of stone.

3.1.2 *specialist*—architect, conservator, engineer or other professional with experience in the selection and use of stone consolidants, hereinafter referred to as the stone conservation specialist.

4. Significance and Use

4.1 This guide provides information on methods that can assist the design and conservation professional in the selection and use of consolidants for stone.

4.2 Use of a consolidant should be considered only after developing a thorough understanding of all factors contributing to the deterioration of the stone. Such an understanding is best reached through a comprehensive survey of existing conditions, environment, and a definition of stone performance requirements, followed by laboratory analysis of the stone and its deterioration products. With this information it should be possible to identify the decay mechanisms and to develop a conservation plan for the stone. However, careful preliminary investigation may indicate that consolidation is an inappropriate treatment.

4.3 *Decay Mechanisms*—A discussion of decay mechanisms is beyond the scope of this document; however, an understanding of decay mechanisms is critical to the evaluation and selection of appropriate treatment methods for stone including chemical consolidation. See Bibliography, for references.

4.4 Stone consolidation should only be done as part of an overall conservation plan. Consolidating stone without resolving underlying problems contributing to its deterioration (such as rising damp or improper drainage) can cause the consolidation treatment to fail completely or to accelerate the rate of deterioration of the stone. The condition of the stone should be documented before and after treatment.

4.5 Past experience has shown that application of some consolidants may contribute to deterioration or create unanticipated problems. In some cases, it may not be appropriate to use a stone consolidant at all. Consolidation should be considered

only after unsuccessful attempts to remove or modify degradation sources have been carried out.

4.6 Consideration should be given to the fact that consolidation of porous stone is an irreversible process. Consolidants that allow future retreatment should be selected if possible. For example, treatment of stone, particularly porous stone, with hydrophobic materials may not allow future retreatment with water-based consolidants.

4.7 No consolidant should be used that prevents or significantly retards water vapor migration through the stone.

5. Methodology

5.1 This document is organized into sections covering each step of the consolidant selection process.

5.1.1 Identification of Stone Consolidants Performance Goals.

5.1.2 Identification of Consolidant Selection Considerations.

5.1.3 Analysis and comparison of the properties of treated and untreated stone samples.

5.1.4 Preparation and evaluation of in-situ test panels.

5.1.5 Final evaluation of consolidant performance.

6. Performance Goals for Stone Consolidants

6.1 Prior to selection of a consolidant, it is necessary to define the required physical properties (performance criteria) of the consolidated stone under the environmental conditions in which it will be exposed. The following is a list of properties that have been found to be important under a variety of exposure conditions, however, not all properties are germane to each specific application. It will be necessary for the stone conservation specialist to select those properties that are applicable and need to be considered for the specific application at hand.

6.1.1 *Depth of Penetration*—The consolidant should penetrate at least through the weathered layers of stone and into sound stone. Experience indicates the greater the depth of penetration, the more likely is the success of the treatment. Bonding of the consolidated damaged layers to the sound, interior stone will minimize delamination or flaking of the treated layer.

6.1.2 *Consolidating Ability*—The treatment should improve the mechanical properties of the stone, such as compressive or flexural strength, abrasion resistance and erosion resistance.

6.1.3 *Water Vapor Permeability*—The treatment should not appreciably affect the water vapor transmission rate of the stone.

6.1.4 *Resistance to Internal Expansive Forces*—The treatment should increase the resistance of the stone to deterioration by salt crystallization or freeze/thaw effects.

6.1.5 *Thermal Expansion Characteristics*—The treated stone should have a coefficient of thermal expansion not significantly different from that of the untreated stone.

6.1.6 *Appearance*—Ideally, the consolidant should produce only minor changes in the appearance of the stone, specifically, changes in texture, hue, value, chroma, lightness, gloss, or reflectivity.

⁷ U.S. Department of the Interior, National Park Service, Preservation Assistance Division, revised 1995, Washington, D.C..

⁸ UNESCO, 7, place de Fontenoy, 75352 Paris 07 SP, France.

⁹ American Institute for Conservation of Historic and Artistic Works, 1717 K Street, NW, Suite 301, Washington, D.C. 20006.

¹⁰ RILEM, Bâtiment Cournot, 61 avenue du Président Wilson, F-94235 Cachan Cedex, France.

6.1.7 The treated stone should not be more susceptible to attracting and absorbing airborne particles, gases, and soil than the untreated stone.

6.1.8 *Durability*—The consolidated stone should retain its improved properties for an extended time period.

6.1.9 *Water Resistance*—Treatment of the stone should improve its resistance to water dissolution and water erosion. The treated weathered stone should be more resistant to erosion than the untreated stone.

6.1.10 *Biodegradation*—The consolidant should not provide nutrients that support the growth of degradative types of microflora, bacteria and higher plants.

7. Consolidant Selection Considerations

7.1 *Objective of Consolidation Treatment:*

7.1.1 The objective of the consolidation treatment must be defined. Typically, the purpose of consolidation treatment is to reestablish bonds between particles that have been lost or weakened through weathering, microcracking or other decay mechanisms. The treatment should increase the service life of the stone without causing adverse effects.

7.2 *Historic Preservation Guidelines:*

7.2.1 The treatment must be in accordance with applicable building and safety codes and historic preservation guidelines as accepted by the preservation community. See 2.2 for references.

7.2.2 For structures that may possess artistic, architectural, cultural or historical significance, consideration should be given to writing a Historic Structure Report prior to finalizing a consolidation treatment.

7.3 *Stone Characteristics*—The following characteristics of the stone should be evaluated: Type, chemical composition, mineralogical composition, structure and texture, pore structure, pore size distribution and condition.

7.4 *Past Performance History*—The past performance of the consolidant(s) on the particular type of stone should be considered. The effectiveness of the treatment may be strongly influenced by the method of application and conditions during cure.

7.5 *Consolidant Application Method*—In selecting a consolidant, the feasibility of the recommended application method for the particular stone or structure, the skill of the applicators and the size of the area to be consolidated, should be considered. Application methods include brush, misting, or spray; liquid flooding of surface; capillary rise impregnation; and pressurized infiltration.

7.6 *Environmental Protection Considerations*—Efforts should be made to use consolidants and solvents that do not release hazardous pollutants. Volatile Organic Compounds (VOC) content of the consolidant should have been determined by the manufacturer in accordance with Practice D 3960. Application of consolidants must comply with all current applicable environmental regulations. Such regulations are subject to change; it is the responsibility of the user to be aware of any changes to applicable standards.

8. Analysis of Untreated Stone

8.1 Untreated deteriorated stone samples should be analyzed to determine the degradation mode and causes of deterioration, and necessity for a consolidation treatment.

8.1.1 No consolidant should be used that prevents or significantly retards vapor migration from the building interior to the exterior since this could cause major disintegration of the stone.

8.2 The applicable tests should be selected and the results interpreted by the stone conservation specialist. Testing should be performed on representative samples of deteriorated and sound stone. ASTM test procedures may be modified by the stone conservation specialist as appropriate for historic materials.

8.2.1 *Petrographic Examination*—The mineralogical composition, morphology, and geologic history, and their significance with respect to the stone's service history can be determined by petrographic and x-ray diffraction examinations. The examination should be conducted and interpreted by a scientist specializing in these areas in coordination with the stone conservation specialist. Refer to C 295 modified for use on stone.

8.2.2 *Water Absorption*—In accordance with Test Method C 97. These methods cover the tests for determining the water absorption and bulk specific gravity of all types of natural building stone, except slate. Test Method C 97 is a simple gravimetric determination of the mass increase of a stone sample following immersion in water for a twenty-four hour period. The method is widely accepted and can be used to determine the change in water absorption of stone after consolidation and, as a function of time, after accelerated aging. Treatment of stone with an hydrophobic consolidant will reduce the water absorption appreciably and the rate of loss of hydrophobicity can be followed as a function of aging by means of this procedure. Precision of this method has not been determined.

8.2.3 *Karsten Tube Capillary Absorption Test*—See 2.2. The Karsten tube is a pipe-like apparatus that has a flat, circular brim at right angles to the bottom of a graduated tube. The brim is attached to the vertical masonry surface with an adhesive putty. After the tube is attached to the wall, water is added through the upper open end of the pipe until the column of water reaches the 0 gradation mark. The quantity of water absorbed into the masonry surface is determined as a function of time.

8.2.4 *Soluble Salt Analysis*—Analyses are performed to determine the presence and identity of soluble salts such as sulfates, chlorides and nitrates in the stone. Typically, salts are extracted from crushed stone with water and analyzed for anions and cations by various standard microchemical or instrumental analytical techniques (atomic absorption, ion chromatography, etc.). Determination of the actual compounds present can be done by x-ray diffraction, refractive index, and polarized light microscopy, etc. The presence of salt can preclude the use of certain consolidants. If salt is found and the stone has sufficient strength to withstand mechanical treatment, surface salt efflorescence is brushed away. Removal of deeper salt deposits is performed by poultice treatment for no