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Standard Guide for Selection and Use of Stone Consolidants[1]

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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 Sulfate[2]

C 97 Test Method for Water Absorption and Bulk Specific Gravity of Natural Building Stone[3]

C 99 Test Method for Modulus of Rupture of Natural Building Stone[3]

C 170 Test Method for Compressive Strength of Natural Building Stone[3]

C 295 Petrographic Examination of Aggregates for Concrete[2]

C 418 Test Method for Abrasion Resistance of Concrete by Sandblasting[2]

C 779 Test Method for Abrasion Resistance of Horizontal Concrete Surfaces[2]

C 880 Test Method for Flexural Strength of Natural Building Stone[3]

C 1352 Test Method for Flexural Modules of Elasticity of Dimension Stone[3]

C 1353 Test Method Using the Tabor Abrasor for Abrasion Resistance of Dimension Stone Subjected to Foot Traffic[3]

D 2244 Test Method for Calculation of Color Differences from Instrumentally Measured Color Coordinates[4]

D 3960 Practice for Determining Volatile Organic Compound (VOC) Content of Paints and Related Coatings[4]

E 96 Test Method for Water Vapor Transmission of Materials[5]

E 179 Guide for Selection of Geometric Conditions for Measurement of Reflection and Transmission Properties of Materials[4]

E 284 Definitions of Terms Relating to Appearance of Materials[4]

E 632 Recommended Practice for Developing Short-Term Accelerated Tests for Prediction of the Service Life of Building Components and Materials[6]

G 26 Practice for Operating Light Exposure Apparatus (Xenon–Arc Type) With and Without Water for Exposure of Non-Metallic Materials[6]

G 53 Practice for Operating Light—and Water—Exposure Apparatus (Fluorescent UV-Condensation Type) for Exposure of Non-Metallic Materials[6]

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 Buildings[7]

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.

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and Restoration of Monuments and Sites (Venice Charter). 1964, 1986[8]

AIC. 1979, Code of Ethics and Standards of Practice. 1976, Revised 1994[9]

RILEM. Test No. 11.4, Water absorption under low pressure (pipe method), RILEM Commission 25-PEM, Tentative Recommendations, 1980[10]

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 President 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 or, for low porosity stone, by water washing or other methods. If stone is weak and cannot withstand mechanical treatments, preconsolidation with an appropriate consolidant should be carried out followed by one of the aqueous salt removal methods. In all cases, the source of salt contamination should be identified and preventive measures taken to eliminate the possibility of future recontamination following consolidation.

9. Analysis and Comparison of Treated and Untreated Stone Samples

9.1 Once the necessity for consolidation has been established, both treated and untreated stone samples must be analyzed using identical test methods to evaluate the relative performance of consolidants and determine whether or not its use on a stone structure is recommended. Care must be taken to insure that the method of application of the treatment to the samples can be replicated when used on the structure.

9.2 The following tests may be performed as part of the analysis. The appropriate tests should be selected by the stone conservation specialist. Tests may be modified to reflect the number and size of available samples if deemed appropriate by the stone conservation specialist. Test results should be reported and compared for treated and untreated samples.

9.2.1 *Depth of Penetration*—Depth of penetration of the consolidant into the stone should be uniform and deep enough to reach undeteriorated stone because thin, incompletely consolidated surface crusts tend to delaminate. See Reference Kumar 1997 for a survey of methods for assessing penetration depth.

9.2.2 *Consolidant Loading*—The test measures the mass gain of the stone following treatment. The treated sample is allowed to cure until constant mass is achieved. Consolidant loading is expressed as a percentage of the total sample mass. Excessive consolidant loading will reduce stone porosity and water vapor transmission. The minimum loading required to achieve performance goals should be determined experimentally and should be used to predict coverage rate.

9.2.3 *Strength Properties*—Estimation of the improvement in the mechanical properties of stone following consolidation may be obtained from the results of a number of separate tests. These include measurement of compressive strength, flexural strength, modulus of rupture, and abrasion resistance. Each method provides information that can be related to specific performance requirements for consolidated stone.

9.2.3.1 *Compressive Strength*—Compressive strength measurements are important if the consolidated stone is required to perform a load-bearing function. Test Method C 170 covers the sampling, preparation of specimens, and determination of the compressive strength of natural building stone. In anisotropic materials, such as marble, the compressive strengths in three orthogonal directions are different, reflecting the existence of bedding planes, grain, and head grain in the material. The precision of this method has not been established.

9.2.3.2 *Flexural Strength and Modulus of Elasticity*—The flexural strength of consolidated stone is a measure of the ability of the consolidant to restore some degree of elastic deformability to the stone. Test Method C 880 is the preferred method because it uses quarter point loading on a long beam, which distributes the high flexural stress over a large area in the center of the beam. Other methods, such as C 99, use center point loading, which defines the failure location as the location the load is applied, rather than the weak point in the stone. The flexural modulus of elasticity is determined by Test Method C 1352.

NOTE 1—When testing using Test Method C 880 or C 1352, loading of five specimens each in the direction parallel to and perpendicular to the bedding plane of the stone should be done. The sample size in the standard should be used, if material is available. If not, any thickness stone can be used, and the span should be 10 times the thickness. If small samples are used, the consolidant should penetrate through the entire laboratory sample, rather than only the surface region, as will occur in the field. The treated and untreated samples can be tested for comparison but may not reflect field conditions where the consolidant will not penetrate through the entire stone thickness.

9.2.3.3 *Abrasion Resistance*—Consolidation is often performed to minimize abrasion or erosion loss of deteriorated stone surfaces. Test Method C 1353 describes a procedure for evaluation of the abrasion resistance of dimension stone. The method can be used also to evaluate the relative increase in abrasion resistance brought about by consolidation. Test Method C 418 covers determination of the abrasion resistance characteristics of concrete by subjecting it to air-driven silica sand. Blasting is applied for a fixed time and the hole volume is determined by filling the hole with modeling clay and determining the clay mass required. The method was designed for concrete and mortar but may be suitable for stone. A similar, non-ASTM method, has been described in the literature for use on consolidated plaster and involves an airbrasive blaster used by conservators. The hole volume in this case is determined by weighing the quantity of abrasive required to fill the hole or by direct mass loss (Phillips 1982).

9.2.4 *Water Absorption*—For test methods, see 8.2.2.

9.2.5 *Water Vapor Transmission*—The Water Vapor Transmission Rate (WVT) of the treated sample should not be reduced substantially by the consolidation. The impact of reduced wvt on a building assembly should be considered.

9.2.5.1 The test methods in E 96 cover the determination of water vapor transmission rate through various materials, including stone. The test methods are limited to specimens not over 1¼ in. (32 mm) in thickness except as provided in Test Method E 96. Two basic methods described in E 96, the Desiccant Method and the Water Method, can be used for the measurement of permeance, and two variations include service conditions with one side wetted and service conditions with low humidity on one side and high humidity on the other. In the Desiccant Method the test specimen is sealed to the open mouth of a test dish containing a desiccant, and the assembly placed in a temperature and humidity controlled atmosphere. Periodic weighings determine the rate of water vapor movement through the specimen into the desiccant. In the Water Method, the dish contains distilled water, and the weighings determine the rate of vapor movement through the specimen from the water to the controlled atmosphere. The vapor pressure difference is nominally the same in both methods except in the variation with extremes of humidity on opposite sides of the test specimen. These tests should be performed on untreated stone and only on uniformly consolidated stone samples. Agreement should not be expected between results obtained by different methods. The method selected should be the one that most reflects actual stone environmental conditions.

9.2.6 *Salt Crystallization Damage Resistance*—The resistance of treated and untreated samples to salt crystallization disintegration can be evaluated by alternate immersion of the stone in sodium sulfate solutions and oven drying. See Test Method C 88. The rate of mass loss resulting from sample degradation is a measure of resistance to salt crystallization damage. This test is not performed on samples treated with water-repellent type consolidants.

9.2.7 *Appearance Change*—The treated stone sample should be compared to an untreated sample to determine appearance change and/or surface gloss change created by the consolidation treatment. The comparison can be made visually using Munsell colorchips or by using an instrument that measures the CIE Lab coordinates. Treatment of stone with a consolidant often leads to a perceived change in appearance of the stone surface. Despite this, no standard procedure for measurement of appearance of stone has been developed. The changes that are usually observed following curing of the consolidant or evaporation of the solvent are darkening of the surface, and if excessive surface deposition occurs, an increase in specular reflectance or gloss. Acceptable consolidants should be water-white and the material itself should not impart a permanent color or hue change to the stone. It is conceivable, however, that stone contaminants might be soluble in the consolidant and contribute to a perceived color change. A change in appearance of the stone surface may occur during, or as a result of, aging. It has been noted in some cases that an initially yellowed appearance fades (owing to oxidation and loss of surface consolidant). In other instances, color development occurs, an effect resulting from oxidation of the consolidant to form chromophoric compounds. Because of the inherent non-uniformity of stone surfaces, the instrument used for appearance change measurements, either a spectrophotometer or a colorimeter, should be capable of viewing an area of the stone sample surface that is large enough to provide a statistically significant average of the surface features. To obtain an indication of uniformity, readings should be taken at several different locations on the stone surface. Instruments are available that can measure both specular-included and specular-excluded reflected radiation and these should be used where development of gloss is a factor for consideration.

9.2.7.1 Test Method D 2244 covers the calculation of small color differences from instrumentally measured color coordinates. It was designed to be used on data obtained for opaque, uniformly painted surfaces. Because natural stone surfaces are rarely uniformly colored, either before or after consolidation, the section on "Precision and Bias" is not applicable. Many of the modern color measurement instruments are computerized and are capable of performing calculations that provide both perceived color differences and changes in lightness or darkness of the sample. The method does not provide an operating procedure for appearance change measurements but it details the basis for the computations and refers the user to the instrument manufacturer's instructions.

9.2.7.2 Test Method E 179 is intended for use in selecting measurement scales and instrumentation for describing or evaluating such appearance characteristics as glossiness, opacity, lightness, transparency, and haziness in terms of reflected or transmitted light. This guide does not consider the spectral variations responsible for color, but the geometric variables described herein can affect instrumentally measured color values. This guide is general in scope rather than specific as to instrument or material.

9.2.7.3 Test Method E 284 defines the terms used in the description of the appearance of materials.

9.2.8 *Accelerated Weathering Tests*—Accelerated weathering tests are carried out on treated and untreated samples to determine the relative thermal, humidity and light stability properties of consolidated stone.

9.2.8.1 Standard Recommended Practice E 632 covers steps that should be followed in developing accelerated tests for predicting the service life of building components and materials. Results of the tests may be used for comparing the relative durabilities of treated and untreated building components and materials or for predicting their service lives. This practice covers a uniform approach to service life prediction, including the identification of needed information, the development of tests, the interpretation of data, and the reporting of results. Predictive service life tests can be divided into two types: short-term accelerated tests that use an "accelerated" aging test and short-term "in-service" tests that combine non-accelerated tests with tests capable of measuring minute changes in properties. This recommended practice emphasizes the development of improved accelerated aging tests to provide predictive service life tests.

9.2.8.2 Various types of accelerated aging tests can be carried out but typically only those conditions that apply to the service environment of the stone need to be tested.

Exposure to UV radiation, under conditions of controlled temperature and relative humidity
Wet-dry and thermal cycles
Freeze-thaw cycles
Salt crystallization cycles
Corrosion by acid or saline mist cycles

9.2.8.3 See Standard Practices E 632, G 26, G 53 and Feller, 1994 for information on conducting accelerated tests.

9.2.9 Treatment of stone specimens with consolidants often results in a change, usually a reduction, in the stone porosity and a change in the pore size distribution. In the former case, a significant porosity reduction can lead to entrapment of water and the subsequent buildup of internal freeze/thaw stresses. A pore size distribution change may be the result of selective filling of pores of differing diameters. The effects of these changes on durability to weathering vary with stone type, initial pore characteristics, and the stressful environment, and correlations are not always straightforward. A combination of mercury intrusion porosimetry with other techniques, such as SEM observations, surface area measurements, water absorption characteristics and sonic velocity data, can provide information on how the pore structure changes could affect weathering resistance. Reference Rossi-Doria 1985.

10. In-situ Test Panel

10.1 *Purpose of Test*—The purpose of the in situ test is to evaluate the performance of the selected consolidant or consolidants on a representative area of the stone structure before applying it to the entire area in need of treatment. When selecting an area for an in-situ test, use the smallest area that will give representative results and, whenever possible, select an inconspicuous area. The treated area should be allowed to weather for at least one year, before evaluating the performance of the consolidant. One or more consolidants can be tested, based on the results of the previous laboratory testing program. The stone specialist as well as the owner of the building, structure, or artifact should be aware that most of the treatments are irreversible, and that the treatments at the test areas cannot be removed.

10.2 *Selection of Test Area Locations*—The test area locations should be selected to represent the various environmental conditions to which the stone will be subjected. An area similar to the treated area should be left untreated (control). The conditions to be considered in selecting the test area include: Existing condition of the stone (surface deposition and deterioration, type of deterioration, progress of the deterioration), architectural features that will affect the performance of the stone (ledges, parapets, roofs), exposure to prevailing weather, and artistic and historic importance of the feature to be tested.

10.3 *Preparation of Test Areas*:

10.3.1 *Documentation*—The condition of the stone prior to treatment should be documented with photographs, including large format or stereo photographs, notes and/or sketches. Both the control area and the areas to be treated should be documented.

10.3.2 *Applications Procedures*—The procedures used on the test areas should be the same as the procedures that will be used on the entire structure. Federal, state and local regulations regarding safety and air pollution must be followed. The test area should receive the same treatments as those planned for the building. For example, if cleaning, patching and repointing are planned for the structure, they should be done on the test area as well.

10.3.3 *Treatment of Test Area*—Application of the consolidant should use the same material and techniques as planned for the entire structure. For example, if spray application is planned the consolidant should be sprayed on the test area. During application, record the amount of consolidant used, the temperature, the timing of application, and other relevant details. Areas adjacent to the test area may have to be protected from overspray or spilling. Depending on the particular consolidant chosen, the test area may have to be protected from rain or sun, during and after treatment.

10.4 *Evaluation of Test Areas*:

10.4.1 *Consolidant Consumption*—The amount of consolidant used per unit surface area of the stone is determined, first to estimate quantities necessary for treatment, and second, to check that similar quantities of consolidant are actually applied during treatment.

10.4.2 *In-situ Evaluation*—Evaluation is made immediately after the consolidant has cured and after one year of seasonal cycles, or at times prescribed by the specialist.

10.4.2.1 The treated and control test areas should be compared for any adverse effect on the appearance.

10.4.2.2 The amount of deterioration occurring on the treated and control areas should be compared to the condition of the stone prior to treatment, using the previously made sketches and photographic documentation.

10.4.3 *Laboratory Analysis*—Laboratory analysis is used to verify that the field performance is consistent with lab results. Samples of the control and treated areas can be removed for laboratory evaluation, if permitted. The tests may include: depth of penetration, water vapor transmission, petrographic and SEM examination, and water absorption (total and capillary).

11. Final Evaluation of Consolidant Performance

11.1 The selection of a consolidant to be used should be made by the specialist. The test area should be reviewed and the following questions answered:

Did the consolidant meet the performance goals identified in Section 6?
Were there any adverse effects on the structure during the in-situ test?
In the test areas, did the treated stone show less deterioration than the untreated stone?
Is the treatment practical and economically feasible?

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