

CLEANING STONE *and* MASONRY

James R. Clifton, EDITOR



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Foreword

This publication, *Cleaning Stone and Masonry*, contains papers presented at the symposium on The Cleaning of Stone and Other Masonry, which was held in Louisville, Kentucky, on 18 April 1983. The event was sponsored by ASTM Committee E-6 on Performance of Building Constructions. Seymour Lewin, New York University, presided as chairman of the symposium, and James R. Clifton, National Bureau of Standards, served as editor of this publication.

Related ASTM Publications

**Masonry: Research, Application, and Problems, STP 871 (1985),
04-871000-07**

**Masonry: Materials, Properties, and Performance, STP 778 (1982),
04-778000-07**

A Note of Appreciation to Reviewers

The quality of the papers that appear in this publication reflects not only the obvious efforts of the authors but also the unheralded, though essential, work of the reviewers. On behalf of ASTM we acknowledge with appreciation their dedication to high professional standards and their sacrifice of time and effort.

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Introduction

Cleaning is an important process in the preservation and restoration of historic stone and masonry monuments and buildings. In addition, cleaning can have an important role in rehabilitation and repair projects by allowing inspection of the surface conditions before decisions are made on the extent of needed repairs. While often the main purpose of cleaning is to improve the aesthetic appearance of masonry, cleaning can also significantly increase the life of the masonry by the removal of deleterious surface deposits. However, the use of improper cleaning materials and practices can cause serious damage to masonry. A need, therefore, exists for standard test methods and performance criteria to form a technical basis for selecting effective but safe cleaning materials and processes. This need has become more urgent during the past two decades as growing levels of air pollution have resulted in increased accumulation of surface deposits containing acidic materials.

This volume contains papers presented at the ASTM symposium on The Cleaning of Stone and Other Masonry, sponsored by ASTM Committee E-6 on Performance of Building Constructions. The symposium was organized to disseminate information on the state of the art of cleaning materials and practices and on current research. Hopefully, dissemination of this information will result in more effective cleaning programs for stone and masonry.

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Selection of Cleaning Methods and Materials

K. Lal Gauri,¹ George C. Holdren,² and Willard C. Vaughan³

Cleaning Efflorescences from Masonry

REFERENCE: Gauri, K. L., Holdren, G. C., and Vaughan, W. C., "Cleaning Efflorescences from Masonry," *Cleaning Stone and Masonary*, ASTM STP 935, J. R. Clifton, Ed., American Society for Testing and Materials, Philadelphia, 1986, pp. 3-13.

ABSTRACT: Salt efflorescences attack masonry in all parts of the world, but in the arid regions they are the major cause of masonry decay. The efflorescences crystallize repeatedly from saturated solutions and become hydrated, generating, in the confined pore space and under surface crusts, pressures large enough to overcome the strength of the masonry material.

Common methods for removing these salts are washing with water and application of surface-active poultices. These methods have their shortcomings: the first tends to transport salts into deeper regions by capillary action while removing some salts from the surface; the second method, besides being highly cumbersome, may result in masonry damage due to the salt crystallizing at the poultice-masonry interface.

This paper describes two suction techniques, one of which appears to eliminate these shortcomings while promising maximum removal of salt from large surfaces in the shortest possible time.

KEY WORDS: architectural preservation, masonry cleaning, efflorescences, historic preservation, masonry, masonry decay, masonry preservation, monuments, Sphinx, stone durability, weathering

A major cause of deterioration of masonry materials is the crystallization of water-soluble salts in the pores of the masonry. Most bricks, concrete, and natural stones contain such salts inherently. When uniformly and sparsely distributed throughout the mass of the masonry, these salts are harmless, but when they are concentrated near the surface as efflorescences as a result of being repeatedly dissolved and recrystallized, these salts are a major cause of masonry decay.

The efflorescences occur in all climatic zones of the world. However, their potency as agents of masonry decay is particularly great in the arid and semiarid regions, because of the uniqueness of the water budget in these areas. The scarcity of water prevents the depletion of these salts. However, the droplets of

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water that condense at the masonry surface, as a result of excessive cooling of the masonry at night, evaporate at sunrise, leaving crystals in place for the next cycle of solution formation and crystallization likely to occur in the following 24 h. Condensation of the moisture needed to form solutions is augmented by the hygroscopicity of certain salts frequently found in the efflorescences. Also, under conditions of high humidity, certain highly soluble salts become hydrated even in the absence of liquid water, contributing considerably to the phenomenon of masonry decay.

The salts damage the masonry in two ways. In one case, the crystallization alone generates hydrostatic pressure because of the expanding boundary of the growing crystal. In the other case, the salt crystallizing from the solution, and the crystals of salt that may be present in the pores, become hydrated, so that the new mineral is attended by a large increase in volume. In most cases of decay due to salts, both of these processes are operative. The generated stresses work repetitively against the walls of the pores and are eventually able to shatter the masonry structure.

The processes just described, and their results, appear to be similar to those involved in the freezing of water in a confined space. The formation of ice crystals with their larger volume, in comparison with that of an equal mass of water, disrupts the stone. In the case of salts, however, the pressures are much larger.

The ASTM Test for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate (C 88-83) and the German Standard DIN 52111 on the durability of natural stone are based on the ability of these materials to withstand pressures generated by the crystallization of sodium sulfate impregnated in their pore spaces. A typical example in nature of decay due to sodium sulfate is offered by the disintegration of the 5000-year-old archeological structures in Mohenjo-Daro in the Indus Valley [1]. In this case, the disintegration has been attributed to phase changes of sodium sulfate from therandite (Na_2SO_4) into mirabilite ($\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$) at the transition temperature of 32.4°C . These structures had been excellently preserved until their excavation in the 20th century. While buried they were not subjected to the meteorological conditions prevailing in the desert environment, characterized by high diurnal ranges of temperature and humidity, which allow repetitive solution and crystallization of salts.

That salts, indeed, are the major cause of stone disintegration in dry climates is further revealed by the study of the Great Sphinx [2,3]. The Sphinx is a monolith left behind in the process of quarrying the Gizeh Plateau for limestone [4]. The lower part of the Sphinx has been veneered with limestone blocks constructed to prevent deterioration of the bedrock. Burial of the Sphinx for centuries under the desert sand has, it appears, resulted in the migration of salts from the depth of the bedrock toward the surface. The authors deduced this phenomenon from observations made in the process of mapping the Sphinx geologically [2], when sand was removed that had piled up in recent times against the rock surfaces bounding the ditch around the Sphinx. Even though the

sand appeared dry at the surface, it was completely soaked with water a few inches below the surface. Also, the bedrock in contact with the sand was soaked with water. The source of this water is the atmosphere, and not the subsurface, because the water table lies many meters below the surfaces under consideration. Therefore, during the long burial of the Sphinx, the rock must have become wet to a considerable depth, and as it dried when exposed to the sun, the salts must have become concentrated in the surface layers. This conclusion is further supported by Fig. 1, which shows variable quantities of salts from one stratum to another, reflecting the quantities of salts indigenously present in the respective layers of the monolith.

Several excavations of this monument from under the sand throughout its history, including a major excavation in the 1880s, have resulted in the differential weathering of the rock units into alternating highly projected and recessed layers, the intensity of the weathering being proportional to the quantity of the occluded salts, halite, sodium chloride (NaCl), and gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$), in the layers of the bedrock (Fig. 1). Further, the application of salt-rich mortars between the less-durable limestone blocks of the veneer in postpharaonic restorations have damaged the earlier, well-selected, highly durable limestones and mortars.

The universality of the phenomenon of efflorescences is also displayed in their appearance after rain as whitish patches on the surfaces of structures made of such materials as brick, fire clay, and mortars. Removal of these efflorescences from the surface and subsurface regions considerably increases the durability of the affected structures. This paper reports the application of a suction technique to control the movement of water through stone and thus to permit an optimal extraction of salts.

The research reported in this manuscript was conducted in two separate phases. Vaughan conducted the experiments — as a part of his master's degree work in the Department of Chemical and Environmental Engineering — on salt-impregnated stones which, while immersed in water, had been subjected to suction treatment (Fig. 2). The other aspect of research consisted of suction application while fresh water was run over the stone surface (Fig. 3). This second mode of experiment has led to the development of a process that permits almost complete extraction of salts in a short time, while the immersion process permitted only partial extraction of salts. Both of these studies are included in the following treatment.

Experimental Procedures

All the experiments were conducted on specimens obtained from Indiana limestone. These stones have a porosity of nearly 15% and an initial capillary water rise rate of nearly 2 cm/h.

Salt concentrations in the test specimens were obtained by infusion with saturated sodium chloride (NaCl) solution to better evaluate the effectiveness of the salt removal procedures used. The test stones were placed for 24 h on a rubber

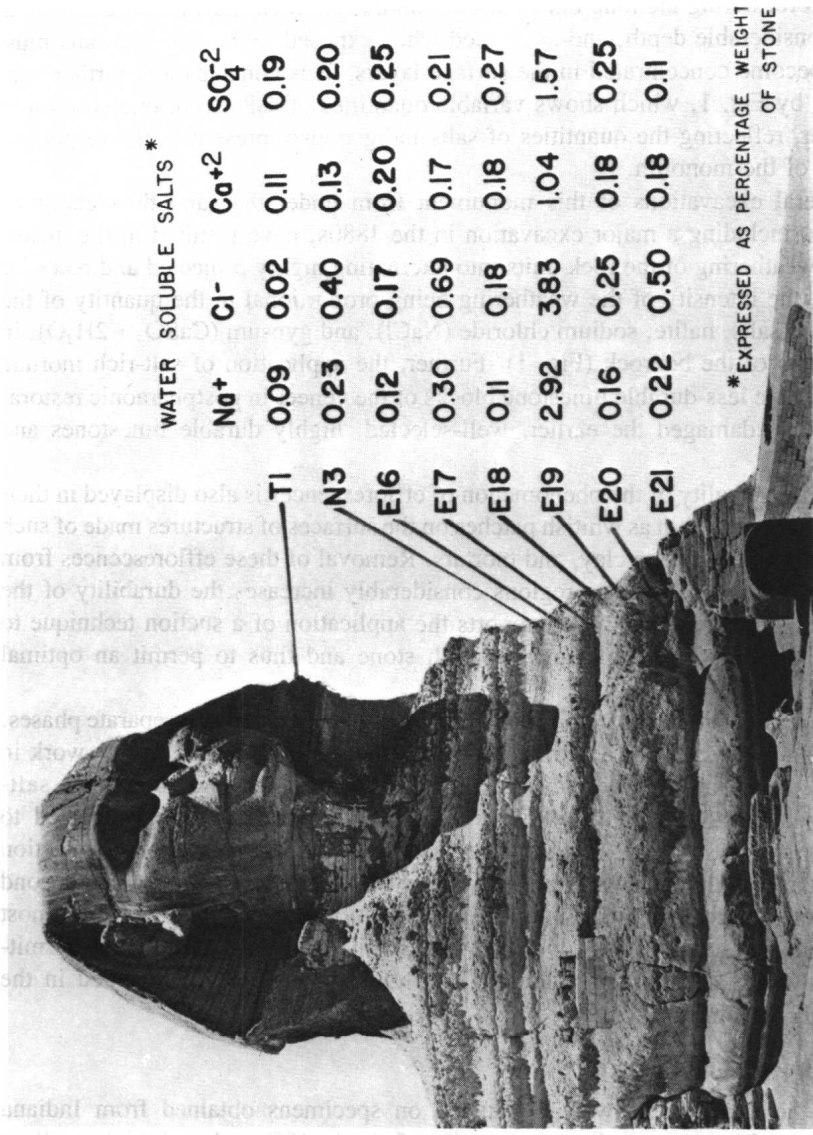


FIG. 1 — Bedrock of the sphinx, showing the distribution of salts and the differential weathering of limestone beds.

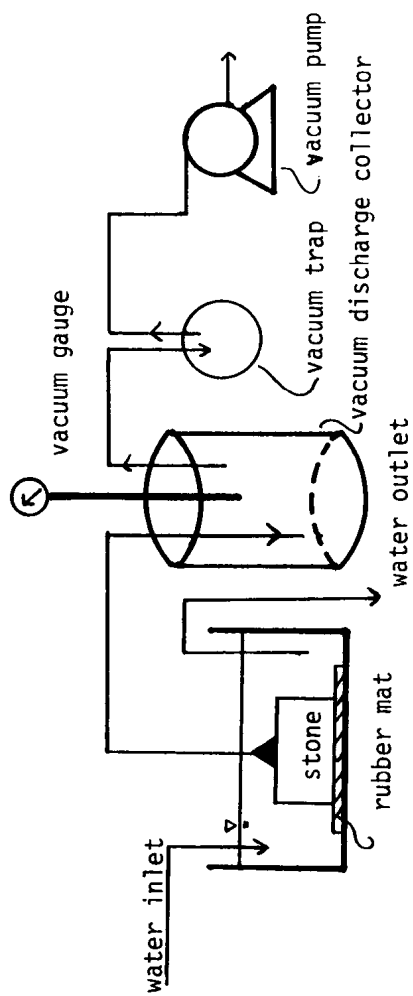


FIG. 2—Apparatus used for suction desalination of immersed stones.