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Evaluation of cleaning procedures on the facades of the Bank of Greece historical building in the center of Athens

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Abstract

The facades of the Bank of Greece historic building, mainly consisted of porous stone, gray marble and white pentelic marble, are subjected to an intensive air pollution attack in the center of Athens. A diagnostic study was carried out prior to the cleaning procedures for the weathering evaluation. Weathering appears mainly as black depositions, salt crusts, and oily depositions, due to the heavily polluted urban atmosphere from the nearby traffic. Previous improper cleaning treatment by water spray under high pressure caused detachment of grains and fissuring which were recognized as mechanical abrasion of the surfaces.

In this study, a pilot investigation is performed with the intention of evaluating the most appropriate cleaning treatment. Therefore, several cleaning procedures were performed in the laboratory and in situ for the evaluation of methods and products applied on the facades. Both chemical and physical cleaning procedures were applied and they were chosen for their selective action: only water and sepiolite for solvent action, ammonium bicarbonate for exchange action, EDTA for the chemical chelating action and microblasting for physical action were used. In situ non-destructive evaluation was performed by Fiber Optics Microscopy in order to assess the counteractions of each cleaning method to the original surfaces. Digital Image Processing was also used to account for the efficiency of each cleaning method.

Keywords: Historic buildings; Pollution impact; Architectural surfaces; Cleaning materials; Cleaning treatments; Non-destructive techniques; Evaluation procedures

1. Introduction

A number of physico-chemical processes take place on the surfaces of historic buildings, developing various crusts related to the type of the environmental attack (industrial and marine atmosphere, various types of total suspended particles, etc.) and the type of the exposed surface. In a polluted environment, two kinds of crusts are usually developed on calcareous rocks; the so-called "white" and "black" crusts.

White crusts are formed through the dissolution of calcite and the reprecipitation of gypsum at the surfaces that are subjected to wash out [1], which takes away the deposits and the products of dissolution [2]. On the other hand, black crusts are developed by gypsum formation on surfaces sheltered from water and attacked by an SO_2-polluted atmosphere. On the areas protected from intensive wash-out, SO_2 and water vapor or rainwater diffuse at a high rate through the pores towards the $CaCO_3$–gypsum interface. Thus, new porous gypsum film layers must be formed at the $CaCO_3$–gypsum interface. As the thickness of the gypsum increases, the number and length of the pores decrease due to the larger molecular volume of gypsum compared with that of $CaCO_3$ and finally, at ca. 30 nm thickness of gypsum, the pores cease to exist.

Thereafter, the rate-determining step becomes solid-state diffusion of Ca^{2+} towards the environment [3]. The transformation of the stone into gypsum is not only associated with the presence of gaseous SO_2, but also with S contained in the residual carbonaceous particles of combustion of fossil fuels for domestic heating [4]. A high uptake of

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Fig. 1. General view of the building.

atmospheric particulate matter (Fe_2O_3, Al_2O_3, SiO_2, C, etc.) is observed on the weathered surfaces [5–7]. Silicate particles are emitted by e.g., the combustion of coal and they are deposited at the exposed surfaces [1].

The historic building of the Bank of Greece in the center of Athens renders on its surfaces in various alteration forms, the impact of a heavily polluted urban environment. Hence, the necessary cleaning treatment should be planned on a pilot scale and evaluated in order to proceed properly; i.e., to overcome the negative environmental impact on the altered surfaces, within comparatively acceptable limits of surface activation.

The cleaning of the stone surfaces is a complex procedure, due to the difficulty of identifying objective parameters for the evaluation of the effects on the surface [8] always corresponding to the new physicochemical conditions of the materials, which could be improved or aggravated, as a result of the cleaning procedure. In any case, the cleaning of the stone surfaces should not modify the physico-chemical properties of the materials [9].

Cleaning treatments act not only on the decay layer of the stone but even on the sound inner layers. Therefore, a pilot investigation is suggested, to describe the changes which the treated surface underwent, according to the adopted criteria, with the objective to minimize the chemical, physical, textural and chromatic counteractions [10].

In the present work, the physical observations, connected with the morphological and color variations of the surface were taken into consideration. The cleaning procedures were evaluated on site by non-destructive techniques, employed for the first time with this objective. Fiber Optics Microscopy accounts for the morphological investigation of the surface, in order to assess the counteractions and Digital Image Processing for the cleaning efficiency of the various materials and techniques applied.

This study was carried out on stone surfaces of the building of the Bank of Greece (Fig. 1), situated in the center of Athens. A diagnostic study [11] was initially carried out, and successive pilot applications [12] based on the results of the diagnostic study were performed. Previous investigations [13–19] and practical considerations account for the choice of chemical and physical cleaning as tested treatments for their selective action: only water and sepiolite for solvent action [20], ammonium bicarbonate for exchange action [21], EDTA for the chemical chelating action, [22–24] and microblasting for physical action were used. The use of sepiolite or in general absorbent clays, is more efficacious for the removal of the salts from the stone, compared with the direct use of aqueous solutions. The disadvantage associated with the use of sepiolite, is the need to repeat the treatment more than once, increasing the cleaning time. The effect of ammonium carbonate is to reconvert the gypsum into calcium carbonate and ammonium sulfate, that is very soluble. The calcium carbonate formed is a white, non-adherent powder and easily removed through successive washes. In theory, the re-formation of calcium carbonate could be thought of in positive terms, if we could render it active [25].

It is clearly evident that the cleaning process includes various successive steps and is often a combination of more than one method.

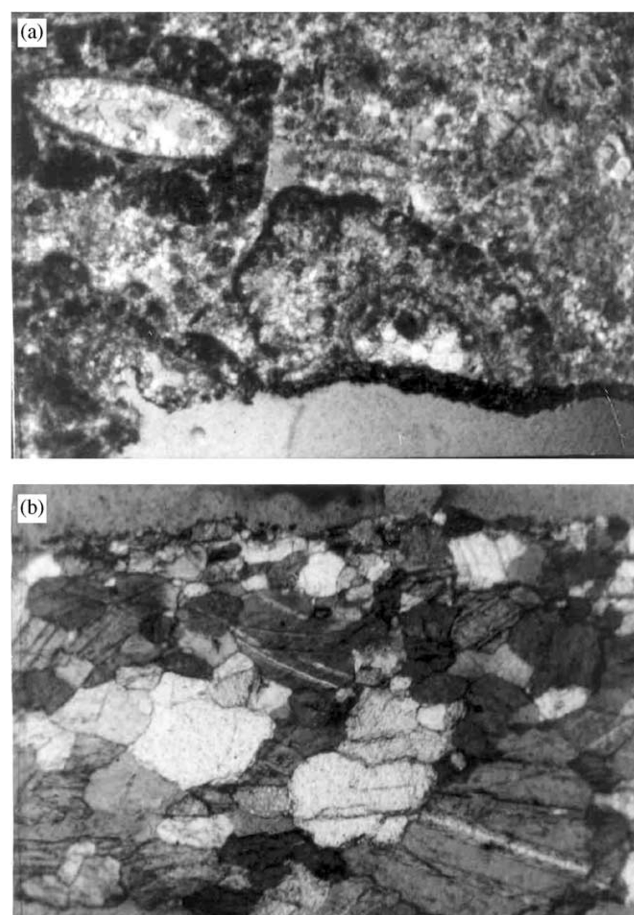

Fig. 2. Optical microscopy observations. (a) Porous stone (×20). The main mineral is calcite, micritic mass, with cracks. The color can be attributed to the presence of oxidized ferrous phases. (b) Gray marble (×20). The texture is compact with the shape of irregular crystals.