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Reverse engineering methodology for studying historic buildings coatings: The case study of the Hellenic Parliament neoclassical building

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ABSTRACT

In this work a reverse engineering methodology for the study of historic buildings coatings is presented. This includes different stages: characterization and evaluation of historic coatings, criteria and methodology for the selection of raw materials and the production of restoration coatings, criteria and procedure for the evaluation of restoration coatings and evaluation of coatings during setting and hardening. The proposed methodology was applied for the study of the Hellenic Parliament building. More specifically in order to recognize and map the original historic coating non destructive techniques were used, such as fibre optics microscopy, infrared thermography, ultrasonic technique and ground penetrating radar. The chemical composition of the original coating, its decay and its production technology, were assessed by granulometric and thermal analysis, as well as by X-ray diffraction. Additionally the colorimetric values of the coating were assessed, using the $L^*a^*b^*$ colour space. It was found that the colourization resulted by a crushed stone, used as aggregate, without the addition of any pigments. Based on these data, various compositions of restoration coatings were prepared and tested. Their evaluation was performed based on compatibility criteria with the historic coating.

1. Introduction

In this work a reverse engineering methodology for the study of the historic coatings of the Hellenic Parliament is presented. Additionally new coatings are proposed for the restoration of buildings façades.

Hellenic Parliament building is a neoclassical three-floor structure, designed by Friedrich von Gärtner in 1843 (Fig. 1). The construction works were completed in the period from 1836 to 1840 and the building initially served as King Otto Royal Palace. After suffering fire damage in 1909, it entered a long period of renovation. The building was then used for many different purposes – functioning as a hospital and a museum, among other uses – until November 1929, when the government decided that the building would house the Parliament. The works for the modification of the Old Palace started in the summer of 1930. The building houses the Parliament since 1935, with only few exceptions during the dictatorship of Metaxas, the German conquest and the coup that was staged by junta (stratocracy) on April the 21st, 1967 [1–3].

Concerning façade coatings, the authentic materials of 1840, were totally removed in 1930 restoration. The materials of 1930 are now considered as the original materials of the building. In 1966, the facades were cleaned with the use of a rotary abrading tool. During the period of 1985–1986 extended reparation works at buildings facades took place. The new materials used at that time were white cement based plasters with marble dust, polymer additives and inorganic pigments. The original coating materials have been deteriorated by natural weathering, by the corrosive action of polluted atmosphere of the city centre and by the successive interventions with improper materials, such as the extensive use of cement and polymer-based materials.

Hellenic Parliament building except its architectonical value carries ideas and ideals, which are registered in Greeks collective unconscious as powerful landmarks and symbols. The restoration of this building is strongly connected with Greece modern history and collective memory. Thus the restoration of buildings façade coatings according to historic preservation principles is more than a necessity.

Plasters used in historical buildings, served as coatings, provide important and helpful information about building technology of their historical period [4]. In Greece, the art of masonry and mortars flourished from the ancient years to Byzantium. A variety of hydraulic mortars have been studied by the Materials Science and Engineering Department, of National Technical University of Athens [5,6]. This led to a methodology for the production of

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Fig. 1. Hellenic Parliament South façade at Syntagma Square.

restoration coatings simulating the historic ones, called reverse engineering methodology, which includes four stages:

- Characterization and evaluation of historic coatings
- Criteria and methodology for the selection of raw materials and the production of restoration coatings
- Criteria and procedure for the evaluation of restoration coatings
- Evaluation of coatings during setting and hardening

The final decision on the most appropriate restoration coating is influenced by a large set of factors, components and constraints. The performance of a coating depends on a certain number of properties of the substrate (composition, physical and mechanical parameters) and the properties of the coating itself (composition, physical and mechanical parameters, durability, and workability) [7].

The proposed designed syntheses were evaluated using criteria and parameters related to their compatibility with historic coating, such as physicochemical and colorimetric compatibility.

2. Materials and techniques

The first stage of this study was the in situ investigation of the state of the buildings' façade, through a diagnostic campaign, which included visual inspection, non destructive testing and sampling. The non-destructive techniques used, were fibre optics microscopy, infrared thermography, ultrasonic technique, ground penetrating radar and colorimeter. These techniques contribute to materials characterization, as well as to the assessment of the deteriorating impact of the environment. Their ability to be applied in situ, without affecting the structure under investigation, creates an innovative tool for monitoring, preservation and quality control of structures/infrastructures [8,9].

More specifically a portable fibre optic microscope (SCOPEMAN-MORITEX) was used, which has the great advantage that no special surface treatment is necessary before performing the inspection. The infrared camera used was the Therma CAM^{TM} (FLIR SYSTEMS, wavelength 5–13 μm). The processing of the acquired infrared images was performed with the aid of FLIR QuickReport 1.2 software. Ultrasound velocities were measured using Pundit 6, CNS Farnell. The georadar used was a SIR 2000 (GSSI). For colour measurements "spectro-colour DRLANGE colour-pen" (LMG 159/160) was used. Colour measurements were evaluated in $L^*a^*b^*$ colour system.

For the characterization of the materials in the laboratory, the following analytical techniques were used: optical microscopy, granulometric analysis, simultaneous thermal analysis (DTA/TG Netzsch 409 EP) and X-ray diffraction (D5000, Siemens). As it is know these techniques lead to the assessment of the physicochemical and mineralogical characteristics of materials [10–12].

3. Results and discussion

3.1. Diagnostic campaign: visual analysis and documentation

The diagnostic campaign started with the visual analysis of the Parliament façades. The building façades coatings consisted of materials of different appearance, especially in the areas around windows, causing an image of "patchwork". It was crucial to define the exact sites of the original and restoration materials. As it can be seen in Fig. 2, the various coatings presented noticeable differences in texture and colour, but all of them were produced in a way to create an imitation of "stone". In Fig. 3 the imitation of stone units is clear resulted through the use of graphite for depicting mortar joints. Discolouration areas of materials surface were also detected.

In order to achieve a finish appearance that imitates stone units, coatings were "polished", using specialized abrasion equipment. This technique is not a modern one, since coloured and polished material finishes date back many millennia. In ancient Egypt the interior chambers of pyramids were finished with an extremely refined and durable plaster. The ancient Greeks were the first who used "marmorino" stucco (lime and marble dust), followed later by the Romans. During the Italian Renaissance the application and development of decorative techniques experienced radical progress, principally in Venice and the Veneto region. Experiments concerning the pigments coloured marble dust and the layering techniques, had transformed polished plasters coatings form functional materials into highly decorative mediums [13].

After determining mainly the original materials, their types of damage were analysed. The main decay types investigated were macro-cracks between the new and the old plasters, due to difference of their physicochemical characteristics, such as chemical

Fig. 2. Different restoration materials finished at west façade of the Greek Parliament.