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Original article

Corrosion rate evaluation by gravimetric and electrochemical techniques applied to the metallic reinforcing structures of a historic building

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ABSTRACT

This work presents the diagnosis procedure followed to determine the degree of damage of a 100-year-old reinforced concrete building located in Barcelona city, the *Sant-Manuel* pavilion at *Hôpital de la Santa Creu i Sant-Pau*. Some structural components of this building were affected by severe corrosion problems in the reinforcing steel UPN profiles. In order to obtain a representative sample set, a preliminary inspection of the macroscopic architectonic structure was applied at selected zones that exhibited the metallic backbone. Gravimetric and electrochemical techniques have demonstrated that some UPN profiles presented high corrosion rate. This was mainly due to the presence of water pipes installed beside the metallic structure, which was a source of humidity, and also to the presence of calcium carbonate, calcium silicate hydrate, and calcium chloride substances inside the cement in direct contact with the metallic structures, which were responsible for the steel depassivation. The work shows a practical example of how a suitable combination of chemical, physical and electrochemical techniques can be applied together to characterize a corrosion process, the obtained results validating and corroborating the prediction of the corrosion rate in metallic structures.

1. Introduction

Historical building construction have not only architectonic interest but also technical and scientific application to carry out different studies on some aspects of buildings, in particular those related with physical properties and their degradation through corrosion processes. Multidisciplinary risk-based analyses for supporting the decision making process on conservation, restoration or to predict the effects of different pollutants on deterioration of European cultural heritage and other emblematic places have been assessed [1–5].

The *Hôpital de Sant-Pau* was declared artistic historical monument in 1978 and world heritage in 1997 by the UNESCO [6]. *Lluís Domènech i Montaner*, a Catalan architect born in Barcelona, Spain (1850–1923), was the person entrusted to elaborate the most important project corresponding of the Catalonia's modernism in 1902. In coincidence with the beginning of application of news materials in construction, as carbon steel and Portland cement, this architectonic ensemble was thought to profit natural resources, as natural light, and also to enjoy of close environment constituted by gardens and parks. Nevertheless, after several decades, the materials used to build the *Hôpital de Sant Pau* started to undergo degradation, affecting one of the most emblematic buildings projected by *Domènech i Montaner* architect.

Therefore, this work is supported on the basis of structural problems arising during the rehabilitation of one of the pavilions of this historic building, constructed of principles of 20th century [7]. The rehabilitation, restoration and fitness of the *Hôpital de Sant-Pau* were included in a European regional development fund (ERDF) project jointly funded by European Union, Government of Catalonia and the Private Foundation of *Hôpital de la Santa Creu i Sant-Pau* in the period of 2007–2013 [8]. The main objective is to show the results of the detailed study carried out to help the engineers and architects on the conservation status of the building, a century after its construction. The main causes of its deterioration were the

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Fig. 1. (a) Photograph of *Sant Manuel* pavilion nowadays and (b) general view of ground floor at the beginning of restoration.

corrosion problems found in some zones where metallic structures were in contact with cement and close to water pipes.

The present work is related with the evolution of the corrosion process in the metal profiles used in the *Sant-Manuel* pavilion building (Fig. 1a) and with the degradation of neighbourhood cement in contact with them.

The protocol followed was supported by an experimental methodology including a preliminary overall inspection of general status of building structure (Fig. 1b), in particular of metallic skeleton. The random selection of different pillars and beams of carbon steel was carried out to pull a specimen collection to be tested in accordance with gravimetric and electrochemical methodology in order to estimate the corrosion degree. Complementarily, composition of carbon steel and surrounding cement was examined to obtain the influence of possible pollutants in corrosion of carbon steel.

2. Methodology

2.1. Study object

The *Sant-Manuel* pavilion, one of different components of the *Hôpital de Sant-Pau* in Barcelona (Catalonia, Spain) was the object of this work. This building was projected by the architects *Lluís Domènech i Montaner* and *Pere Domènech i Roura* between 1922–1925 and refurbished by architects *Víctor Argentí*, *Albert Casals* and *José Luis González* in 2009–2011, for its present use as headquarters of the United Nations University Institute on Globalization, Culture and Mobility and *Casa Àsia*. Therefore, the *Sant-Manuel* pavilion, with a built area of 2.563 m^2, was included in the overall restoration process oriented to preserve the main structure of building and its modernist identity, ensuring simultaneously the absence of corrosion problems in the future. For this purpose, a detailed study of metallic corrosion into the structure is essential to predict the viability maintaining the same metallic structure and the expected corrosion rate for the next years.

The metallic structure of this building is made from UPN profiles of steel (UPN100, UPN200 and UPN300) placed as pillars, beams and reinforcing struts dome (Fig. 2). Although there are other profiles in horizontal arrangement on the side walls, these were not considered for analysis because they do not constitute basic elements of structure (Fig. 3). The metallic profiles are not visible except for the sample extraction in selected zones where excess of iron oxides are present on the surface. Then, the reinforced steels were cut in the appropriate size by engineers working in the restoration of *Sant-Manuel* pavilion, from the selected zones, shown in the Fig. 2, whereas others samples needed to be extracted from zones cemented.

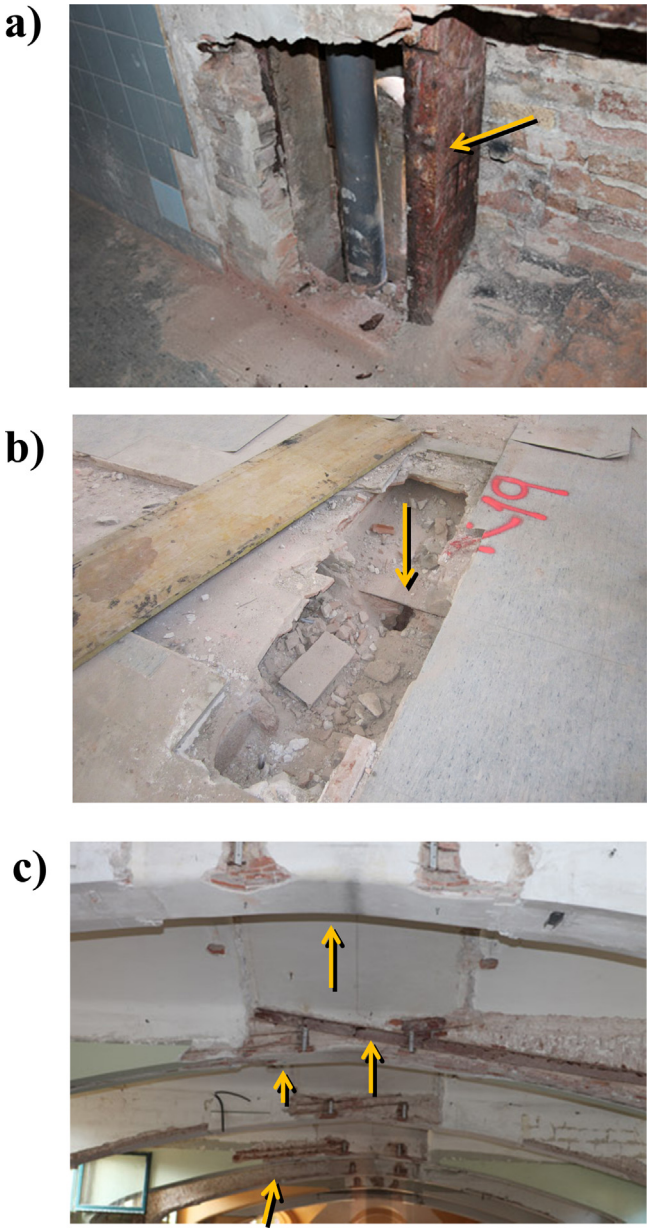

Fig. 2. Metallic structures based on pillars (a), beams (b) and purlin from roof truss (c). Arrows indicate the zones where the corroded profiles are located.

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