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Classification of damage to the structures of buildings in towns in coastal areas

Jose M. Adam *, Jose D. Moreno, Mercedes Bonilla, Teresa M. Pellicer

ICITECH, Universitat Politècnica de València, Camino de Vera s/n, 46022, Valencia, Spain

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ABSTRACT

Damage to the structure of buildings near the coast is often caused by the marine environment. This paper describes a study carried out on the state of the structures of buildings in towns near the coast in Valencia (Spain). The findings were based on inspections carried out on all the buildings in 14 towns considered representative of those in the area. A total of 1816 buildings were inspected, and the typical damage found in structures exposed to a marine environment was identified. The percentage of affected buildings was found to be quite high, in some cases over 40% of the total number in the town. Damage was classified into four levels of severity, and a significant percentage of structures were found to be gravely affected, requiring immediate repairs. Based on the experience acquired in these inspections, this paper proposes a tool that would allow the general state of buildings in coastal areas to be assessed by what is called a *Global Damage Index*. This tool can classify towns according to the predictable presence and level of structural damage to its buildings, and provides a preliminary assessment together with criteria for the measures to be taken, including access to finance from public bodies to cover the repairs, maintenance and protection of buildings.

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1. Introduction

The marine environment has a considerable influence on the durability of building structures located close to the coast, with the corrosion of reinforcement being the main type of damage sustained by reinforced concrete (RC) structures [1–4]. The marine atmosphere has a high humidity and contains a high percentage of salts, the combined action of which accelerates corrosion in reinforcement bars, basically due to the attack by chloride ions and/or carbonation of the concrete. Both these factors can act either separately or in combination [5–6] and in all cases seriously affect the durability of RC structures.

Of all the factors that influence corrosion in the reinforcement of RC structures close to the sea, the following are the most important [7]: distance from the coast, speed and direction of prevailing winds, relative atmospheric humidity, presence of wetting-drying cycles that affect RC elements, and presence of obstacles that increase or reduce the exposure level. Each of these factors is analysed below.

The salinity of sea spray is closely related to distance from the coastline and the greater this distance is, the lower its salt content [8,9]. As regards wind speed and direction, Meira et al. [10] and Fitzgerald (1991) [11] demonstrated the direct relationship between this factor and the salinity of the marine atmosphere. At speeds over 3 m/s, atmospheric salinity rises and the effect is increased when the wind is perpendicular to the coastline [10,12]. Atmospheric humidity in coastal areas affects concrete resistivity and thus has a decisive influence on the corrosion rate [3]. Medeiros et al. 2013 [13] showed that wetting-drying cycles influenced the

* Corresponding author.
E-mail address: joadmar@upv.es (J.M. Adam).

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chloride ion content in the structure itself and constituted a risk to the reinforcement. The presence of obstacles also has a significant influence on the salinity of sea air [9]. This latter effect is more marked in towns with a large number of buildings that act as screens to one another.

Due to the magnitude and seriousness of the damage done to building structures, the Mediterranen coastline in Spain is in a special situation as regards the effect of the marine atmosphere [7,14].

The growth of tourism in Spain in the last 50 years has mainly been concentrated in zones on or near the coast and this is especially so in the Mediterranean region. Tourism has been largely responsible for the enormous growth in the construction of buildings, the consequent rise in its stable population and the number of people who have acquired holiday homes there. This effect has been especially notable on the Valencia coast, as has been shown by Moreno [14]. However, in this rapid growth of coastal housing, the types of construction and their structural characteristics have not been suitably adapted to the aggressive marine atmosphere endemic to the area. In fact, the primary design considerations of these buildings have concentrated on other aspects, such as making the most of the sea view and the context of the beach. Following such criteria, the buildings are generally designed with large terraces, flat roofs and enough height to provide good views of the sea. However, most of these buildings near the coast and used by holidaymakers are highly exposed to the marine atmosphere, and as most of them have RC structures, the damage caused by this phenomenon is quite severe.

All the factors mentioned above were taken into consideration in the planning of the present study, whose objective was to determine the present state of buildings on the Valencia coast by quantifying the damage done to their structures. For this, a visual inspection of 1816 buildings was carried out, the total of number of all the buildings in 14 towns. The 14 towns studied were considered to be representative of the area.

This paper's main novelty lies in its classification of the habitual damage found in RC structures in coastal zones, which is divided into different levels. The second novelty is its proposal of a method of estimating the level of damage in buildings in coastal towns,

Fig. 1. Location of Valencia in Spain and Europe.

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