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In-situ assessment of physical performance and degradation analysis of rendering walls

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HIGHLIGHTS

- In-situ techniques for physical performance rendering walls assessment.
- Inspection methodology proposal with non-destructive diagnosis techniques.
- Visual inspection with infrared thermography, Karsten tubes and moisture meter.
- Three experimental campaigns on cement and lime based renders.

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ABSTRACT

The use of in-situ diagnostic techniques can lead to a more accurate evaluation of the performance level of façade claddings. The paper aims to evaluate the advantages of using visual inspection and selected in-situ techniques (infrared thermography, Karsten tubes and moisture meter) for the evaluation of the physical performance of renders and their state of deterioration. The main objective of the study is to propose a methodology for in-situ inspections with a low degree of intrusion for the evaluation of physical in-service performance of renders applied on external walls. Three experimental campaigns were performed and different types of renders were analyzed for several in-service conditions. This work enabled the identification of the various factors that affect the results of the selected in-situ techniques. Furthermore, it was made evident, that there are advantages in the cross-comparison of different results, which in certain situations can complement the visual inspection.

1. Introduction

Renders play an important role to the buildings' facades durability. In order to ensure adequate hygrothermal conditions inside the buildings, renders must guarantee the protection, waterproofing, finishing and durability of the walls, against the external actions and usage that they are subjected.

The importance of knowing the in-service performance of renders requires the implementation of in-situ inspections. These inspections are based on a visual inspection and, when possible, require the use of complementary test techniques. These techniques should be low-intrusive in order to not compromise the aesthetic and performance of the renders. Therefore, strict methodologies of observation, recording and analysis of anomalies should be followed together with in-situ tests [1–3].

The manifestation of anomalies on renders can begin even when they are applied, caused due to intrinsic material defects and by the processes of curing and drying, associated to improper application and performance. Beyond its natural aging, the service conditions and degradation agents that renders are subjected can accelerate the degradation mechanisms, namely solar radiation, water and wind, pollutants exposition, temperature variations and colonization of microorganisms [4].

Among the degradation processes that affect the exterior walls, water is the main cause of the appearance of anomalies. In fact, water gives rise to the presence of moisture, biological colonization stains and runoff of soluble salts which accelerates the degradation processes [5,6]. Therefore, the knowledge of in-service physical performance of renders is fundamental and should be evaluated through the measurement of porosity, permeability to liquid water and water vapor, the coefficient of capillarity, the rate of drying or the presence of soluble salts in the composition [7]. However some of those characteristics need the use of destructive techniques and the collection of samples for lab assessment.

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In this study, nondestructive techniques are used on field inspections. These techniques allowed the proposal of an inspection methodology to evaluate in-situ physical performance of renders, starting from a visual inspection with expedient techniques such as hammer, compass, level, among others (Fig. 1), followed by infrared thermography, Karsten tube and moisture meter for a more accurate evaluation in localized areas (Fig. 2).

This study aims to contribute to a better understanding of the physical behavior of the rendered facades, based on the analysis of different in-situ techniques and intends to assess the advantages, disadvantages and efficiency of these techniques. Furthermore, the added value of combining the obtained results with those from visual inspection is also discussed.

2. Diagnostic techniques

This work intends to evaluate the applicability of some in-situ techniques in assessing degradation state and the determination of minimum performance levels. The use of diagnostic techniques to complement visual assessment reduces its subjectivity [1,8] and facilitates the collection of more accurate in-service data. In this study, tests with infrared thermography, Karsten tubes and moisture meter were carried out. These techniques are briefly described in the following sections.

2.1. Infrared thermography

Thermal imaging is a technique for measuring infrared radiation that enables to gather the surface temperature distribution of objects, which should follow several standards [9–11]. Infrared thermography relies on the theory of energy transfer by infrared radiation and in the fact that all bodies at a temperature higher than 0 K emit thermal radiation. The higher the temperature of a surface, the greater will be the energy of the emitted radiation [12].

Any variation in the thermal properties of the elements, such as thermal bridges, defects in isolating or blisters, cause variation in surface temperature that can be easily detected in the thermograms. However, for these defects to be visible on the thermograms a temperature gradient is necessary [13].

In active thermography, the studied surface is artificially heated or cooled in order to produce thermal contrast areas. The thermography image is captured during the return to the state of thermal equilibrium. The thermal contrast can be induced using various energy sources that interfere in different ways with the surface under study. Those energy sources can be external, when the energy hits the surface propagating through the material until the anomaly is found, or internal, when energy is injected directly into the specimen so as to enhance existing defects. In this case, an ultrasonic system is used in order to cause the vibration of the particles without the need to heat the surface [14,15].

In the case of passive thermal imaging, the study takes place without interference from any artificial source of external heating (or cooling). The irradiation sunlight and the temperature gradient between the interior and exterior environments are considered as natural sources of heat. The main advantage of this approach is that the only necessary equipment is the infrared camera. In this research only the passive approach was used.

The Stefan–Boltzmann law relates the surface temperature (T) and the flux of radiation emitted by the object (E) with the introduction of a constant σ (Stefan–Boltzmann constant, $\sigma = 5.67 \times 10^{-8}\ \mathrm{W\,m^{-2}\,K^{-4}}$). This law is valid for perfect blackbody defined as bodies which absorb all the incident radiation, irrespective of the direction and wavelength. In real bodies, not all the incident energy is absorbed. To this end, a coefficient of emissivity (ε) of the object is introduced into the Eq. (1):

$$E = \varepsilon \cdot \sigma \cdot T^4 \ (\mathrm{W/m^2}) \quad (1)$$

The emissivity is a surface property whose value is influenced by several factors such as the orientation and the surface condition, temperature, radiation wavelength and the type of material [16–18].

Thermography is useful in various stages of construction processes and can assist in the project design phase and in facilitating the investigation research of new materials and technologies. This technique allows performing rapid tests which detects heat loss through building envelope, resulting in poor thermal insulation (thermal bridges) or infiltration of air, cracked areas in the opaque building elements and points of water leakage. The main advantage for users resides in the fact that the technique is quite nondestructive and non-invasive [19–24].

The results of this technique depends on various factors such as: the surface emissivity, which vary depending on the materials; reflectivity, resulting from reflection of the radiation emitted by near objects; the atmospheric attenuation, resulting from absorption of radiation by the elements diffuse into the atmosphere (gas and particles); the angle of observation. In addition to these factors there is the incidence of solar radiation, the occurrence of shading or the wind speed in direct contact with the analyzed surface [20]. The experience of the surveyor and the quality of the equipment used can also limit the quality of results.

While some infrared thermography tests, such as detection of thermal bridges, require stable environmental conditions other are favored by varying environmental conditions, such as detecting the presence of moisture and delamination. In fact, in the latter case the rapidly changing environmental conditions (sunset, sun, sudden appearance of clouds) will quickly modify the temperature

Fig. 1. Example of expedient tools used: from left: hammer tapping; crack width microscope measure (down) and crack width gauge (up); thermo-hygrometer; sodium hypochlorite solution.