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Variability of in-situ testing on rendered walls in natural ageing conditions – Rebound hammer and ultrasound techniques

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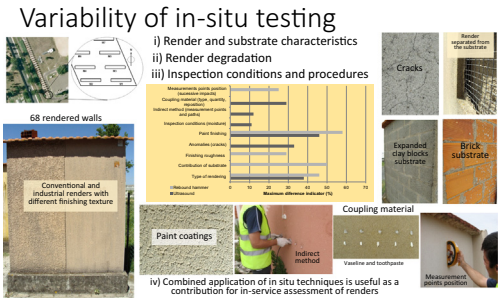
HIGHLIGHTS

- Variability of in-situ testing in natural ageing conditions.
- In-situ techniques for mechanical performance rendering walls assessment.
- Ultrasound and pendulum rebound hammer techniques.
- Experimental campaign on around 68 rendered walls.

GRAPHICAL ABSTRACT



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ABSTRACT

External renders are the first barrier against degradation agents and their performance affects directly that of building façades. During the life cycle of renders there is a progressive reduction of their performance until they are no longer able to fulfil their required functions, such as protection of walls and finishing of surfaces. The evaluation to understand how a render performs over time is a complex activity, not only due to the multiple factors concerning its exposition, but also to the difficulty in assessing the in-service behaviour. The use of in-situ techniques gives the possibility of obtaining the information about in-service performance of renders.

This paper discusses the use of ultrasound and pendulum rebound hammer techniques for assessing the mechanical performance of rendered walls under natural ageing conditions. The results of ultrasound pulse velocity and rebound hammer index, in conventional and industrial renders, allowed identifying some of the main influencing factors, related both to the rendering-wall system (characteristics and degradation) and the inspection conditions and procedures. This study has confirmed the usefulness of these in-situ tests to evaluate the mechanical performance of rendered walls, despite their variability in natural ageing conditions.

1. Introduction

1.1. In-service performance testing

The concept of performance is directly related to the way in which buildings and their components achieve the goals demanded from them. In order to meet these requirements,

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renders must ensure the protection of walls both against water and other aggressive agents and finishing of surfaces in real service conditions during the life cycle [1,2]. The performance of renders during their service life depends on their performance in relation to mechanical, thermal, dynamical, physical and chemical nature actions. The appearance of anomalies (including cracking, loss of adherence and loss of cohesion) most of the time reduces renders' performance, if no corrective measures are taken. Related to the mechanical performance of renders, this essentially involves adherence, internal mechanical resistance, surface resistance and deformation [1,3,4]. The in-situ performance evaluation can start with a visual inspection using expedient techniques such as a hammer, bubble level or cracking measure [5] but the use of diagnosis techniques to complement the assessment reduces its subjectivity and provides useful information [1,6,7]. In several cases, a visual inspection is adequate to detect pathological phenomena affecting the rendering, when their symptoms are visible [8,9]. However, this can produce data that is dubious or difficult to interpret [10]. It is also affected by the academic background and experience of the technician carrying out the inspection, as well as the accessibility of the area being inspected. Furthermore, most problems affecting the performance are often not visible, which means that they need to be measured [1,2,3,6]. The use of in-situ diagnosis techniques reduces the subjectivity of visual inspections, and has proved increasingly beneficial in characterising in-service performance, as a complement to visual inspection [1,5,6,10,11].

Nowadays there is a great variety of in-situ testing techniques that can be used for in-service evaluations of existing (recent, old or historic) rendered walls [5,6,7] in order to increase the effectiveness of maintenance and rehabilitation actions in the built environment [11]. An in-situ technique is more suitable if it is easy/quick to perform and if contributes to the in-service performance assessment. The techniques used in the diagnosis significantly depend on the material, the available human and financial resources, the in-service assessment objectives, and the time needed to collect and interpret the data [10,12,13]. In this paper the variability of ultrasound and pendulum rebound hammer techniques due to factors related to the rendering-wall system and the inspection condition and procedures is discussed. The selection of these factors is based on the available assessment techniques of the present study and depends on the type and degradation of the existing rendered walls located at the natural ageing station.

1.2. Ultrasound and pendulum rebound hammer

Ultrasound testing works by determining the ultrasound pulse velocity (UPV) of longitudinal waves between two points which gives information on the mechanical characteristics of the elements under test. The ultrasound testing has been used to assess the homogeneity and compressive strength of concrete structural elements [14,15]. The application of ultrasound testing in non-structural elements, such as cementitious renders, has seen little research, in the particular case of wall renderings in natural ageing conditions. The degradation of the elements tested (e.g. discontinuities such as voids, cracks and loss of cohesion) affect the speed at which the ultrasound waves are transmitted [14,16,17]. It is a non-destructive method, quick and easy to use, and no special training is needed to handle or use this apparatus [17].

The rebound hammer is based on the rebound method, in which the bounce of an elastic mass launched against a surface depends on the surface hardness of the material under analysis [18,19]. The result is the rebound hammer index (RHI), which is an arbitrary indicator as it depends on the mass and the energy stored by the device's spring. The classical Schmidt hammer device, with different impact energies, is often used to estimate the strength or assess the uniformity of in-situ concrete, to delineate zones or areas of poor quality or deteriorated concrete in structures [12,13,15,18]. Other studies [6,7,16] used the Schmidt pendulum hammer device for in-situ characterisation of rendered walls, combined with other non-destructive methods. This technique is useful in characterising degradation and mapping areas with poor mechanical performance of rendered walls (due to the presence of moisture or lack of render's adherence) [6].

1.3. In-situ testing variability and influencing factors

The variability of the in-situ techniques is a crucial aspect that has to be considered during the inspections and in the results interpretation. The in-service factors contribute considerably to the variability of the in-service analyses, which does not occur in controlled laboratory conditions [6,20] and is usually measured by a variation coefficient of 13–16% for the ultrasound technique [17,21] and 10–19% for the pendulum hammer [21,22].

The literature review showed that specific influencing factors should be highlighted, increasing the reliability of in-service performance diagnosis under natural ageing conditions. This paper is in line with in-situ testing on concrete structures [12,13,14,15,18,23]. However, it focuses rendered walls that have different elements (e.g. substrate, render, finishing layer). For these reasons, distinct influencing factors can be discussed. According to Table 1, the results of ultrasound and pendulum rebound hammer techniques depend on several factors that are mainly related with: i) the characteristics of the rendering-wall system; ii) degradation of the render; and iii) inspection conditions and procedures, hindering the establishment of standardized performance criteria. Furthermore, the influencing factors related with the inspection conditions and procedures are still scarce in walls, so references concerning concrete structures were also added in Table 1.

2. Experimental program

2.1. Case studies

An experimental campaign was performed at the natural ageing station (EEN) of the National Laboratory of Civil Engineering (LNEC), in Lisbon, Portugal. The EEN (Fig. 1) was built at the end of the '70 s and has a large variety of applied renders, ranging from 30-year old

Table 1
Influencing factors of the ultrasound and pendulum rebound hammer techniques.

Factors	Techniques		References.
	Ultrasound	Pendulum hammer	
i) Renders and substrate characteristics			
Surface roughness	–	x	[6,23*]
Low surface resistance	–	x	[16,22*]
Low adherence	–	x	[1,6]
Render density	x	x	[1,17]
Render porosity	x	–	[24]
Substrate type	–	x	[1,6]
ii) Render's degradation			
Moisture content	x	x	[1,6,17,25*]
Biological colonization	–	x	[6]
Cohesion loss	x	–	[6,16]
Cracks/detachments	x	–	[1,6,16,17,26,27]
Voids	x	x	[1,28]
iii) Inspection conditions and procedures			
Direct/indirect method	x	–	[22* 29*]
Transducers distance and position	x	–	[6,17,22*, 29*,30*]
Calculation method of the pulse velocity	x	–	[31*]
Inspection conditions	–	–	[6,32]

* references related with concrete structures due to the lack of studies on walls.