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Non-Destructive Structural Wood Diagnosis of a Medieval Building

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Abstract

This work seeks to demonstrate the role of non-destructive inspection and diagnosis techniques, trying to find a simple and expeditious supporting decision maintenance/rehabilitation or replacement. The evaluation of the state of conservation of the structures can be made with non-destructive testing to obtain the resistance of the wood structural elements. The case-study is the Gralheira Inn, "Pousada Medieval da Gralheira" in Portugal, which is an example of the antique constructed buildings in the region of Trás-os-Montes. The owners of the heritage buildings neglect it leading to accentuated degradation, making the recovery and rehabilitation interventions, complex. An inspection and diagnosis was carried out to assess the current state of structure conservation and to know the mechanical characteristics, were performed non-destructive tests, using the resistograph and humidimeter.

Keywords: Masonry structures; Wood Structures; Non-Destructive Diagnosis; Rehabilitation; Pathological characterization.

1. Introduction

The development and occupation of old city centers are their physical history testimony [1]. Human adaptation to the physical environment, generates unique urban scenes [2]. The structure and materials knowledge of a building

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and the correct inspection and pathologies diagnoses are the base for a good rehabilitation and maintenance plan [3]. To avoid misinterpretations is important to choose the right inspection tools [4]. In the case of the wood, its heterogeneity affects the mechanical properties and performance. The heterogeneity can be caused by natural defects or biodegradation, and it's location is important to know because it affects the strength and performance of wood elements [5]. The wood decay is a consequence of its state of conservation and not of its age [6]. Non-destructive (ND) or semi destructive (SD) techniques are used in the structures where's not possible to extract structural members to perform destructive tests [4, 7, 8]. Because of the lack of knowledge of the potential of woods, many times the rehabilitation process, substitutes woods in good state leading to unnecessary costs, so is important to study the wood structural behaviour [9]. In this paper are presented non-destructive techniques, such as the resistograph and humidimeter, and the data that is possible to obtain.

2. Non-destructive testing techniques

The non-destructive testing techniques allows to evaluate the conservation status of the wood elements, e.g., providing mechanical characteristics, without compromising the structure integrity. The tools which could help in this diagnosis are: hammer and chisel (traditional techniques), resistograph and humidimeter. These non-destructive techniques are very important in the inspection of buildings with historical and cultural value, which could not be extracted elements for destructive experimental tests.

2.1. Traditional inspection techniques

With aims to make an adequate intervention in the structure is necessary to assess the state of conservation of the structural woods, can be used a hammer, which the sound of impact in the solid wood and degraded is different, allowing to perceive the existence of deterioration, due to cracks, internal voids, etc., and its location. By visual and touching in the wood should be searched for signs of biotic agents on the wood surface.

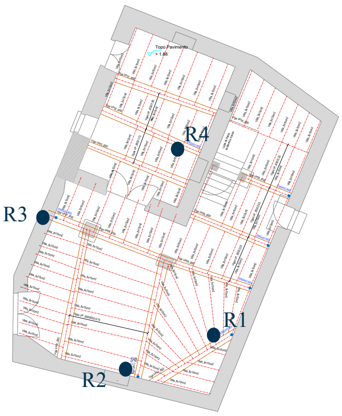
2.2. Resistograph

The resistograph is used to detect degraded zones due to biological degradation, cracks and voids in the elements, invisible by visual inspection. It allows to obtain a graphic of the density variation along the cross section of the wood, due to the resistance that the wood impose to the drill [10]. In this test was used a resistograph, model F-400S, brand IML, as it can be seen in Fig. 1. This test is made by leaning the machine in the wood element, so that the needle is perpendicular to it, and drill the wood through a micro-hole, at constant speed, measuring the wood resistance to rotation and progressive penetration of the needle. It produces a record that allows to identify the variations of density in function of its profundity. This technique is considered a non-destructive inspection method, due to its almost invisible perforations, and good application, especially when the buildings have an patrimonial interest [11].

Fig. 1. Resistograph used in this study (images from: [9]).

2.2.1. Results

Resistograph was used in some floor areas to assess the state of preservation of most its structural wood elements, already inspected with the use of hammer. A total of 4 tests were carried out with this apparatus, in the locations presented in Fig. 2 (a) along the floor beams. The results show that exists in some cases surface degradations and internal degradations of the wood. In Fig. 2 (b) is showed the example of a test in a beam. In the Fig. 3 to Fig. 6 are presented the resistograph graphics obtained for the 4 pavement beams tested.



(a)

(b)

Fig. 2. (a) Location of the points where the tests were carried out with the resitograph; (b) Structural plant of ground floor; (b) Resistograph testing (images from: [9]).

The beam R1 results, next to the support, are presented in Fig. 3, being possible to verify that the beam is in food state of conservation and without apparent degradation, showing only a superficial degradation in the surface as it is possible to verify in the abscissa axis when the needle crossed the piece at 5 cm. It is also possible to see the total cross section dimension of the beam, in this case is around 33 cm.

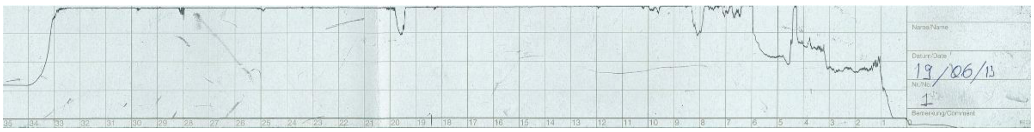


Fig. 3. Obtained graphic of the R1 beam of the pavement, through resistograph (image from: [9]).

Fig. 4 show the graphic results for the beam R2, near the support delivery on the wall, displaying that this wood element was in poor state of preservation. It has a cross-section with constant deterioration, reaching the maximum resistance at approximately 6 cm of profundity. The deterioration in this beam should be associated with the high humidity content present, that lead to rotting. The beam cross section is about 24.5 cm.

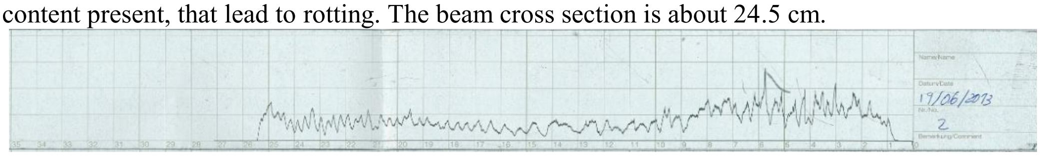


Fig. 4. Obtained graphic of the R2 beam of the pavement, through resistograph (image from: [9]).

Fig. 5 presents the graphic results obtained for the R3 beam next to the support delivery in the wall. As the R2 beam this one, by visual inspection was detected humidity, which is according to the results obtained in the resistograph that showed a degraded cross-section, probably due rotting. The maximum resistance occurs at approximately 5.5 cm probably due to existence of a knot. The cross section of the beam is about 25 cm.

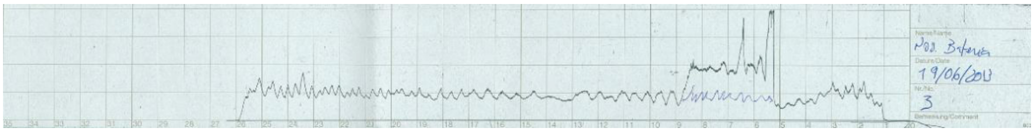


Fig. 5. Obtained graphic of the R3 beam of the pavement, through resistograph (image from: [9]).

Fig. 6 presents the R4 beam, next to the delivery support in the wall, graphic obtained with resistograph. This element is degraded in the interior, between approximately 7 and 21 cm, in the abscissa axis. In the first 6,5 cm the beam shows some resistance losing it completely and then recovers it at 20 cm. The beam cross-section has approximately 28 cm. Due to the humidity observed in this element, it can be suspected that the beam is rot in the interior.

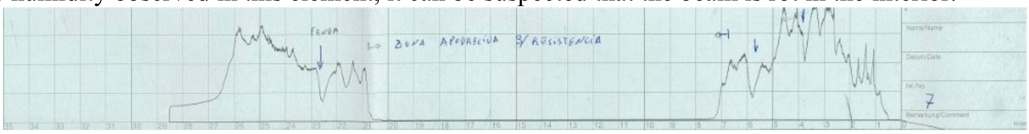


Fig. 6. Obtained graphic of the R4 beam of the pavement, through resistograph (image from: [9]).

2.3. Humidimeter

The humidimeter allows to measure the water content of the wood elements based on the variation of the electric resistance [12]. Was used a TRAMEX humidimeter MEP as it can be seen in Fig. 7, to obtain the humidity of wooden elements. According to Eurocode 5 exists a risk of fungal attack when the wood is exposed to humidity values higher than 20% [13]. For woods that already suffered fungal attacks, this limit is reduced to 18% [14]. With this machine is possible prevent biological contamination by, periodically, checking areas with greater potential for humidity.

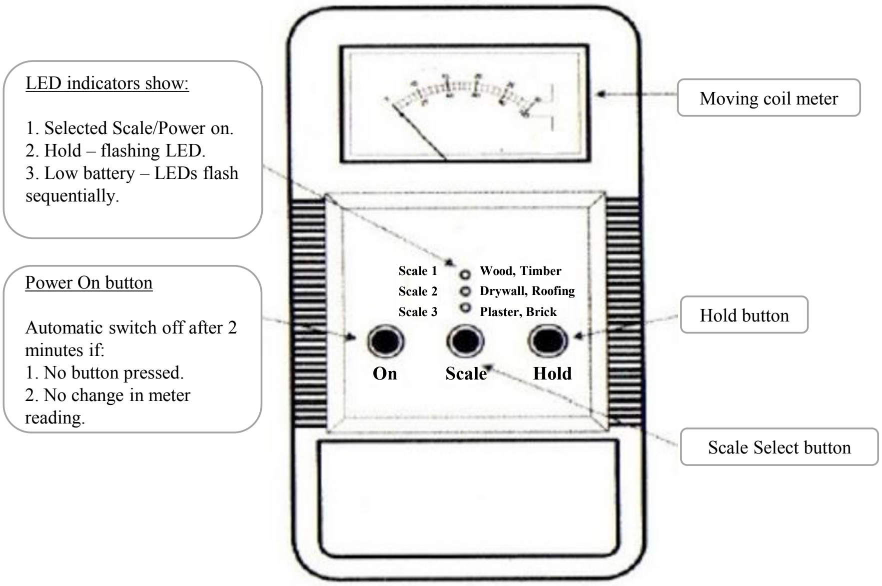


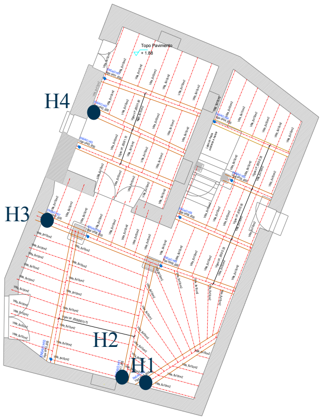
Fig. 7. Mode of operation of the humidimeter (image adapted from: [9]).

2.3.1. Results

In Fig. 8 (a) are presented the inspection with humidimeter sites. In Fig. 8 (b) is showed an example of the evaluation of the humidity content of a beam with the humidimeter. Were tested 4 beams, recording the section diameter, conservation state, obtained by visual inspection in the supports and the water content. The information obtained through visual inspection was classified as: good, degraded and reasonable scale. The areas of the pavement more exposed to rain, had a higher humidity content. The humidimeter readings were compared with the resistograph results for the correspondent elements. In Table 1 are presented the results obtained in this test, and it's possible to observe that the H3 spot has a higher humidity content (14%), and the lower value occurs in the H1 spot.

Table 1. Humidimeter obtained results (table adapted from: [9]).

Designation	Mean Section, Ø (cm)	Actual state	Left support	Right support	Humidity content (%)	Visual observation
H1	35	Reasonable	Good	Degraded	12	Cracks and Nodes
H2	32	Degraded	Degraded	Degraded	13	Node at ½ span
H3	30	Degraded	Degraded	Good	14	Crack
H4	30	Reasonable	Reasonable	Good	13	Node



(a)

(b)

Fig. 8. Structural plant of the ground floor with the identification of the inspection sites (images from: [9]).

3. Conclusions

Non-destructive tests allow the perception of the state of conservation of the structure without destroying it. Some instruments, such as the hammer and chisel, resistograph and humidimeter, used in wood structures have been revealed to be important tools in structural evaluation, allowing the acquisition of qualitative information. This work started with a visual inspection of the structure to assess the conservation status and the potential degraded zones, then was made an inspection with the aid of the resistograph and humidimeter to confirm the dimension of the degradation, allowing to develop knowledge to support a future decision in a rehabilitation project. The floor is under infiltrations so a non-destructive test campaign was carried out. Resistograph and humidifier permitted to evaluate, in a non-intrusive way, the state of preservation of the wooden floor. The resistograph results allow to identify variations of density along the sections of the structural elements, growth rings, biological degradation zones, cracks and voids in the parts, normally, not visible by visual inspection. The results of resistograph combined with the results of the humidimeter and visual inspection can lead to the reasons why the sections are degraded.

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