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COMBINE USE OF NDT/SDT METHODS FOR ASSESSMENT OF STRUCTURAL TIMBER MEMBERS

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SDT methods as part of a conservation process

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Abstract

This paper refers to the assessment on site by SDT (semi-destructive testing) methods of the consolidation efficiency of a conservation method developed by [1]. This is a solution for improve the physic and mechanical characteristics of wood moderately degraded by fungi, avoiding its substitution and contributing to the conservation of building heritage. The decay level and the evaluation of the proposed solution efficiency were checked on site by SDT methods of drill resistance and of penetration resistance. The objective was to assess the consolidation efficiency on site by SDT. The technique involves traditional methodologies used in the conservation of wooden cultural heritage area applied to wooden elements in buildings. This study set out to ascertain on site the mechanical performance of scots pine (*Pinus Sylvestris* L.) wood degraded by fungi after treatment with a biocide product followed by consolidation through impregnation with a polymeric product. The SDT methods used showed good sensitivity to the presence of the products and could evaluate their effectiveness.

Introduction

This conservation process was developed in order to help keeping the timber in buildings that lies slightly deteriorated but yet has strength capacity determined on site. The process of consolidating degraded timber by impregnation consists of forcing a specific fluid material into it, which when hardened will restore its integrity and improve the physical and mechanical characteristics [2-4].
In addition to strengthening the wood structure, the materials used may also provide some protection against biological pests [5,6]. However it was found that synthetic consolidants, including epoxies, do not significantly increase the resistance of wood against fungi [5-7]. So the application of biocides before or with the consolidant became necessary and the use of boron was a possibility because of its good fungicide and insecticide properties [8,9].
The pair of products which showed the best mechanical results by laboratory tests was an epoxy consolidant and a boron-based biocide [10-12].

After that it was necessary to evaluate the efficiency of the method in wooden elements in buildings [10]. This evaluation was done using the SDT methods of drill resistance and of penetration resistance due to the superficiality of the consolidation (up to 15 mm) and to the necessity of some tools sensitive to that.
The drill resistance device has been seen as a reasonable tool to evaluate mechanical characteristics of timber, even though that was not its original objective [14], nor its most usual application field. Due the sensibility of the tool several authors have recently been evaluating wood properties like the density of some species with the drill resistance equipment in laboratory conditions to estimate this characteristics in timber applied on site [10,14-17]. The mechanical strength and modulus of elasticity have also been correlated with the drill resistance results [14-16]. The penetration resistance technique is also applied to evaluate the surface physic-mechanical characteristics of timber as well as the level of damage of the timber, which depends on its surface hardness and density [10,15,17].

Case study

This case study presents the *in situ* experimental conservation process performed on six moderately degraded sections of structural timber elements from a XIX century palace: three floor beams, a staircase, a wall and a roof beam. In every case the degradation was located in a small part of the element with an extent generally lower than 80 cm. The laboratorial development of the process considered it applicable to wood degraded by fungi, with mass losses lower than 20%. This value is regarded as a limit for the intervention success. For higher values of mass loss, laboratory tests indicated that the resistance was lower than the minimum structural class of Scots Pine [1,18].
The evaluation of the local timber elements condition was made with a drill resistance device and with an penetration resistance device before and after the treatment and consolidation application. The main goals of the use of non-destructive techniques *in situ* were the evaluation of the local degradation condition [19,20] as well as a physical / mechanical efficiency evaluation of the applied treatment and consolidation products.

Materials and Methodology

Treatment and Consolidation

The process consists on an initial application of a boron-based aqueous biocide (Bora-care® - Nisus Corporation). On a second stage, and after the stabilization of

the water content, the two component consolidation product is applied (EPO 155® + K 156® - C.T.S. Srl.). This pair of products was selected among others with a similar individual efficiency, because they proved to have the best joint mechanical efficiency [1,11,12].
Both products were applied on the timber elements by brush (Fig.1). It is also possible to resort to injections whenever it is justifiable [10].
In each of six timber element to be analyzed, three analysis zones were determined: in sound wood (zone C), to control, moderately degraded by fungi (Zone A) and heavily degraded by fungi (Zone B), for comparison

Fig. 1. Application of consolidant a) Wall; b) Staircase; c) Pavement beam 1 [18]

Evaluation tools

Aiming to identify local timber elements condition, drill resistance and penetration resistance equipments were used. To assess the increase of mechanical strength after applying the proposed method, the devices were used before and after the treatment and consolidation application. As verified by [1], the penetration depth of consolidation product is in the order of 10-15 mm. Therefore, the drill resistance measure was determined in an extension of 10 mm for non-structural elements and 15mm for structural elements, always excluding the initial 2 mm, considered as a perturbation zone.
It was verified that drill resistance equipment allowed the identification of strength increase through the density profiles analysis [18].
By a comparative analysis penetration resistance equipment also allows the identification of strength increases, identified by a reduction of the penetration depth.

Results

The results are presented through medium values comparing the situation before and after treatment and consolidation in each timber element moderately degraded by fungi.

Comparing C and A zones is possible to get a rough idea of timber decay levels through both drill resistance and penetration resistance methods, but was no possible to quantify it because of the great variability of results obtained [10,18].
Also with C and B zones, used as references, it is possible to see the significance of the resistance gain after the application of the process. In fact, as shown in table 1, the values of zone A after the treatment and consolidation, in a great number of the cases, approached the registered value for sound wood (zone C).

Table 1 - Summary results of tests performed

Timber Element	**Properties – mean values**	**Zone A** moderately degraded			**Zone B** (heavy degr.)	**Zone C** (sound)
		Initial	**Treated and consolidated**	**Property variation**	**Initial**	**Initial**
Wall	Moisture content (%)	5	5	**0%**	2	12
	Drill resistance	8,5	9,2	**8%**	6,3	13,1
	Penetration resistance (mm)	-	-	**-**	-	12,3
Staircase	Moisture content (%)	10	10	**0%**	7	9
	Drill resistance	6,4	8,7	**36%**	1,0	11,6
	Penetration resistance (mm)	14,1	11,4	**-19%**	17,8	11,4
Timber beam 1	Moisture content (%)	7	8	**14%**	3	7
	Drill resistance	11,8	15,6	**32%**	7,0	12,8
	Penetration resistance (mm)	14,8	13,9	**-6%**	21,3	16,2
Timber beam 2	Moisture content (%)	9	9	**0%**	8	8,5
	drill resistance	10,8	11,1	**3%**	8,2	11,7
	penetration resistance (mm)	19,7	18,2	**-8%**	37,3	16,6
Timber beam 3	Moisture content (%)	9,5	9	**-5%**	8	-
	Drill resistance	9,1	12,3	**35%**	5,98	-
	Penetration resistance (mm)	24,4	19,1	**-22%**	38,1	-
Roof beam	Moisture content (%)	9,5	9	**-5%**	7	9
	Drill resistance	9,4	11,1	**18%**	5,8	10,3
	Penetration resistance (mm)	19,3	18,4	**-5%**	34,3	18,0

The penetration resistance and the drill resistance measurements are affected by moisture content and to obtain correlations of those values with wood properties one must adjust the measurement to a common wood moisture content, such as 12% [21]. For the purpose of this study the goal was to equilibrate de MC for the initial conditions to be possible to do the value comparison in almost the same conditions.
The rise in the drill resistance measurements and the decrease in penetration depth, point to the increase in mechanical strength after the application of the conservation process proposed.
Unable to perform the penetration resistance test on the wall because this element was not supported, which influences the results. For other elements a tendency to

decrease of the penetration resistance penetration was generally verified, which indicates a gain of mechanical resistance.

Final comments

The SDT methods of drill resistance and penetration resistance were very important auxiliary instruments to assess and confirm on site the results obtained in laboratory for the treatment and consolidation process [18].
Conclusions of the case study:
•Efficiency of consolidation by impregnation as a technique of local mechanical strength increase of wood moderately degraded by fungi, applied after the biocide treatment;
•SDT drill resistance and penetration resistance as methods suitable for assessment of consolidation efficiency levels;
•Good sensitivity of the methods to the superficiality of the conservation method (up to 15 mm);
•Suitability application of that technique on site.

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