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Review

In situ assessment of structural timber using the resistance drilling method – Evaluation of usefulness

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HIGHLIGHTS

- Resistance drilling method is useful to estimate the depth of wood decay in timber structures.
- Resistance drilling method should be treated as a qualitative assessment rather than a quantitative one.
- Testing has a point focus and so making responsible estimates of timber properties requires many measurements.

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ABSTRACT

The paper presents a survey of the state-of-the-art of the application of drilling resistance methods as quasi non-destructive (semi-destructive) diagnostic techniques for testing timber structures, with examples of their application. The method is based on correlating drilling resistance and hardness – density of materials. Resistance drilling tests are quasi non-destructive as the openings arising from drilling do not affect the mechanical and aesthetic properties of the material being tested. The average diameter of an opening remaining after testing does not exceed 3 mm. The method enables assessment of the extent of wood damage of the tested elements and a preliminary assessment of the mechanical properties based on an appraisal of internal defects (e.g. wood decay) in the material. The paper presents also research using a mobile drilling resistance device carried out by the authors to investigate the technical state of buildings, including those of high historical value.

Contents

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1. Introduction

Actions aimed at conserving and strengthening historical timber structures are often undertaken without detailed diagnosis of what caused damage. Renovations and interventions in the historical building substance are carried out most often on the basis of analyses of interventions in comparable structures. Researchers, engineers, conservation specialists are overly reliant on intuition when carrying out repairs and strengthening, which can translate into unjustified solutions on economic grounds, mistakes and exceeding the specifications required for strengthening. An accurate diagnosis, which is most important in the conservation of historic buildings, must address in detail the technical condition of structural elements. Testing methods for timber structures can be divided into three types: destructive, semi-destructive (SDT) and non-destructive (NDT).

Wood construction elements are characterised by a large load bearing capacity and stiffness in relation to their own relatively low weight. As a natural material, wood is very sensitive to moisture and damage by biological agents and is characterised by lack of homogeneity. The most common defects in structural timber elements include: flaws in material – slope of grains, knots, shakes and burls, defects due to fungi – stains and rots, defects due to insects, defects due to over-loading – timber cracks, structural failure of members and joints, excessive deflections [1]. The lack of homogeneity in timber translates also to different strength values both in relation to the direction in which fibres have grown in the trunk of the tree, and also to variations in the wood material in terms of its physical and mechanical parameters (density, presence of knots, cleavages). The EN 338:2009 standard [2] defines wood class in relation to specific values describing mechanical properties. These are taken to refer to the whole structure, but in reality for the reasons cited above, parameters of specific structural elements differ from one another [3]. It is important to note, that aside from lack of homogeneity, in the case of historic wooden structures, a number of additional factors influence the mechanical properties of the wood: moisture changes, temperature changes, impact of biological agents and the duration of use of the structure.

The guidelines included in [1] indicate that the appropriate strength grading of timber is one of the most important aspects identified in a detailed survey of timber structures. In order to allocate a wooden structural element to one of the strength classes set out in the EN 338:2009 standard, it is necessary to have ascertained its physical and mechanical properties, such as modulus of elasticity, bending strength and wood density [4]. Assessment of these three timber properties is especially important as overestimation of wood class can result in failure of the building structure, whereas underestimation results in over-sizing of new elements and structural strengthening and unnecessary replacement of historic timber elements with new ones in order to avoid insufficient load-bearing capacity.

One method for assessing wood quality is destructive testing. In the case of historical buildings, extracting samples is as a rule impossible on account of the building character, which is why analysis needs to be based on non-destructive and quasi-destructive testing [5]. Moreover, an additional problem is that interpretation of test results carried out on small wood samples is problematic [6]. When using the NDT method, obtaining qualitative results (extent of possible damage, structural discontinuities etc.), as well as quantitative results (density, resistance, modulus of elasticity) from non-destructive testing requires carrying out non-destructive tests alongside destructive tests on samples taken from structural elements. Correlation of results obtained from non-destructive and quasi-non-destructive and wood strength testing generates system-wide data for carrying out static analysis of timber structures. Appropriate interpretation of results enables the formulation of parameters to be adopted as appropriate solutions for strengthening and conservation of heritage timber structures.

Non-destructive and quasi-non-destructive testing include research on: identifying the mechanical and physical properties of materials and structural elements, identifying flaws and discontinuities in materials, measurement of the geometric dimensions of building structures without interfering with the continuity of their structure or influencing their functional properties. The features, which distinguish the NDT method are: mobility, possibility of testing in a variety of field and atmospheric conditions and much lower costs when compared to more traditional approaches, which are a function of the type of measurement equipment used and analyses carried out. A key factor is also assuring safety of both the structures being tested and the persons operating the measurement equipment.

The most common flaws appearing in timber elements include internal damage and discontinuities. It is important to emphasise that these are difficult to identify as often there are no signs visible on the external material surface until significant damage has taken place. According to [7], 30% of flaws and damage in timber arises internally in structural elements, and so these are impossible to determine through visual assessment methods. Testing timber structures using NDT and SDT methods causes minimal damage to the surface of the elements while at the same time providing information about timber quality inside the structure.

The application of non-destructive testing is especially important in regular monitoring of the structural condition of an heritage building when it is in use. Regularly repeated measurements carried out in specified locations, especially in sensitive areas (e.g. corners, which are susceptible to the impact of damp) in the structure enable identification of threats, which can cause damage suddenly or lead to the destruction of structural building elements. Such threats include structural wood damage caused by for example by insects infesting the wood or by the presence of fungi. The variety of NDT-tools can be used to estimate the extent of such threats and to assess if they are intensifying over time. In addition, such regular monitoring allows for comprehensive, continuous assessment of the condition and function of historical structures. Such actions contribute to assuring the safety of users, helping to preserve the historical and artistic values of buildings and providing for checks, assessments and audits of technical solutions used to date to preserve such sites.

Among non-destructive and quasi-non-destructive tests used to assess and diagnose timber structures, the most common are methods and techniques presented in Table 1, and which are described in detail inter alia in [5,8–14]. Non-destructive and quasi-non-destructive methods can be categorised into two groups: global test methods (for example visual evaluation, ultra-

Table 1
Selected methods available for assessing timber in building structure.

Organoleptic methods	Acoustic methods	Quasi-non-destructive (semi-destructive) methods	Radiographic methods
Visual evaluation	Stress waves	Resistance drilling	X-rays
Acoustic evaluation	Ultrasonic technique	Core-drilling	Gamma rays
Fragrance evaluation	Acoustic emission	Screw withdrawal	
		Hardness tests	
		Needle penetration	
		Pin pushing	
		Tension microspecimens	