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A semi-destructive tension method for evaluating the strength and stiffness of clear wood zones of structural timber elements in-service

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ABSTRACT

The paper presents a new semi-destructive method for obtaining a prediction of the tension parallel to the grain properties of clear wood of structural timber members. This method is less intrusive than other existing methods and consists in extracting four small specimens along the length of the timber members. The tension strength and stiffness obtained is intended to be used as input data for the assessment of timber members in situ. Since the method only provides information regarding clear wood, it will have to be used together with other non- or semi-destructive methods that could accommodate the effect of defects on the loss of clear wood properties. The validation of the method was carried out by a comparison with results obtained from a standard method used for determination of clear wood properties. The results show a good agreement between stiffness values but a medium agreement in the case of tension strength.

1. Introduction

The assessment of the structural performance of existing timber structures is strongly dependent on the capacity to evaluate in situ the physical and mechanical properties of timber elements. Current in situ evaluation is made through the visual assessment of the quality of timber elements (identifying the wood species and their features) having as reference a Visual Strength Grading Standard (VSGS). This procedure leads to the allocation of characteristic strength values or allowable stresses to the timber members. These values can then be modified taken into consideration the load and moisture history of the structure and also its status of conservation (biological and mechanical deterioration). This general process is followed by the Italian standard UNI 11119 [1]. This same standard makes reference to a possible use of non-destructive techniques (NDTs) but it does not indicate the available NDT and in what way they could assist in the definition of the mechanical properties of timber elements.

It is usually accepted that the application of VSGS and of structural design codes intended for new constructions assures over conservative serviceability and safety confidence levels [2]. This approach frequently leads to the demolition or to undertake heavy strengthening (often non-reversible) of timber structures even in cases where no deterioration signals exists and the structures are in service for more than 100 years. This result is critical for historic timber structures where the safety concerns balance with the principle of the conservation of cultural heritage.

The application of VSGS could also deliver unsafe characteristic values in some particular cases (adoption of VSGS developed for other wood species or from wood species with a different provenance) [3]. VSGS along with other available non-destructive methods evaluates the strength and stiffness indirectly by using the correlation between parameters as sound time-of-flight or knot's dimension and the mechanical properties of timber.

A procedure for the prediction of the bending behaviour of timber in service using different non-destructive methods was proposed [4]. This procedure applies the concept that assumes a timber member as a heterogeneous element composed of clear wood and weak wood zones (defined by the presence of knots) [5]. More recent results indicate the usefulness of having semi-destructive methods that could validate the results obtained from the usual non-destructive methods [3].

The need to get more reliable data on the real strength capacity of timber elements was the basis for the studies on semi-destructive or low-destructive methods carried out so far [6–9]. These methods do not estimate but instead actually measure the strength and stiffness of wood by destructive testing of small samples removed from the structural element.

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Semi-destructive tests were developed for determining the Young's Modulus and the compression strength along the grain of clear wood [6,8]. These methods use cylindrical wood cores extracted from the timber elements. The samples are then subject to a diametric compression along the grain. A coefficient of determination of 0.89 and 0.76 was obtained between cylindrical specimens (cores) and ASTM standard clear wood specimens, respectively for compression strength and modulus of elasticity parallel to the grain [6], respectively.

This method is relatively easy to perform using a drill-borer and does not affect the mechanical behaviour of the element since it involves the extraction of a small amount of wood material. However the method requires a careful adjustment of force and grain directions since any slightly deviation can significantly affect the results obtained.

Other authors present a semi-destructive method to determine the tension behaviour of timber elements [7,9]. This method is based on the extraction of a small piece of wood by means of two diagonal cuts along the grain of the timber element. As a result a prismatic specimen with 3–8 mm (side dimensions) is obtained. The ends of the specimen are glued to grooved wooden blocks to reduced the effect of clamping and the specimen is tested in tension, being registered the Young's Modulus and the tension strength. The comparable cross-sectional area of the semi-destructive specimen and the ASTM tension specimen led the authors to conclude that no correction was necessary (assumed a unitary coefficient of determination). The application of this method to structural timber members in service implies the use of a thin-kerf saw blade to carry out the cuts along the grain. The weight of equipment and its operation in situ are two of the setbacks of this method. Also it is not easy to obtain a constant angle between parallel cuts, necessary to get a prismatic section with a minimum removal of wooden material. Another setback is the difficulty in coping with wood variability, since the cross-section of the test pieces only includes a small proportion of the growth rings that exist in a structural timber cross-section [10]. This setback could be minimised by extracting and testing more specimens. However the size of the test pieces limits the number of pieces that could be extracted from the structural members.

When comparing results from test pieces of different dimensions it should be taken into account a possible size effect. The reduction of wood mechanical properties as wood element dimensions increase supports the different studies that have been carried out on size effect [11]. Most of the studies assume a weakest-link model, where rupture takes place at the weakest point along the length of a test element. As the size of the wood element increases the probability of occurrence of a weak point increases. This model seems suitable when considering the brittle behaviour of wood subject to tension parallel to grain. Although the size effect have to be taken into account when comparing results from small clear wood samples, the need to consider it for structural dimension test pieces (containing knots and other gross defects) are not so clear [12].

The present paper presents a new semi-destructive method to assess the tension behaviour of clear wood zones of structural members. The prediction capacity of this method is studied by comparing the results from the new method with the results obtained from a standard test method, used for the determination of the tension parallel to the grain properties of clear wood in the laboratory. The hypothesis tested was that the results obtained using the average result of four mesospecimen were not significantly different from the result obtained using a standard specimen. The comparison study included two different wood species (one hardwood and one softwood) commonly found in timber structures in Portugal.

The data obtained is intended to be used in combination with information provided by other non- and semi-destructive techniques for predicting the mechanical properties of timber structural members in service [3].

2. Description of the semi-destructive tension method proposed

The method was developed having in mind:

– getting direct information (destructive testing) about the strength and stiffness of clear wood zones of structural timber members;
– involving the extraction of small volumes of wood;
– defining a simple and easy procedure to extract the wood sample on site.

Therefore it was devised a method based in the extraction of a small amount of wood material from the arris of the element. The sample corresponds to a prismatic cross section (around $15 \times 15 \times 25$ mm^3) with 150 mm length. The amount of wood material corresponds to the presence of wane within the limits generally accepted by VSGS (not reducing the width or thickness of the timber element by more than 2/3 of the original dimensions).

The extraction is made using an electric jig saw. The wood sample is obtained by performing a cut along the arris (between face and edge) of the timber element, Fig. 1. Compared with a similar method [10] this procedure has the advantage of removing a smaller amount of material and being easier to execute in situ.

The wood sample is then prepared to obtain a specimen with a shape analogous to that used in tension tests of polymeric materials (dumb-shell-shaped) [13]. The modifications made to the dimensions stated in EN ISO 527-2 [13] had in mind: the application of the strain gauge in the middle of the element; the tension grips available; and the necessity to have grip areas long enough to avoid slip and to reduce as much as possible the wood crushing at the jaws areas. The nominal dimensions of the specimens are presented in Fig. 2a). The small cross-section of the specimens at the testing zone (uniform cross-section – 10×5 mm^2) makes the test to be carried out at growth ring's scale. For this reason the specimens are thereafter called mesospecimens.

Regarding the representativeness of the test results two aspects should be taken into consideration:

1. the method only represents the tension properties of the external layer of the timber members at a particular location in the beam. To deal with the lengthwise variation of properties it is

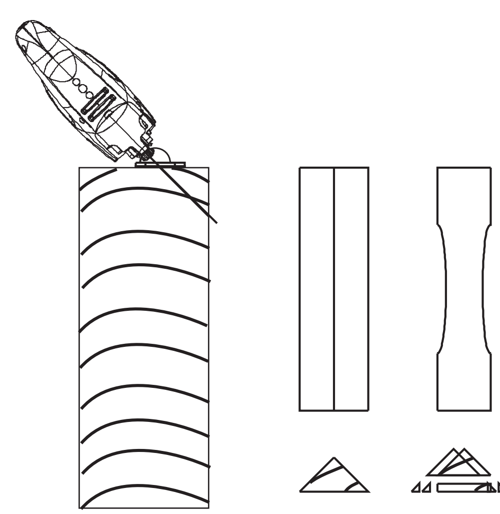

Fig. 1. Method of extraction of the mesospecimen, from left to right: cut of the face-edge corner with a jigsaw, the obtained triangular prism specimen and final arrangements to reach the desired shape.