Assessment of the structural properties of timber members in situ – a probabilistic approach

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Abstract The assessment of the structural performance of existing timber structures is dependent, among other factors, on the capacity to evaluate the physical and mechanical properties of structural timber elements in situ. This paper discusses the possibilities/advantages of using a probabilistic approach to obtain a more reliable prediction of the reference properties of these timber members in situ. The presented approach combines information from common non-destructive techniques (NDT), such as visual assessment and ultrasounds, and those from semi-destructive tests (SDT), as meso tension specimens and wood cores. An application of this approach to maritime pine (*Pinus pinaster* Ait.) and chestnut (*Castanea sativa* Mill.) timber pieces of structural dimension is presented.

Keywords bending strength, modulus of elasticity, non-destructive techniques, structures, visual assessment

1. INTRODUCTION

The assessment of the structural performance of existing timber structures is significantly more difficult for timber members in comparison with other materials, in part due to the high variability of timber properties, both within and between members (heterogeneous material). Nevertheless, in some circumstances (e.g. alteration of use, detection of deterioration) the structural performance of existing structures has to be addressed. The present paper aims to discuss the possibilities/advantages of using an alternative probabilistic approach to obtain a more reliable assessment of the mechanical behaviour of timber members in situ. This approach uses current information taken from visual strength grades and crosses that information with the one obtained by using non and semi destructive methods.

2. A PROBABILITIC APPROACH

The probabilistic modelling of timber elements requires the capability to predict the expected values for the *reference properties*. Two alternative probabilistic models for assessing the reference properties can however be used. One approach uses information about the original quality of the timber element - the most likely visual strength grade to be allocated to a structural member. Indirect or direct tests made at the structural elements or at the structure (proof-loading) can lead to *a posteriori* information about the quality of the timber members. This last information will be use to update the *a priori* information (probabilistic Bayesian approach). The other approach does not take

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into consideration any *a priori* information about the quality of the timber elements, but only the information from direct or indirect measurements made during the appraisal of the structural elements (classical inference).

3. CASE STUDY

The following tests were applied to thirty home-grown maritime pine (*Pinus pinaster* Ait.) and chestnut specimens (*Castanea sativa* Mill.):

- Visual strength grading;
- Ultrasonic time-of-flight readings in different clear wood zones.
- A four-point proof-loading bending test according to EN 408
- Two tension meso-specimens for determinating the modulus of elasticity ($E_{0,t,m}$).
- Two wood cores for density prediction (ρ_c).

As for the Bayesian inference, the initial data (*a priori* information) was provided by the assignment of a particular strength class according to the visual grade of the timber element.

The comparison of the predicted and experimental values of modulus of elasticity, using both the classical and Bayesian approach, shown that Bayesian inference, using information from current approach (visual grading → Strength Class) and from semi and non destructive methods, provided for both wood species the less biased result.

A clear difference was observed for the two species. In the case of maritime pine, an exhaustive mechanical characterization was conducted between 1989 and 1991, leading to the establishment of a visual strength grading standard. These studies can explain that the application of the current approach delivered, as expected, significant conservative values. The two proposed approaches resulted in a shift of the curves to the right and a more unbiased prediction of the modulus of elasticity. In the case of home-grown chestnut, the mechanical characterization of structural elements was never carried out and, therefore, a specific strength grading standard (considering the geographic origin) does not exist. The application of the Italian visual grading standard led to a significant over estimation of the global modulus of elasticity. Nevertheless, there is again a clear contribution of the Bayesian inference for a more unbiased prediction of the modulus of elasticity.

These results shows the importance that the information provided by semi or non-destructive testing can bring to improve the assessment of timber members in situ, when the geographic origin of the wooden material is not known. It should be stressed that this uncertainty about the origin of timber elements in situ is common for many timber structures.

4. CONCLUSIONS

The application of new approaches to the evaluation of the *reference properties* of timber structural members shows that a clear benefit can be attained by combining information from visual strength grading with information gathered from semi and non-destructive techniques.

In the case of the modulus of elasticity, the application of the two probabilistic approaches (with and without *a priori* information) resulted in a less biased estimator (mean error closer to zero) than the simple use of visual grades or strength classes.

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