The strength and stiffness of large ancient timber beams: experimental assessment of the effectiveness of combined visual grading and non-destructive testing

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Abstract

Twelve large ancient beams of Fir wood (Abies alba Mill.), average transverse section 34 x 30 cm, extracted from a XV century building, were studied in order to assess their residual sections and strength/stiffness properties. Visual grading and evaluation of wood defects and decay were performed, since they are necessary not only for the in situ assessment, but for the interpretation of subsequent non-destructive (NDT) instrumental tests as well. Among several NDT techniques, the following were used, since previous experience has shown their effectiveness: stress waves propagation, vibration and hardness tests. All tests have been performed in the laboratory, bearing in mind the practical constraints of in situ operations (costs, easiness of use, etc.). Results show that a thorough visual inspection performed by a skilled operator can provide a reliable chart of the effective residual sections of the beam. Moreover, even though the sample's numerosity cannot authorise any broad generalisation, NDT techniques proved themselves able to give results (E-moduli or strength indexes) well related to the ultimate bending strength of the beams, with correlation coefficients R~0,8. Further improvements in those relationships were achieved through the combination of NDT and visual methods into multi-parameter regressions.

1. Introduction

Large timber structural elements belonging to historical buildings subjected to restoration, repair, strengthening or simply to a change of use, need a correct assessment of the actual individual load-bearing capacity. Appropriate design rules (e.g. Eurocode 5) require reliable characteristic values for density, stiffness and strength properties.

The traditional approach based on testing small clear wood pieces and subsequent mathematical derivation of allowable stresses by application of «appropriate» and unreliable modification factors allowing for defects, decay, duration of load, etc. proved itself intrinsically inaccurate for old timber beams. In fact, the main way to acquire reliable design values for old timber beams is to test full-size old timber beams.

A number of visual and instrumental methods have been developed and used - in Italy and abroad - in order to obtain quantitative data about the strength of timber, but only in a very few cases such data could be related to the actual strength values of full-dimension ancient timber beams through failure tests, as in this study.

2. Material and methods

Twelve large ancient beams were extracted from a XV century Florentine building, during its restoration and reconstruction works. The beams were part of a totally reconstructed large floor.

The beams of Fir wood (Abies alba Mill.) were 5 meters long, and the average transverse size was 34 x 30 cm. This species is traditionally used for structures in many old buildings, particularly in the Central Italy, due to the large availability of large trees purposely cultivated for this use (and also for ship masts).

2.1. *Visual grading*

The first step for the assessment of the selected old timber beams was the visual inspection. In general the main information on the history and actual conditions of the material is achievable through this kind of approach.

Visual evaluation of original wood defects, estimation of decay, identification of previous interventions and visual grading was performed on the twelve specimens, as follows:

- dimension and distribution of knots,
- average and local slope of the grain,
- dimension and distribution of checks and ring shake.

The average width of growth rings and possible changes in the rates of growth, were also recorded.

Location and extension of wood decay was evaluated using simple devices: awl, gimlet, drill etc. The extent and the depth (estimated) of the decay were