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THE prEN 17121: HISTORIC TIMBER STRUCTURES - GUIDELINES FOR THE ON-SITE ASSESSMENT OF LOAD-BEARING TIMBER STRUCTURES.

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Abstract

The intention of this paper is to present the summary of the prEN 17121, a European standard proposal that will be published within 2019.

The scope of the standard is to give guidelines on the criteria to be used for the on-site assessment of load-bearing timber structures in heritage buildings. It is intended for all those concerned with the conservation of heritage buildings that contain wooden elements, from the building owners or authorities who are responsible for them to the professionals employed.

The assessment procedure is based on two phases. The first phase involves: a desk study, a visual survey and a measured survey; the surveys to inform the preliminary structural analysis and the preparation of the preliminary report. The preliminary structural analysis and report should then be used to identify areas of the structure subject to high stresses where a careful inspection is necessary to determine the extent of any damage or deterioration and hence the residual capacity of the members. This is the second phase, which will produce a diagnostic report from the information obtained by the detailed survey.

The detailed survey is aimed at identifying the wood species, at measuring moisture content and moisture gradients, at characterising the biological damage and at assessing the strength of timber. The detailed survey of timber joints closes the survey.

1 INTRODUCTION

The Technical Committee of the European Standardisation Committee CEN/TC 346, "Conservation of cultural property", has the following scope: "Characterisation of materials, the processes, practice, methodologies and documentation of conservation of tangible cultural heritage to support its preservation, protection and maintenance and to enhance its significance. It includes the characterisation of deterioration processes and environmental conditions for cultural heritage and the products and technologies used for the planning and implementation of their conservation, restoration, repair and maintenance". Within the aims of this list are also historic timber structures, which undoubtedly form part of the European and world tangible cultural heritage. For these reasons the TC decided in its 2012 business plan to establish the WG 10 (Historic timber structures). The scope of the new working group was the assessment of load bearing timber structures in heritage buildings, that is to prepare within five years a pre-standard in the form of guidelines for the evaluation and diagnosis of historic timber structures.

The request for the opening of this working group started from a previous activity of a group of specialists who met as a collateral activity of the COST Action IE0601 "Wood Science for the conservation of Cultural Heritage", active from 18th April 2007 to 17th April 2011 producing a frequently mentioned paper published by the International Journal of Architectural Heritage [1].

The official start of the activity took place with the first meeting on 11th March 2013, held in Italy, while the delivery of the final document, numbered as prEN 17121, ready for the formal vote, took place at the end of February 2019. The formal vote was closed in the month of May of the same year, since a six-month concession was obtained with respect to the closure of the initially planned activities. Given the topics covered by the document, the text was also subjected to an evaluation by the CEN TC250 "Structural Eurocodes" expert group.

The purpose of this work is to present the main aspects of prEN 17121, as a summary of the main guidelines indicated in the text.

2 GENERAL ORGANISATION OF THE STANDARD

After an introduction stating some important points regarding the protection of historic timber structures, the standard is organised in three main parts: the description of the preliminary assessment, the description of the detailed survey and, finally, an informative annex that lists current tools for non-destructive analyses on timber structures.

It is worth mentioning some of the important statements of the introduction: heritage structures are important historic artefacts, which differ from other existing structures in that a greater value is placed on their fabric because of their historical significance. This may justify greater expenses and caution both in the survey, diagnosis and assessment of the structure and in the consideration of the repair that might be employed.

The standard doesn't extend to providing guidelines for the design of repairs, nevertheless it suggests that intervention works should only be carried out to a heritage structure as a last resort and should have a minimal impact on the building fabric.

Before describing the operational aspects of the standard, it is important to present its general scope: to give guidelines on the criteria to be used for on-site assessment of load-bearing timber structures in heritage buildings. It is intended for all those concerned with the conservation of heritage buildings which contain wooden elements, from building owners or authorities who are responsible for them to the professionals employed.

Although the original intention was that the standard should be applicable to any kind of timber member and to any kind of historic timber structures, it was decided to exclude timber members made of engineered wood products (i.e. glued laminated timber).

3 THE ASSESSMENT PROCEDURE

The guidelines state that the procedure required for the on-site examination and assessment of an historic timber structure is based on a first phase that is the preliminary assessment, including desk study, visual survey, measured survey, preliminary structural analysis. All these steps lead to the preparation of the preliminary report. The second phase is the detailed survey that produces the diagnostic report.

The previous list suggests a linear process, but often conservation work involves iterations, such as repeating the detailed survey in particular parts of the structure after applying the results to the preliminary structural analysis. It is important to regard historic buildings as organisms, so we need to use a holistic approach, considering and evaluating the structure as a whole, rather than individual members and joints.

All the detailed works should be carried out by professionals already having knowledge of timber structures.

3.1 The preliminary assessment

The assessment is performed in order to determine whether the structure is at present adequate to carry the loads that it is required to carry and will continue to be adequate for the foreseeable future, recognizing that structures that have proved to be adequate in the past will continue to be adequate except when: there is a possible change in loads; timber has been decayed by organisms or mechanically damaged; there have been alterations or interventions to the structure; there is the need to ensure that the structure is adequate to withstand extreme climates or events; there have been changes in the service conditions.

The first part of the preliminary assessment is the desk study, aimed at gathering documentary and other sources of information relating to the structure. Through the desk study it will be possible to obtain information on the historical aspects of the structure, the associated load history and the previous interventions or restorations. These are basic for the historical analysis aimed at describing the process and phases of building and identifying any subsequent events that had a significant influence on the behaviour of the structure.

3.1.1 Preliminary visual survey and measured survey

Before analysing the operational parts of the document, it is worth underlining three main aspects strictly related to the survey methodology. First, any survey and diagnostic method used for the assessment of heritage structures shall be semi or non-destructive. Second, the assessment results pertain to the moment of the assessment, since degradation is a continuing process. Third, any survey must be carried out meeting the following conditions: structural safety, health safety, appropriate accessibility, accompanied by the right lighting and the cleanliness of the members to be examined (Figure 1).

Figure 1: operators must have a safe access to the structures

Once all the points listed have been ascertained, a preliminary survey is required to identify any obvious damage and susceptible and dangerous zones of the structure, to set the assessment strategy, and to identify the possible need for immediate propping/safety measures/access restriction.

The preliminary survey is also aimed at planning the measurement and detailed survey and to note what provisions are required to provide adequate access to the structure.

The measured survey will show the general arrangement of the structural members, various phases and execution and modification of the structure and the dimensions of the members (sections and sizes) and of the joints through the geometric survey.

The measured survey includes also the diagnostic survey, that shall comprise a general indication of wood species by the visual appearance of the members. At this level it is important to distinguish between softwood or hardwood. Together with wood species the diagnostic survey will collect measurements about the environmental conditions and related wood moisture content [2], and will record all the strength reducing characteristics and any damage.

3.1.2 Structural analysis and preliminary report

The person in charge of the preliminary survey should use all information gathered to carry at a preliminary structural analysis. The analysis must describe the structural system, that is both how the loads are brought to the ground and the type and stress levels in the principal structural members.

The main aim of the preliminary structural analysis is the identification of highly stressed areas of the structure where more attention is required, particularly for the critical areas/zones identified during the condition survey, where a careful inspection is needed to determine the extent of any damage or deterioration and hence the residual capacity of member (the principal scope of the detailed survey). In some cases, a simple and conservative assessment of the structural system, of the member properties and their effective cross sections, as well as joint performance, may be sufficient. Alternatively, when the survey identifies timber members or joint carrying loads critical to the behaviour of the structure as a whole, the preliminary assessment shall indicate the need for a detailed survey.

It is important that the results of the structural analysis are compatible with the recorded pathology of the structure, such as failure of members or joints or excessive deformations.

Finally, the preliminary structural analysis will be followed by the final document of the preliminary investigations, the preliminary report. This shall include: dimensioned drawings of the whole structure; documentation of problems and pathologies; a note of timbers and joints that have not been inspected and why; service classes and service uses; structural assessment showing the assumptions for the calculations; existing wood treatments (for the

safety of the operators and support to possible recommendations regarding curative or protection treatments); interpretation of the causes of damage and the general behaviour of the structure.

The report will identify subsequent survey work required, fully justifying the need for any recommended work and noting any places where there is need to open up the structure to enable the detailed survey work to be carried out.

3.2 The detailed survey

Following the results of the preliminary structural analysis and the conclusions of the preliminary report, the detailed survey will apply a greater detail in order to determine for all members and structural joints: wood species; moisture content and moisture gradients; presence and effects of biological decay; strength grade or strength values.

The listed features are particularly important for the critical areas of the structure, to recalculate stress and deformation levels, to support the final diagnostic report that will contain all the detailed information concerning the points previously listed.

To perform the detailed survey, operators will need to literally touch members and joints in order to be able, for example, to identify sawn faces and axe hewn or adzed faces, thus the conditions for safety, accessibility, visibility and cleaning are as important as for the preliminary survey.

A couple of examples to compare the detailed survey to the preliminary one: the identification of wood species will require, where the visual evaluation cannot reach a satisfying reliability of the result, the drawing of samples to be sent for laboratory identification of timber [3]. The moisture content must be measured in any point of the structure where there is higher risk of biological attack and where the presence of a fungal decay suggests a need to estimate the moisture gradient in depth or along the length of members.

3.2.1 Characterisation of biological damage

The characterisation of the biological damage must ascertain two main aspects: its nature and cause and, the assessment of the effective cross section.

Hence the first aspect to note is the nature of the decay, principally fungal rot and/or insect attack, and if the attack is still active. The possible interaction between the attack and the environment shall be noted, together with the determination of moisture conditions of wood in contact with other materials, such as masonry and/or metals.

Figure 2: an important fungal rot at a tie-beam rafter joint. The external appearance does not allow to infer the real residual cross section.

For sections with a biological attack, or where insect attack is confined to a well-defined area of the cross section, the effective cross section shall be measured and used to calculate the strength (Figure 2). Non-destructive or low-destructive techniques may be used to help the estimation of the effective cross section; the method used shall be recorded, remembering that the strength of wood attacked by fungal rot is always equal to zero and that the insect attack on the surface of large cross-section members may be ignored.

3.2.2 Strength assessment of timber

All members judged to be important in the preliminary report for the strength, serviceability and stability of structure have to be strength graded, noting that the grading depends highly on the structural type, for which, for example, the members subjected to compression do not need to be classified. The standard lists the different structural types and their different need for classification.

The European standard EN 14081-1:2016 [4] lists the strength reducing characteristics that must be used to visually strength grade the members, according to their dimensions and position. In detail the strength-reducing characteristics measurable in a non-destructive way during a detailed on-site survey are knots (Figure 3), grain deviation and shrinkage fissures, evaluated by an experienced specialist in wood and timber structures.

As stated in EN 14081-1, because of the diversity of existing visual grading rules in use in different countries, it is currently impossible to lay down a single set of acceptable rules for all Member States, thus only the basic principles are indicated here. Measurement methods, grading rules and strength classes will be then determined at national level, taking into account the supposed provenance of the material rather than the location of the structure.

Figure 3: measurement of knot dimensions and position along the member

Those responsible for the assessment can also decide to complete the assessment by supplementary tests through the use of one or more non-destructive methods, even for a global assessment of the structure. In any case test methods shall be chosen without having an adverse effect on the structure.

3.2.3 Detailed survey of timber joints

Historical timber structures always have structural joints that transfer the loads from one member to another. So the health of a timber structure is based not only on the quality of the individual members but also on the efficiency of its structural joints.

It is important to understand the way in which the joint was made (or should have been made) and the way in which it was intended to transfer loads. The joint may not be performing in this way today because of poor initial design or workmanship in the first instance, because of changes and/or damage that has occurred over time. In fact, existing joints in historic structures may usually be considered as adequate for the loads that they are carrying and will

require no detailed assessment except where there has been an increase in the load or when they show obvious deficiencies or damage. The standard document lists the possible critical conditions according to the joint type and the applied stresses.

In these cases the detailed geometry of joints should be measured, noting any deviation from the original conditions, considering the possible workmanship and alterations (wood decay, failures, movements, human interventions, metal fasteners, etc.).

4 THE INFORMATIVE ANNEX

Even if the annex is not normative, but only informative, it cannot be considered of negligible importance, even though we recognize possible updating problems. It is in fact a list of tools that can be used for detailed on-site diagnosis of timber structures, some of which need to be used, such as electric moisture meters for estimating wood moisture content.

But the annex is not a simple list, because for each of the listed tools an explanation is offered on their use and what use may be made of them in the course of on-site diagnostics.

Some examples of particular relevance can be given here. For electric moisture meters it is noted that, according to European regulations on sawn timber, these tools do not measure the wood moisture content, but only estimate it. That is because the measurement of wood moisture can only be done with the gravimetric method, which is destructive and therefore not applicable to an on-site activity, nor to heritage structures [5].

Another important example is the on-site use of resistance drilling tools, which are nowadays a basic tool for the evaluation of the residual cross sections. Other applications, although mentioned in some documents [6]. Are not mentioned in the standard given some doubts about their reliability.

As already mentioned, the major concern with this list is that some of the detailed equipment may become obsolete over time, while at the same time new ones may appear on the market. However, at the time of publication of the standard and in the period before its revision, this annex can be considered to be sufficiently reliable.

5 CONCLUSIONS AND OUTLOOK

This contribution is intended to explain in summary the main guidelines described in the standard (at the time of writing this article was still at the prEN level) on the Assessment of historic timber structures.

The normative document closes by stating that the detailed diagnosis must be followed by a detailed structural analysis, but without specifying how and what its contents should be.

Similarly, guidelines for the structural recovery, i.e. repair of historic wooden structures is not covered.

This could be the subject of a possible new normative document, but for the moment, the working group WG10 believes it has brought to publication a sufficiently useful document, necessary for the recognition phase of the importance of historic wooden structures and for their protection.

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