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Italian Standardisation Activity in the Field of Diagnosis and Restoration of Ancient Timber Structures

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ABSTRACT: The standardisation activity in the field of cultural heritage started in Italy in 1996, following an agreement between the Ministry of Culture and the Italian Standardisation body (UNI) through the constitution of the Technical Committee UNI / NORMAL (Cultural Heritage). The activities of the WG 20 (Wood and wooden materials) began in 1999 and gave the rise to the standardisation actions on wooden artefacts belonging to the cultural heritage.
Even if timber structures are only a part in the huge world of wooden objects coming from the past, nevertheless the importance of many structures, the safety needs of many public historic buildings and many bad restoration examples forced the WG 20 to start working on different standard projects on the ancient timber structures. The first two standards published embrace the problems of the diagnosis through visual on-site inspections and of the intervention criteria on ancient timber structures to be restored. The aim of the paper is the description of the two mentioned standards.

1 FOREWORD

On June 1996 an agreement was signed by the Ministry of Cultural Heritage and U.N.I (Italian standardisation body). The aim of the agreement was to activate a collaboration which would help in developing common technical standards valid on a national level and suitable for proposal on a European level.
The agreement consequently gave birth to the UNI - NORMAL Technical Committee whose activity is unique in the world in developing specific standards in the conservation of artefacts which constitute the cultural patrimony of every country. Presently, are active the Work Groups listed in table 1.

Table 1 : lists of WGs within the UNI – Normal TC.

WG 1 Biological methodologies	WG 10 Methodologies for documentation
WG 2 Experimentation in the control of biodeterogens	WG 11 Methodologies for the characterisation and restoration of historical mortars
WG 3 Chemical methodologies	WG 12 Metallic materials
WG 4 Atmospheric pollution	WG 13 Methodologies for petrography
WG 5 Methodologies in conservation of surfaces	WG 14 Non destructive and mechanical tests
WG 6 Methodologies for the characterisation of ceramics and WGasses	WG 15 Structures
WG 7 Laboratory physical methodologies	WG 19 Humidity in walls: methodologies for the evaluation
WG 8 Environmental physics	WG 20 Wood and wood based materials
WG 9 Methodologies for the survey	WG 21 Paper
WG 22 Museum technologies	WG 23 Mixed group

Work Group 20 (Wood and wood based products) of the UNI -NORMAL TC was established in 1999, with the aim of studying and producing standards focused on the approach to material.
This approach derives from the observation that the versatility of wood as a raw material is such that the actual variety of typologies of wooden artefacts considered a part of Cultural Heritage, is extremely vast: from a building to a painting, from inlaid work to furniture, from musical instruments to work tools and from statues to archaeological wooden fragments more or less legible. Confronting each artefact's typology independently would have allowed for unacceptable dispersion and would have produced a series of enormous super impositions of analysis in the characterization of material. It is in fact, this kind of analysis which is the unifying element: whatever kind of wooden artefact, the characterization of material is uniform.
The participation to the Work Groups is very broad from the outset: more than 40 experts belonging to diverse fields were invited to contribute their varied activities of study in the restoration of wooden artefacts in order to obtain the widest possible shared documents.

2 THE ACTIVITY OF WG 20

The activity was organized through the institution of *ad hoc* groups on a series of standard projects.
The final product is a set of published standards that indicates a correct approach towards wooden material and deteriorated wooden artefacts, including criteria to follow in their restoration, conservation and maintenance.
Projects which have been set up and for the most part have already been approved have two principle goals in mind: the development of a common terminology and a common standard.

2.1 Standards on terminology

The participation of numerous specialists from diverse disciplines required the development of a series of standards which contained a common language.
A series of *ad hoc groups* were formulated for the above-mentioned reason and for the development for the following documents (having all the same initial title of Cultural Heritage - Wooden Artefact):

- Terminology for wood decay
- Terminology for wood treatments
- Load bearing structures - Terminology for the configuration and constituent parts of timber structures
- Door and window frames - Terminology for structural configurations and constituent parts
- Substrate of paintings - Terminology for constituent parts
- Load bearing structures - Terminology for structural decay of load bearing timber structures.

2.2 Methodological standards

The *ad hoc* groups dealing with methodological standards followed two principles: first, the importance of the actual material rather than the typology of the artefact; second, the methodological standard intended as a guideline.
The first *ad hoc* group which was organized with this approach produced a document already published entitled "Cultural Heritage - Wooden Artefacts - Guide line for the conservation, maintenance and restoration" (UNI 11161, 2005). This document is the *basis* for all the other guideline standards and the *link* between the various steps of the project involving conservation, maintenance and restoration of wooden artefact typology.
What is asked for more specifically is:

- to trace down any eventual historical documentation;
- a description of the artefact and photographic documentation;
- a survey of the artefact and a graphic representation;
- dating of the artefact, specifying the methodology used;
- identification of the wooden species that constitutes the artefact;
- identification of the thermo-hygrometric environment which is typical in the conservation of the artefact and the consequent hygrometric state of the wood;
- determination of the artefact's environmental conditions of conservation after the intervention;
- execution of the diagnosis of the artefact's state of conservation and all of its wooden parts through recognition, classification and quantification of decay (abiotic and biotic);
- a description of the modality of execution of the intervention and control of its efficiency.

Two standards from this group which are already approved and more specifically the object of this presentation are: UNI 11119 "Cultural Heritage - Wooden Artefacts - Load bearing Structures of Buildings - On site inspection for the diagnosis of timber members" (2004) and UNI 11138 "Cultural Heritage - Load bearing structures of buildings - Criteria for the preliminary evaluation, design and execution of works" (2004).

3 UNI 11119 "CULTURAL HERITAGE WOODEN ARTEFACTS -LOAD-BEARING STRUCTURES - ON SITE INSPECTIONS FOR THE DIAGNOSIS OF TIMBER MEMBERS".

3.1 Aim and field of application

The aim of this standard is to establish objectives, procedures and criteria in the execution of inspection through which one can evaluate the state of conservation and assess the performances of timber members in load-bearing ancient timber structures.

3.2 Objectives of the Inspection

The inspection must evaluate the original characteristics of each timber member and the eventual modifications which each member underwent during its service life. The information that one must collect is as follows:

- wooden species;
- moisture content of wood and eventual moisture gradients;
- class of biological risk of the wooden member, according to EN 335-1 (1992) and EN 335-2 (1992);
- geometry and morphology of the timber member indicating the position and extension of main defects, decay or possible damage that is present;
- position, shape and dimension of the critical area and critical section;
- strength grading of the wooden member as a whole and/or in sinWGe critical areas.

For the execution of an inspection the following preliminary conditions must be fulfilled: accessibility, cleaning, lighting.
If these preliminary conditions are absent or insufficiently met they can impede inspection or else limit the quantity and quality of accessible information.

3.3 Procedure

The procedure obviously involves the identification of wooden species, the determination of wood moisture content with non destructive methods, and the determination of the level of biological risk according to the EN 335-1 and 2 standards. These procedures can be carried out on any kind of wooden artefact.

More specifically, the structures must undergo geometric surveys; surveys that take into account the original characteristics of the wooden member (such as position of the pith, growth irregularities); type, length and position of principle defects and any other information that will allow one to obtain all the necessary information about the mechanical characteristics of the timber members.
In order to evaluate the mechanical performance of each timber member it is of fundamental importance to identify the so called "critical area", defined as "part of a wooden element with longitudinal axes no less than 150 mm, which is considered to be relevant because of defects, position, state of conservation and also stress conditions which are determined by static analysis".
Through the individualization of the critical area and based on the of defects and decay it is possible to execute a structural grading of the timber elements.

Table 2 : grading rules for structural wooden members

Feature	On site grade		
	I	II	III
Wanes	1/8	1/5	1/3
Various damages frost cracks ring shakes	absent	absent	admissible only if limited
Single knots	≤1/5 ≤50mm	≤1/3 ≤70mm	≤1/2
Group of knots	≤2/5	≤2/3	≤3/4
Slope of grain in radial section	≤1/14 (-7%)	≤1/8 (-12%)	≤1/5 (20%)
inclination% in tangential section	≤1/10 (10%)	≤1/5 (20%)	≤1/3 (-33%)
shrinkage checks	admissible if not passing through the pith		

This classification derives from a type of analysis which is *visual* and therefore is only practicable on the parts which are directly visible. Where and when the presence of non visible alterations is suspected it is necessary to carry out actions by means of proper instrumentation that prove the presence and extension of alterations, in order to determine the efficient section, "the cross section of a wooden member (including defects) where the critical section is excluded from analysis and where actual wood degradation and/or damage are determined". It is important to note that the surveys to be executed must not only be non destructive but also consider the *impact* on other relevant aspects of the structure (e.g. decorations). The results from the survey must be validated for *each* timber member and for *each* area of a member.
Grading is carried out based on the grading table in table 2.
During the grading phase it is fundamental to observe with great care the following general criteria:

- classify the entire wooden member and if necessary, identify each critical area separately;
- take into consideration the limitations that derive from the conditions of accessibility and visibility of the wooden member's surface;
- if an alteration occurs due to mechanical damage or localized biological decay (rot, insect attacks found on the surface) refer the classification only to the efficient section;

3.4 Inspection Report

The inspection report must comprise of a written account which includes at least the following list:

- data which identifies the structure;
- specific objectives of the inspection;
- period in which the inspection was carried out (date);

- description of eventual technical instruments used;
- description of the results referred to the structure as a whole or to the structural unit;
- name, qualification and signature of the person responsible for the inspection.

The standard also includes a table which gives the maximum values of stresses that can be used applying the *admissible stress design* methods and average MOEs for each category and species of timber. Some research laboratories are undergoing surveys to define and update the criteria for grading and resistance profiles.

4 UNI 111138 "CULTURAL HERITAGE – WOODEN ARTEFACTS - LOAD BEARING STRUCTURES OF BUILDINGS - CRITERIA FOR THE PRELIMINARY EVALUATION, DESIGN AND EXECUTION OF WORKS".

This standard deals with the design and execution of restoration interventions in ancient timber structures that belong to our cultural heritage with the principle aim of the standard being the conservation of above said timber structure typologies. The conservation of the wooden artefacts belonging to our cultural heritage and therefore, of cultural, historical and artistic interest constitutes multidisciplinary activities. In this context, the technical standard establishes the technical-scientific principles to be followed for future operations without supplying all the operative details.

4.1 Scope and field of application

As already mentioned above, this standard establishes general principles to be followed during an operation involving restoration of timber structures of historical and cultural interest and indicates the steps that any restoration project in this field must follow:

a) preventative evaluation of the state of the artefact
b) planning possible intervention, if required
c) criteria for controlling the efficiency of an intervention
d) methodology and techniques in the execution of an intervention
e) periodic inspections

4.2 Preventative evaluation of the actual conditions

The aim of a preventative evaluation is to understand the performance of the overall static suitability of a building and the role of the timber structure within the building. Keeping this in mind, its sole purpose is to serve as knowledge and does not necessarily mean that the execution of a restoration intervention must be carried out.
Preventative evaluation must be based on a series of preliminary operations which can be more or less thoroughly examined or not shown at all, depending on the major or minor complexity of the problem and the level of detail requested for the structure.
Historical analysis is a very important analysis which reveals the historical events of a building such as its structural typology and its evolution, its construction characteristics and traumatic events. A dendrochronological analysis of the wooden member (UNI 11141, 2004) can also play an important role in this documentation area.

Characterization of materials is carried out according to the UNI standards 11118 (2004) and 11119 (2004) , in that it follows the absolutely necessary informative role of the diagnosis.
In all cases, a *geometric survey* must be carried out on the structure and on each wooden member, including its state of deformation, the defects of the wood and its particular shape, which can reach levels that cannot be neglected in cases dealing with ancient structures.

The *characterization of decay* helps to analyze the interaction between biotic decay and micro-climates that have established around the wooden member or a part of it (figure 1). Decay may have established by non biotic causes, therefore, this type of analysis must also keep in mind the state of stress and the interaction between the timber members.
The *structural analysis* must always be considered compulsory even though the different levels of detail can vary depending on the complexity of the problem and the entity of the proposed intervention. The structural scheme must refer to the situation of the building as a whole, including all non wooden parts, and defining their contribution to the whole wooden structural scheme, including single wooden structural units. Particular attention must be paid when verifying the joints of single timber members pertaining to the heads of beams.

Figure 1 : Localized biological decay (rot) at the end of a roof timber truss, at the connection with masonry walls.

4.3 Planning intervention

The section regarding the *planning of an intervention* is the most detailed of the entire standard and indicates at each step informative criteria for planning choices, defines actions and the criteria to follow during a restoration intervention, gives indications regarding the definition of a maintenance and inspection program and gives information about the essential requirements of a project.
Because of space limitations, we cannot go into detail about each point listed below. It must be highlighted the importance of preliminary studies through a multidisciplinary approach, which precisely defines the characteristics of the material (and its interaction with other materials) and the typology of decay/damage found.
The definition of an intervention plan must go through an analysis of compatibility with itself and other materials and with the future function of the actual structure. With this in mind the plan must define:

- the specific aim of every work and its necessity, meaning a statement that demonstrates an absence of necessary levels of safety of the structure;
- the location of the intervention;
- the materials that one intends to use;
- the methodology of application;
- the preliminary evaluation of the effectiveness of an intervention;
- verification during the execution phase and at the end of the intervention, as well as those that should take place periodically.

Figure 2 : On the left, integration with new wooden pieces of the elements of a roof timber truss; on the right, on site integration of timber elements in an ancient queen post truss.

What makes the approach to this standard so innovative is probably in the last two clauses of the list.
Clause e) states that it is obligatory to control the efficiency of an intervention when carried out, in a laboratory or during the realization of the project itself, therefore through direct physical experimentation or through experimental simulation but there is also the possibility of extending similar known results to the case in object.
The following clause f) states that it is required to clearly indicate the type and the time intervals of periodic maintenance carried out on the artefact that has undergone intervention as well as the methodology of efficiency control of an intervention through the course of time.
The most significant criteria pertaining to project choices are listed as indications to be followed whenever possible, within the limits of imposed criteria considered more important such as the stability of a building or levels of safety.
Also stated is that all interventions that have been designed and realized should leave a *trace* that should not be hidden but, rather, pleasantly included within the actual structural context. In addition, operations involving the removal of past interventions are to be generally avoided.
The overall performance of the static model must be maintained and respected during the restoration intervention, in the same way that pre-existing joints and restraints must be restored maintaining their original stiffness values.
Care must be taken, when designing an intervention, in order to guarantee the possibility of a variation of a timber member's dimension which can be caused by variations of its moisture content: therefore, interventions where the longitudinal cracks caused by shrinkage have been tampered with or interventions which impede in any way the transversal swelling and shrinkage of wood are not admissible.

4.4 Criteria for controlling the efficiency of an intervention

The evaluation of the efficiency of an intervention is an integral part of an actual intervention plan, and therefore is obligatory. It can be carried out generically or through direct physical experimentation or through numeric experimentation, (in other words on a laboratory scale sample) based on trusted and proven mathematical models.
Special attention must be paid assuming the results of laboratory simulations (figure 3), with regard to the scale adopted for the specimens and to the time parameter.
The standard also imposes that the interventions are carried out by personnel with proven experience in works involving ancient timber restoration.

Figure 3 : Preliminary evaluation of the effectiveness of an intervention: on the left, test on a full scale model of a composite timber - timber floor structure; on the right, test on the full scale model of a 25 m queen-post truss reconstructed in laboratory.

4.5 Periodic Inspection

Documentation must also contain a *Maintenance Plan*, which should clearly indicate the typology and time intervals of periodic inspections as well as the type of periodic ordinary maintenance. Indeed it has been demonstrated that, more often than not, the decay of a wooden structure is due to the lack of ordinary maintenance, periodic inspections, as well as the bad planning and execution of recent interventions of restoration.
Therefore, periodic inspections should execute an attentive visual examination in order to ascertain if single members show possible new or accentuated dangerous conditions which may be caused by excessive load bearing or environmental conditions.

5 CONCLUSIONS

Most of the standard which was prepared by the WG 20 of the UNI – Normal TC, deals with the problem of restoration of ancient timber structures.
The problems associated with restoration of ancient timber structures was heavily felt by many specialists and operators from various fields of structural restoration: architects, civil engineers, wood technologists, the Superintendence, and building companies.
The two standards here presented are the first produced by the WG 20, with the intention of supplying precise answers to questions posed in the market of monumental building restoration, without neglecting other timber structures of minor noteworthiness but equally important for the safeguarding of buildings pertaining to the Italian cultural heritage.
These documents are the response to a precise request by the Italian industry and are mainly relevant for our own reality, namely, the new Technical Committee in the CEN area of cultural heritage (TC 346) which will be made up of an open ad hoc group which will use these two documents as a basis for discussion when comparing analogous European documents.
At the present time, we hope for a widespread diffusion and application of these two new standards at national level.

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