

## **COST ACTION FP1101 “ASSESSMENT, REINFORCEMENT AND MONITORING OF TIMBER STRUCTURES”**

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**ABSTRACT:** This paper reports on the new COST Action FP1101 “Assessment, Reinforcement and Monitoring of Timber Structures”. The objective of the Action is to increase confidence of designers, authorities and end-users in use of timber in the design of new and in the repair of old structures by developing and disseminating assessment, reinforcement and monitoring methods and guidelines. COST Action FP1101 will build on previous findings, target the existing shortcomings, benefit from multidisciplinary views and innovative solutions by the involved stakeholders, enable synergies between them, and provide an effective way of discussing and disseminating the results from on-going projects. The paper summarizes the relevant results from COST Action E55 and RILEM committee AST-215, provides the rationale for the new Action, and gives an overview of the proposed scientific program.

**KEYWORDS:** timber structures, assessment, reinforcement, monitoring, COST Action

### **1 INTRODUCTION**

Timber has been used as structural material for centuries and numerous examples demonstrate its durability if properly designed and built and when adequately assessed and monitored. In recent years, the use of timber in structures has gained new importance, considering that it is the only truly renewable building material. The timber sector in Europe, however, is characterized by relatively small and locally working companies. While the level of technologies and experience in design and construction is relatively good, the current practice of assessing and monitoring of existing timber structures, based on very heterogeneous traditions, is not sufficient to ensure confident decisions about their reliability and can lead to unnecessary costly rehabilitation measures or premature dismantling.

#### **1.1 ASSESSMENT OF TIMBER STRUCTURES**

The last decades were marked by a widening in the range of application of timber in structures and consequently a growing importance of the assessment of these structures. The time and cost of structural assessment are justified by ensuring safety, and protecting investments and cultural heritage.

A wide variety of methods exist to evaluate timber structures, however, their frequency and scope, the decision making approach concerning safety and the necessary interventions are far from being agreed upon. Most assessment methods used today can give qualitative information about the state of in-situ timber, but only few give reliable quantitative information [1,2].

Methods can be non-destructive (NDT); which are useful for the screening for potential problem areas for the qualitative assessment of structures. But a drawback of NDT is the relatively poor correlation between the measured quantity and material strength. Semi-destructive techniques (SDT) bridge the gap between NDT and fully destructive methods; they often require the extraction of samples for subsequent testing to determine elastic and strength parameters while preserving the member's integrity. One problem of SDT is the high variability in test observations.

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## 1.2 RETROFITTING OF TIMBER STRUCTURES

The need for structural reinforcement of timber buildings results from various requirements such as change of use, deterioration, exceptional damaging incidents, new regulatory requirements, or interventions to increase structural resistance. About 50% of all construction in Europe is related to existing buildings, this leads to a growing need for the maintenance and upgrading of existing buildings, not only for economical but also environmental, historical and social concerns. Over 80% of European buildings are over 50 years old; they need to be upgraded to reflect the requirements of energy- and use-efficiency [3,4].

Recent developments related to structural reinforcement [5-10] can be grouped into three categories: (i) addition of new structural systems to support the existing structure, (ii) configuration of a composite system (timber-concrete, timber-steel, timber-FRP, and timber-timber), and (iii) incorporation of reinforcing elements to increase strength and stiffness. Rational guidelines are needed for these technologies for in-situ use and special considerations are necessary when the structure belongs to cultural heritage.

## 1.3 MONITORING OF TIMBER STRUCTURES

The monitoring of timber structures received special attention after the collapse of the ice rink in Bad Reichenhall, Germany, in 2006 [11], which only stands as one example of a series of structural failures [12]: e.g. those of over 50 timber structures in Sweden [13].

Structures are being monitored: i) during structural renovations where the acquired data is used to provide the basis for further action; ii) to acquire information when progressive phenomena are suspected; iii) to prevent or reduce the cost of interventions during building maintenance; and iv) to evaluate the long-term effectiveness of interventions.

Although recent developments focus on simple, robust and redundant systems [14,15], presently, the monitoring of timber structures mostly consists of regular on-site visits [16,17] that only give qualitative answers to whether a structure conforms to regulations or not.

## 2 SUMMARY OF RECENT WORK

### 2.1 COST ACTION E55

The main objective of COST Action E55 was to provide the basic framework for the efficient and sustainable use of timber as a structural and building material. The Action was structured into three working groups: 1) Assessment of failures and malfunction, 2) Vulnerability of timber structures, and 3) Robustness of timber structures. Within the scope of Working Group 1, focus was laid on studying structural failures of timber structures around Europe, resulting in a scheme to classify failures in the future.

Another objective was to discuss and develop guidelines on implementing inspections on structures to improve their reliability over the anticipated lifetime. To expand this domain, it seemed desirable to append a collection and evaluation of existing assessment and monitoring methods. A Task Group within E55 targeted this objective and published its findings [2]. The report contains the assessment methods which have been evaluated by a group of experts against keywords like applicability, expenditure of time/cost, validity of results and possible constraints. In addition, common approaches towards the assessment of timber structures and the subsequent documentation are given. Consent was found that most assessment methods utilized today can give qualitative information but only few NDT methods can deliver quantifiable information.

Methods to determine strength parameters of built-in timber elements are very scarce; more methods exist to derive timber stiffness parameters. The correlation, however, between stiffness and strength parameters is usually not very high, especially for strength parameters featuring brittle failure modes. From this latter finding and the fact that any single method only allows assessing certain types of material properties, damages or degradation processes, follows the necessity to combine assessment methods to derive a clearer picture of the performance of the structure.

All data require careful evaluation by an experienced engineer and/or wood scientist who considers the context of the structure under investigation. The judgement on the results, which is in the responsibility of the expert carrying out the assessment, will therefore oftentimes, be set up from a standpoint which could be summarized as "the best knowledge available".

The above-mentioned facts show that more focus should be given to the optimization of assessment methods. This includes the improvement of frequently applied methods such as mapping of cracks and measurement of timber moisture content in terms of expenditure of time/cost. In addition, emphasis should be laid on the further development of methods for the in-situ determination of timber strength parameters. The objective of such developments should be to be able to incorporate results from structural assessments into updated models of structural systems ("system updating").

### 2.2 RILEM TECHNICAL COMMITTEE AST-215

The RILEM (The International Union of Laboratories and Experts in Construction Materials, Systems and Structures) Technical Committee AST-215 was established in 2005 and targeted in-situ timber structural members and evaluation of their material (physical and mechanical) characteristics. The physical properties included the species, age, moisture contents, density and level of deterioration; the mechanical properties entailed strength and stiffness. The phenomena studied included life expectancy, failure probability and durability of the structure under investigation.

NDT and SDT methods were experimentally validated on case studies; theoretical studies focused on reliability and robustness of the NDT, SDT and their combination. Technical workshops (07/2006, Prague, Czech Republic; 06/2010, Biel, Switzerland) were organized and allowed training technicians and students from North America and Europe.

A comprehensive literature review of the state-of-the-art was published [1]. This report reflected the knowledge in in-situ assessment of the physical and mechanical properties of timber at the time. NDT and SDT methods are described in a systematic manner discussing the technology, equipment and limitations. Some of the discussed methods are used in other materials such as masonry and concrete; most of the methods, however, are specific to wood and special qualifications are required to understand and apply these effectively.

One of the main conclusions of RILEM TC 215 was that more research is required to both estimate individual member strengths and obtain accurate quantification of deterioration to improve the assessment of in situ timber members. As an example, after extensive research of stress wave techniques, the conclusion was drawn that the relationship between stress wave parameters and timber mechanical properties is not developed enough to accurately predict in situ member strength. Published research and correlation values are inconsistent and at times conflicting depending on technique, species and parameters employed.

Amongst several others, research opportunities were identified in the area of applying stress wave techniques in-situ to arriving at reliable strength estimates. Accurate quantification of deterioration also needs to be addressed, while X-ray and resistance drilling techniques have proven that they can accurately detect areas of deterioration, these techniques can be improved by adding the ability to quantify and identify different stages of deterioration.

### 3 OBJECTIVE

Research on the assessment of timber structures has been coordinated by the COST Action E55 "Modelling the Performance of Timber Structures" and the RILEM technical committee AST-215 "In-situ assessment of structural timber". The European Commission mandates the development of rules for the assessment of existing structures and their reinforcement (M/466 EN) [18]. COST represents an ideal platform to support this assignment. The objective of the COST Action FP1101 "Assessment, Retrofitting and Monitoring of Timber Structures" is to help increase confidence of designers, authorities and end-users in safe, durable and efficient use of timber [19].

## 4 SCIENTIFIC PROGRAMME

According to the objectives, the Action's scientific programme will be divided into three scientific areas expressed as work groups (assessment, reinforcement, monitoring). Common to these areas are following tasks:

- Analysing different approaches and evaluating methods in terms of applicability, expenditure of time/cost, validity of results and constraints;
- Adapting techniques and methods from other materials and systems;
- Validating new technologies with laboratory and on-site experiments;
- Adopting principles for the preservation of historic structures;
- Creating practical tools with an immediate applicability;
- Establishing common practices and methodologies;
- Disseminating knowledge of approaches, new methods and technologies.

### 4.1 PLANNED ACTIVITIES "ASSESSMENT"

- Increasing knowledge in NDT and SDT and combinations thereof to improve applicability of results to assess the remaining structural capacity;
- Compiling methods which deliver reliable and robust results that can subsequently be incorporated into analytical and probabilistic models;
- Promoting the cross-validation of data obtained during inspection using similar methods in different projects;
- Combining visual grading, vibrational methods and mechanical tests, for the decay characterisation and the mechanical characterisation of the material;
- Developing specific in-situ grading standards to both estimate individual member strengths as well as obtain accurate quantification of deterioration.

Research on the following methods will be coordinated:

- Simplified methods for the reliability assessment of structures based on calculations, analytical and visual inspection procedures;
- NDT (e.g. stress wave based techniques, X-ray radiography, Ground Penetrating Radar, vibrational methods, scanning, tomography);
- SDT (e.g. drilling techniques, hardness testing);
- Proof loading actual structures.

#### 4.2 PLANNED ACTIVITIES “REINFORCEMENT”

- Identifying and categorizing types of deterioration, damage and failure of timber structures, weak zones and their relevance for safety;
- Facilitating the decision-making process for choosing an appropriate reinforcement method with consideration of cultural heritage aspects
- Creating a handbook of solutions for the main categories of problems;
- Analysing the relationship between reinforcement techniques and protection technologies, as i.e. coatings to prevent decay and/or fire resistance;
- Evaluating solutions regarding their function as seismic reinforcement;
- Developing computational concepts that allow for safe and reliable design.

Research on the following systems will be coordinated:

- Timber and timber based products (e.g. densified, cross-laminated timber);
- Adhesive systems (considering on-site application and durability issues);
- Mechanical fasteners (e.g. glued-in rods or self-tapping screws);
- Fibre reinforced polymers and natural fibres also applied with adhesives;
- Nanotechnology (e.g. carbon nanotubes with polymeric resins).

#### 4.3 PLANNED ACTIVITIES “MONITORING”

- Identifying relevant properties that should be monitored, including environment;
- Clustering long term experiments according to the involved risks as basis for the development of advanced diagnostic tools and technologies;
- Digital image processing, remote data acquisition and early warning systems;
- Defining criteria for the efficiency control of applied monitoring approach by means of numerical simulations and/or field and laboratory testing;
- Developing practical-operative guidelines and monitor schemes, e.g. survey, documentation, on-site inspections decision making guidelines.

Research on the following systems will be coordinated:

- Simple, robust, redundant and reliable long term moisture measuring devices;
- Deflection and crack propagation measuring devices and methods including contact sensors (fibre-optics) and non-contact approaches (photogrammetry);
- Acoustic emission monitoring;
- Remote data transmission systems;
- Wireless sensors and sensor networks.

## 5 CONCLUSIONS

The COST Action FP1101 “Assessment, Reinforcement and Monitoring of Timber Structures” will form a platform to coordinate on-going research, summarise recently obtained results, and increase and disseminate knowledge. The stakeholders are architects, structural engineers, researchers, lecturers, manufacturers, builders, students, policy makers and standardization bodies. The Action will benefit from multidisciplinary approaches, enable useful synergies and provide the most effective way of avoiding duplication and disseminating the results from a large number of on-going projects.

The Action will create scientific, economic and social benefits. Improving the assessment, retrofitting and monitoring of timber structures are research domains with large-scale activities which require the exchange of information and identification of new research ideas. Increased knowledge of retrofitting techniques will help architects and engineers to make timber a viable option for more applications and new opportunities in design and construction. Reliably assessing timber structures, avoids failures and unnecessary decommissioning, and leads to safer structures and better use of resources. An increased and more innovative use of timber and timber-composites as building materials based on stronger confidence will bring sustainable benefits.

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