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METHODOLOGIES FOR SAFETY EVALUATION OF EXISTING TIMBER STRUCTURES

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EXTENDED ABSTRACT

Introduction

Nowadays, society seeks and demands for a higher level of life quality in a broad range of aspects. Safety is one of those aspects. The integrity and safety of a structure is taken for granted by the general population. It considers that the danger of a structural failure is controlled and that the risk is minimized, therefore relying in the knowledge and expertise of the professionals responsible for the safety evaluation, maintenance and preservation of the structure. However, the safety level of a given structure, in a specific instant of time, depends of innumerous circumstances both external and internal to the structure. Also the construction of a civil engineering structure is inconceivable without the problematic of structural safety allied to the concept of durability being imposed. This paradigm is present since the initial project and throughout the process of construction and following phase of monitoring and planning of maintenance actions.

The research regarding this PhD is focused in finding methodologies for safety assessment of existing timber structures, with special attention to stochastic analysis allied to non-destructive methods.

Timber is a rather complex construction material, due to the fact that its mechanical properties are dependent of the direction of the grain. Moreover, its properties also vary on space and time. Therefore, timber structures are particularly suitable for the use of stochastic reliability methods on structural safety evaluation. Timber is a natural material used in several civil engineering applications either for structural or non-structural purposes. Although its use has decreased due to the emergence of new materials, timber offers many advantages. Nevertheless, since it is an anisotropic material its full mechanical characterization is rather complex, however when well used it provides a good mechanical behavior associated to an effective relation between resistance and density.

Field of research and motivation

The field of interest in timber research is not only dedicated to new construction since timber is present in several ancient and historical monuments all over the globe. Therefore, a better understanding of its performance and durability throughout its expected lifetime may allow a better safety reassessment of existing structures and possible necessary actions to maintain its integrity. In this matter, modeling the characteristics of existing structures may sometimes lead to costly procedures. However, many times the costs of an adequate inspection and monitoring plan are far less inferior to those compared to time inadequate maintenance, repairing interventions or in extreme situations, to the consequences of a structural collapse.

The preservation of historical monuments is also considered as a form of maintaining the identity of a specific place, culture or population and therefore, presents a way to achieve a better life quality regarding social and cultural factors.

Concerning historical monuments, minor or non-destructive tests (MDT and NDT) are often used and they constitute a useful tool for assessment of the existing properties and level of deterioration of the structure. The results gathered from these tests may then be used to update stochastic models and therefore providing a stable framework for safety assessment of timber structures.

Updating structural models or material properties is not only useful for new construction. Actually, this procedure's potential is better suited for the assessment of the reliability of existing structures. When dealing with existing structures, updating of information may be regarded as a very important tool in the assessment of its reliability parameters. Updating is based on prior information and collected observations and measurements, such as visual inspection or tests results. It then results in posterior information used for the reliability assessment of the structure. From this updated model, decisions upon the life-cycle reliability of existing structures may be taken and maintenance or strengthening actions may be considered.

The work so far

During the work already conducted in this PhD, Bayesian methods have been applied to update information into resistance models for timber elements.

Bayesian methods allow quantifying an approximation about the statistical uncertainty related to the estimated parameters, regarding both the physical uncertainty of the considered variable as well as the statistical uncertainty related to the model parameters. They are therefore suitable for parameter estimation and model updating. However, for making this possible it is necessary to take into account the measurement uncertainty and the model uncertainty in the probabilistic model formulation.
During a Short Scientific Mission within the E55 Cost Action conducted in Aalborg University, Denmark, reliability methods for analysis of timber structures were addressed by using information gathered through NDT or MDT results in an upgrading scheme. With respect to that, different methodological procedures were mentioned for implementation of test results into a resistance model of timber structures. Stochastic models regarding resistance parameters, spatial variability, size effect and failure types were mentioned, as well as common used NDT and MDT for timber structures. Further on, a theoretical background for structural reliability assessment including probabilistic concepts for structural systems and stochastic models was made. System models, both series and parallel systems, were presented as well as methods for reliability calculation. The importance and influence of ductility in systems was mentioned.
Regarding the updating of data, Bayesian methods were described and a sensitivity analysis was conducted to study the importance of different parameters introduced in prior, posterior and predictive distributions. A framework for robustness analysis was also taken into account in that work and usual methods to assess robustness were mentioned. Example cases were considered, where a time depending robustness index was proposed with consideration to long term decay phenomenon in timber structures and the design time considered for that structure. Correlations between destructive tests and NDT / MDT were also used in order to incorporate an upgrading procedure for the timber compression strength parallel to grain. The uncertainty regarding those correlations was modeled through a parameter given by a Maximum Likelihood method. The importance of uncertainty was concluded to be preponderant in the analysis of the upgraded resistant parameter. The results from each NDT test were compared to reference models.
Regarding the work plan of this PhD, monitoring of environmental parameters and its influence in timber elements has been implemented in different buildings. Temperature and relative air humidity have been recorded using data-loggers.

Further work

Future work in this PhD is expected to be done in probabilistic modeling of timber structures with implementation of a hierarchic model. Experimental analysis to both new and old timber elements will be conducted and the results will be implemented to a mechanical model for timber elements. The experimental analysis will include visual inspection, non-destructive testing, sample testing and destructive tests.

Goals and repercussions

The goals of this PhD are to obtain a methodology to suitably perform a probabilistic model of existing timber structures, as well as to define a practical methodology to evaluate the mechanical properties of timber elements using visual inspection and non-destructive tests. With this work it is intended to create a more reliable methodology to evaluate the safety level of existing timber structures and therefore making possible to take better and substantially more informed decisions with respect to maintenance actions. By achieving these objectives, a framework for safety evaluation of existing timber structures will be obtained. Then, trough a better maintenance planning, that can be used as a tool to increase the expected lifetime of those structures.
Since life quality of a given person depends on the place where he lives, then preserving the historic and cultural identity will also influence that life quality. Therefore this PhD, by presenting a methodology for safety evaluation of timber structures, presents itself as a engineering possibility to change and influence the life quality of a given society inserted in a given city concept.

AUTHOR BIOGRAPHY

HÉLDER S. SOUSA was born in Guimarães, Portugal, and went to the University of Minho, where he studied civil engineering and obtained his degree in 2009. He was granted a Scientific Initiation scholarship from 2008 to 2009 in the field of safety evaluation of timber structures by means of non-destructive methods and stochastic analysis. Since 2009, he has been working in his PhD thesis concerning "Methodologies for safety evaluation of existing timber structures". In 2010, he participated in a Short Scientific Mission in Aalborg University, Denmark, within the E55 European Action about "Modeling of the performance of timber structures". His e-mail address is: `hssousa@civil.uminho.pt`