Evaluation of Experience – a possible procedure for the assessment of failures and malfunctions

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Executive Summary

Abstract

The main objective of the present COST Action E55 is to provide a better understanding of the load bearing behaviour of timber structural elements and connections in construction. As it is obvious that this task is a major one, having occupied the timber research profession since decades, it is also clear that the defined goal in its broad sense cannot be achieved within the limited potential of one single COST activity. It is therefore of utmost importance that the activities and reinforcements within this action are directed to issues, which are found to be essential for the overall performance of timber structures. The work plan of WG I is mainly focused on this and the planned publication on the Assessment of Failures and Malfunctions will be an attempt to summarise an extract of experience and knowledge represented by the participants of this COST action.

It became evident during the first discussions on this subject at the 1st Workshop in Graz, that it is a necessity to present existing experience in a common format, using the same criteria and terminology. The present presentation is an attempt in that direction. Based on existing reports on the assessment of failures and malfunctions, a possibility to develop a common evaluation raster is discussed.

Introduction

During the last decades structural reliability methods have been further developed, refined and adapted and are now at a stage where they are being applied in practical structural engineering problems. Typical problems in structural engineering such as design, assessment, inspection and maintenance planning are decision problems subject to a combination of inherent, modelling and statistical uncertainties. The structural reliability theory is concerned with the rational treatment of these uncertainties. In general, failures that result from stochastic variability in loads and resistances are addressed. The modelling of errors introduced by the use of structural mechanics models that are based on idealisations of structural and material behaviour and also the simplified representation of load variables are taken into account.

Modern load and resistance factor design (LRFD) formats are calibrated by the use of structural reliability theory, i.e. the partial safety factors are chosen in a way that failure rates for structures designed according LRFD formats are sufficiently low. Thus, it is not surprising that structural failures due to the random occurrence of adverse combinations of high loads and low resistance rarely occur.

However, most structural failures and the majority of damage costs occur as a consequence of errors in planning, design, construction and utilization. This has been shown by several studies where information about collapsed and malfunctioning structures has been analysed (an overview is given in [1] and [2]; timber structures are particularly addressed in [3] and [4]). These errors are not considered by structural reliability methods which are based on the assumption that customary standards of planning, design, construction and utilisation are efficient and are not violated.

Several attempts have been made to model the effect of errors on the structural reliability. Most of them are based on standard procedures for risk analysis of technical facilities. Possible errors and their effect are treated as scenarios that are analysed by means of event trees or fault trees. Being tractable by rational reasoning in principle, the estimation of the effect of errors on the structural reliability in general lacks due to poor information about the types of errors that could occur, the probability of these errors and their effect on the performance of the structure. It is obvious that the assessment of the above raised questions is rather sensitive to the essence of errors. In the present literature various different classification schemes for errors can be found. This makes simple accumulation of the results of these studies difficult; however, a condensed representation of past experience would be necessary to identify the necessary steps for the research and code writing profession towards the goal of a safe and efficient build environment.

The nature of past experience

It is clear that experience about the performance of structures comes in a continuum; most of the structures perform well, i.e. they fulfil their objectives within their lifetime. This experience is reinforcing the customary standards of planning, design, construction and utilisation. However, a minor part of the experience is received to be adverse in terms of performance of the structures; i.e. the objectives of structures are not fulfilled, e.g. structural components deteriorate, the serviceability is violated, components fail or entire structural systems collapse. The consequences of these events range from reduced usability of structures to loss of lives.

Unlike data from scientifically controlled experiments, information represented by a continuum of experience, both “good” and “bad”, is rarely strictly comparable. Structures are in general not unique in terms of the assembly and the surrounding circumstances. Likewise, the design concept and its realisation it differs for every structure. Consequently, a structure cannot be considered as a sample from a real homogeneous population, but rather it is a special case of generically similar, but not identical structures. The comparison of structures therefore requires more care than is the case otherwise. Nevertheless, various attempts have been made to use the observations on the behaviour of structures as raw statistical data for rather formalized evaluation of structural performance. Such evaluations are in general focused on “bad” experience, while unformulated, unstructured evaluation is the norm for evaluation of “good” experience (Melchers et al., [2]).

Several studies from the 1980s tackled the structured analysis of “bad” experience, i.e. of structural failure however it might be defined. Prominent examples are the studies by Matousek and Schneider [5], Smith [6] and Allen [7].

Recent studies that focus on timber structures are Frühwald et al. [3] and Frese and Blaβ [4].

The various reports on the analysis of structural failures are not easy to compare since the definitions and the classification for failures and their causes differ from study to study.

The nature of errors

As discussed before, structural reliability assessment for the purpose of calibration of LRFD codes in general or for the reliability verification of specific structures more specifically requires that the relevant failure modes be represented in terms of limit state functions. The limit state functions include models for the uncertainties associated with the load effects, material strength and uncertainties associated with simplified mathematical and physical models. When formulating a limit state function it is in general the attempt to represent the accepted practice in the area of structural engineering, that is,

- departures from accepted practice are not included in these reliability considerations, and
- the possibility of improper accepted practice is not taken into account.

It is here proposed to consider these two points for the definition of error. The first one (in the following 'Type A') is in general termed human error, the second one (in the following 'Type B') could be in general understood as improper knowledge and models represented by the accepted practice, i.e. this refers to issues not better known by the research and engineering profession at a certain time.

A possible scheme for failure assessment

For the future development of a save and efficient build infrastructure it is of utmost importance to learn from past experience. Insight about errors from Type A might lead to improved quality control schemes, more clear and unambiguous formulations in the design codes or more directed and detailed education policies. Observations of failures due to Type B errors suggest a critical review of accepted practice and/or newly directed research. In a possible scheme for failure assessment the following issues should be addressed:

- The structural system should be described detailed enough that critical failure mechanisms can be reassessed and analyzed.
- The generation of building codes and regulations should be identified and described.
- Additional quality control measures that might have taken place during design, construction and use of the structure should be described.
- The failure mechanism leading to collapse should be described. (in structural engineering terms)
- The cause of failure should be classified and described in detail.
- A feedback system should be developed to keep the engineering and code writing profession informed and aware of possible problems.

A scheme for failure assessment should have the format of a data base where information might be fed in continuously. Such a data base, in the ideal case, would have the potential to inspire and guide future research and developments in regard to enhanced best practice procedures and efficient and directed quality control measures.

References

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