Reliability analysis of timber roofs considering eccentricities

Luís C. Neves and Jorge Branco

1 Introduction

Traditional building construction in Portugal used timber roof and floor structures and in some cases also timber reinforced masonry walls. A significant number of these buildings are still in use, despite some major modifications. Although the use of concrete structures became widespread, even for small structures, timber structures kept an important use in roof construction. The large number of existing timber roofs as well as their current condition, requires a effort in improving the understanding on their performance.

The common Portuguese timber roof structures is formed by trusses with an average span of 6m, mostly following a king-post configuration. Most of these structures were built based on experience only, and were not preceded by any formal design. This resulted in a significant dispersion of the safety levels in roof structures and in a lack of confidence in the structural performance of these structures.

A survey of existing timber roofs in Portugal showed that large eccentricities are common. Nevertheless, trusses are considered to behave essentially as plane structures with normal stress in all elements. Eccentricity in the loads application results in significant changes in the stress distribution and important bending moments arise in some elements, in particular, in the principal rafters.

Moreover, due to climate conditions in Portugal, associated with little snow in most highly populated areas, snow loads are often disregarded or considered of lesser importance.

In this work, a reliability framework is employed to analyze the safety of traditional Portuguese king-post timber trusses, considering the effects of eccentricities. The analysis focuses on the safety under snow, for three main reasons: the disregard of snow loads is common in design; the recent changes introduced by codes in the snow load definition and, the importance of this load (asymmetric) when combined with eccentricities.

Monte-Carlo simulation is employed to assess the reliability of king-post timber trusses, defining the parameters influencing safety based on existing probabilistic models codes and past experience.

2 Proposed model

Traditional timber roofs structures usually have very low redundancy. As a result, any defect or error that may cause a significant increase in stresses in one or more elements tends to cause a significant reduction in the system reliability.

For this reason, it is fundamental to analyze these structures considering a system approach. Considering the failure mode in the elements of this structure, a simple series system was considered, with failure of one element leading to failure of the structure.

The properties of timber elements was defined in accordance with Köhler et al. (2007), considering the percentiles defined in the Portuguese standard. A simple model defining the properties of timber at a element level was used.

The permanent loads were defined considering the distributions and coefficients of variation defined in JCSS (2001) and the traditional king-post configuration in Portugal. Snow loads were defined considering the snow load on the ground and the roof shape coefficients defined in Eurocode 1 (CEN, 2003) for Portugal and the distributions described in JCSS (2001).

Different levels of eccentricity were defined based in a preliminary survey carried out by Branco et al. (2005). Moreover, the effect of the correlation between material parameters of different elements was also analyzed.

Stresses were computed using a simple bar model, under elastic linear analysis. Considering that the computational model was very fast, crude Monte-Carlo simulation could be employed (Melchers, 1999).

3 Conclusions

The results obtained showed a significant effect of the existence of large eccentricities in the safety of both elements and structure, in particular in the main rafters. The effect of different correlations between elements causes a significant impact on the system safety index. Considering the modeling of the structure as a series system, the increase in the correlation between different elements leads to a decrease of the system probability of failure.

The continuation of this work will allow a definition of admissible levels of eccentricities for existing structures, allowing a fast evaluation of problems in simple existing timber roof structures.

References

Branco, J., Varum, H., and Piazza, M. (2005). Portuguese traditional timbers trusses: static and dynamic behaviour. Technical Report E-19/05, DECivil, University of Minho.

CEN (2003). *Eurocode 1 - Actions on structures - Part 1-3: General actions - Snow loads*. Comité Européen de Normalisation, Brussels, Belgium.

JCSS (2001). *JCSS: Probabilistic model code*. The Joint Committee on Structural Safety.

Köhler, J., Sørensen, J. D., and Faber, M. H. (2007). Probabilistic modeling of timber structures. *Structural Safety*, 29(4):255–267.

Melchers, R. (1999). *Structural reliability analysis and prediction*. John Wiley, Chichester ; New York, 2nd edition.