Reliability analyses using finite element models of trussed timber structures with dowelled connections

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Current design of timber structures is mostly based on element-by-element approaches, in which the reliability of the whole structure is unknown, but assumed not to be much smaller than the reliability of each member or connection. A recently started research project at ETH Zurich and Empa, in Switzerland, aims at investigating the global behaviour and reliability of medium and large-span trussed timber structures with connections with dowel type fasteners, taking into account the variability of mechanical properties and of the load-displacement behaviour of its connections. A multi-scale modelling approach will be followed, from the behaviour of a single fastener, to the load-deformation of a connection and behaviour of a complete structure, which will allow assessing the most important material and geometrical parameters at different levels.

Most of the past reliability studies in timber engineering were conducted with analytical models [1]. For such models FORM or SORM analyses have often been accurate enough. However, crude Monte-Carlo simulations (MCS), which require 10^5 to 10^8 simulations (depending on the order of magnitude of the probability of failure of interest), are also feasible with analytical models. The use of computationally-heavy non-linear finite element simulations is, in general, not viable due to the extremely long total running time. Using alternative methods, such as importance sampling or subset simulations, the number of simulations needed can be reduced by some orders of magnitude, depending on the boundary conditions. One of the latest developments in the field of reliability analyses for structural safety are adaptive Kriging MCS methods, which only require hundreds to thousands of model runs [2]. The increase in performance provided by these methods makes reliability analyses with computationally heavier FE-models more feasible, at least for research purposes.

For this investigation two complementary modelling frameworks are being developed: at the connection scale a semi-analytical method (as described by Schweigler et al [3]), based on a beam-on-springs models (similar to that of Lemaître et al [4]) is used for the reliability analyses; at the system level, a finite element approach with 1-D elements and non-linear springs representing the connections is used. The input for the models is based on probabilistic data described in JCSS [5] and Leijten et al. [6] and benchmarked against test data from Jorissen [7].

The proposed contribution will summarise previous studies on the use of simplified models for timber connections and structural reliability analyses of timber structures. It will focus on which analysis methods and modelling strategies are best suited for connections with dowel type fasteners, and trussed timber structures. The overall multi-scale modelling framework will be presented and discussed.

References

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ISBN: 978-91-88898-64-7