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Computational model for W-W-W connections at ambient and high temperatures

Abderrahim Aissa[1], Elza M M Fonseca[2], Belkacemn Lamri[3]

[1]Master Student, Construction Engineering, Polytechnic Institute of Bragança, Portugal (meh.twiska@gmail.com); [2]LAETA, INEGI, UNMEE, Department of Applied Mechanics, Polytechnic Institute of Bragança, Portugal (efonseca@ipb.pt); [3]Faculty of Civil Engineering and Architecture, Chlef, Algeria (lamri_belkacem@yahoo.com)

Abstract

The aim of this work is to present an approach for wood-wood-wood (W-W-W) connections design in double shear at ambient and high temperatures, using dowelled connectors. For each situation, all calculations will be performed to determine the cross-section and the number of fasteners. A procedure will be presented to calculate the load carrying capacity per shear plane and per steel fastener, using a glued laminated in birch W-W-W timber GL28h.

The designed connection will be considered unprotected at ambient temperature, and protected for high temperatures. In this study, it is important to determine the type of insulation material and the correct dimension for guarantee a fire time resistance.

All developed study will contribute to the knowledge in these connections, where the wood material represents a complex behaviour in fire situations and the combination with steel fasteners intensify the heat conduction inside the material. All proposed methodologies could be used to study W-W-W connections with or without insulation material to assess and contribute for a safe design.

Keywords. W-W-W connections, dowels, insulation, thermal analysis, mechanical analysis.

1. Introduction

The use of wood, as a structural material, continues to grow far beyond traditional application. Therefore, connections, indeed, are often considered as the critical point of timber structures because their resistance and durability mainly depend on the connections joining design of the different structural elements. Also they find themselves subject to localized stresses and strains, and may expose the overall stability of the structure. For imposed thermal loads, it remains important to improve the knowledge of the connection behaviour under fire conditions.

2. Methodology

In order to guarantee an intact design for W-W-W connections, the calculation obtained following the rules presented in Eurocode 5 are compared with the results of a numerical model based on finite element method.

The materials properties at both situations will be presented, according the standards, and considering the orthotropic wood.

3. Discussion

The model represents three wooden plates connected to each other by steel bolts, submitted to axial loading and high temperatures, developed into a computational model for independently thermal and mechanical analysis, using a finite element program.

A 3D W-W-W connection was developed according the calculations for un imposed axial load and the shear effect into the fasteners, figure 1.

All materials are considered as non-linear with an elastic-plastic behaviour, as a multilinear material. For the structural analysis the material strength and elastic properties (isotropic for steel and orthotropic for timber) are the major determining factors to obtain desired results of the structural capacity, damage and failure. Due the geometric symmetry and loading conditions, only one quarter of the model was analysed. In this assembly many contacts occur between surfaces such as, the dowels hole, wood-wood plates and wood dowels interactions.

The objective is to determine the maximum capacity of the connection, until end of the running structural problem. The ultimate capacity of the connection leads to a failure mode, as the start splitting or maximum stresses reached in the glulam W-W-W in the direction parallel to wood grain. For ambient temperature, calculations for the ultimate limit state permits to determine the cross-section and the number of dowels for the W-W-W connection in study, according the design equation:

$$\sigma_{t,0,d} = \frac{F_d}{A_s} \leq f_{t,0,d} = \frac{k_{mod} \times f_{t,0,k}}{\gamma_M} \quad \textbf{(1)}$$

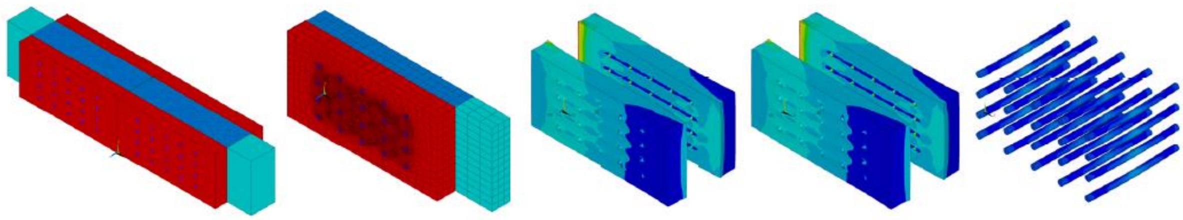

Figure 1: W-W-W connection and equivalent stresses at ambient temperature.

For high temperature calculations, the 2D half-model is introduced for different sides (front, top and horizontal cross-section) exposed to fire conditions. A transient and thermal analysis was conducted to determine the char layer thickness and compared with the proposed from the Eurocode 5, as represented in figure 2. For a required fire resistance period, the following expression is used to determine the char layer needed to guarantee the fire resistance:

$$\alpha_{f_i} = \beta_n \cdot k_{flux} \cdot (t_{req} - t_{d,f_i}) \quad \textbf{(2)}$$

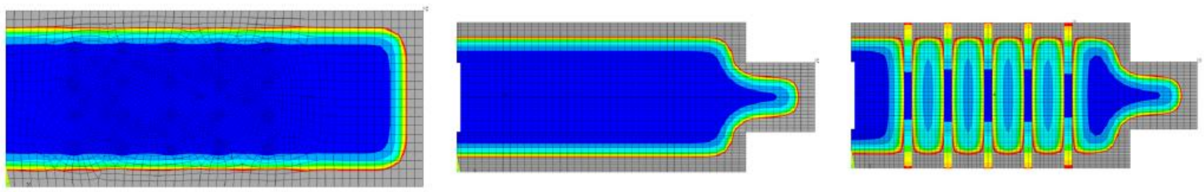

Figure 2: Char layer for different sides (front, top and horizontal cross-section), fire exposure until 30 min.

4. Conclusions

For both situations, W-W-W connections are designed using Eurocode 5 formulations and the results are discussed and compared with numerical experiments.

References

CEN, EN1995-1-2: Eurocode 5: Design of timber structures. Part 1-2: General Structural fire design, Brussels, 2003.