Assessment of the Torsional Stiffness of a Biaxial Hollow-Box Floor System

Degree programme : Master of Science in Wood Technology | Specialisation : Complex Timber Structures
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The hollow-box slab presented here aims to partly replace CLT in the post and slab system developed by Timber Structures 3.0. The relation twist-torque must be isolated and quantified to model its biaxial behaviour accurately in commercial software. A pure torsion testing procedure is defined and applied experimentally and numerically to this aim. Also, an analytical estimation method of the torsional stiffness is formulated.

Introduction

The bi-axial hollow slab is an evolution of the CLT post and slab system. Dedicated to less solicited areas, its principal benefit is to offer a more cost-competitive solution thanks to low material consumption and similar structural performance to CLT slabs. One of the characteristics of bi-axial load bearing is that torsional stiffness is involved. This stiffness can be, in specific cases, governing the design. It is, above all, a property to be integrated into the plate stiffness to model the slab as an equivalent surface with integrated stiffness parameters in commercial use.

Objective

The main objective of the thesis was to evaluate the torsional stiffness K_{xy} of a plate and to understand the leading parameters influencing this value. The question is whether it can reach comparable values to the system it is willing to replace: CLT.

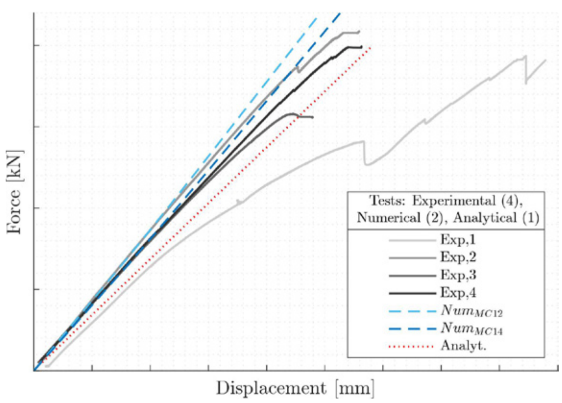
Methods

An analytical method was created to approximate the torsional behavior of the hollow slab. An analysis of the fundamental theory of plate permitted the isolation of the kinematics principles for the experiments. It also underlined the involvement of shear and flexural stiffness on the overall stiffness value. Then, an approach with cross-section properties was considered to treat the problem as a beam. The multicell torsion theory was employed to understand shear flows within the section and isolate critical stress combinations. The plate analogy of the girder grid was then employed to extrapolate bi-axial stiffness. The literature review enabled to develop an adapted testing method to measure the samples in pure torsion. A protocol was made to evaluate the state of the sample and their MC. A setup with three corners supported and the fourth on which the load was introduced was built. Deformation of the loaded corner was collected through a set of LVDT's. The translation measurement of the cylinders and the LVDT on the slab's surface were used to cross-check the global deformation.

The same methodology was applied in numerical simulation through FEM. Monolithic solid wood panels were modeled. The model was achieved with material properties taken from literature for the experiment since no values could be directly measured from the sample. A full orthotropy was assumed as opposed to transverse isotropy, and the glulam beams were assumed with radial property towards global Z. Stiffness and, to a lesser extent, stresses were analyzed.

Results

The correlation between all three methods was considered suitable. The biaxial hollow slab achieved a torsional stiffness comparable to a CLT with 80% of its height. The analytical calculation proved the major impact of the panel's thickness and, conversely, the small contribution of inner beams. A stiffness 12% lower than in experiments was evaluated, but it provided a matching maximal load with a shear and torsion verification in the outer purlins. In the experiments, shear and tension perpendicular failure were observed essentially in lap-joint areas. The numerical simulations mostly proved the influence of the moisture content since a decrease of 2% MC increased the stiffness by 7%. The stress analysis proved the load-bearing mechanism based on the multicell theory.



Corner resisting force in function of applied displacement on the sample.

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