Abstract

The development of cross-laminated timber (CLT) in the 1990s marked the beginning of a revolution in the field of timber construction. Thanks to their many advantages, these panels have expanded the possibilities open to designers, enabling them to imagine constructing timber buildings with large cantilevers, complex shapes such as folded or curved structures, and even high-rise buildings. If these panels are used as slabs, their limited vibration performance can nevertheless be an obstacle to their use over long spans. To overcome this problem, solutions have emerged that use CLT panels as a component in composite slabs. By proposing a new type of composite slab made of timber multi-lattice beams (MLBs) and CLT panels, the work presented here is part of this trend.

In this thesis, an analysis of the issues associated with CLT-lattice beam composite slabs is used to propose a design for such a slab. The CLT panels are connected to the MLBs by mortise and tenon joints, with the tenons glued between the boards forming the chords of the MLBs. The large number of design parameters defining the geometry of a slab means that the designer has to invest heavily to obtain an efficient solution. The specific objective of this work is therefore to develop a design support tool that will enable the user to optimise the geometry of the slab in order to minimise its area cost. During the optimisation process, the analysis step of a possible solution requires calculation methods adapted to this slab for determining its bending stiffness and the forces and moments carried by its members.

The first calculation method developed in this thesis concerns the structural analysis of lattice beams with homogeneous or composite chords. The analytical method adopted differentiates between the global behaviour of the lattice beam and the local behaviour of its chords. These two aspects are analysed separately, and the results are then superimposed to determine the whole behaviour of the lattice beam. The results of the method are then compared with a finite element model to identify the parameters influencing the accuracy of the results.

Since characterising the joints of the new composite slabs is crucial to the structural analysis of a floor, an experimental campaign on mortise and tenon joints is used to determine their strength, stiffness, and failure mode. The application of the component method to the particular case of connections developed in this thesis provides an analytical calculation method capable of describing their behaviour. The consistency of this method with the experimental results is then verified and discussed.

The analytical calculation methods developed as part of the thesis are then used in the design of the morphological optimisation algorithm for slabs. The optimisation method chosen is a single-objective genetic algorithm that allows a population of solutions to evolve towards solutions that are better fitted to the problem being studied. The application of this algorithm to specific examples demonstrates its usefulness and effectiveness in finding near-optimal solutions.

Keywords: CLT, composite slab, lattice beam, analytical calculation method, mortise and tenon joints, component method, optimisation, genetic algorithm