Delft University of Technology

Advancing material-efficient and environmentally friendly construction

Assessment of Steel-CLT Composite Floor Systems

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Cover: Construction site of the new Beaverton Public Safety Center (BPSC) by FFA Architecture and Interiors (Modified)

Abstract

With the building and construction sector accounting for a significant portion of final energy use and emissions, and society's increasing focus on environmental awareness and improvements, the importance of sustainable construction has never been greater.

The utilisation of timber in construction offers clear sustainability benefits and has the potential to replace traditional functions of concrete. One notable replacement is the use of Cross-Laminated Timber (CLT) in composite structures with steel, enabling the potential creation of greatly performing floor systems which has seen a limited amount of research. The research explores the application of Steel-CLT Composite floor systems and assesses composite beam performance as well as predictive methods for analysing their behaviour in hopes of advancing the body of knowledge on this method of environmentally friendly construction.

The literature study revealed the current knowledge on steel-CLT composite floor systems and connections. Two particular floor systems, with and without the use of grout, are highlighted as well the potential for future exploration.

The steel-CLT composite connection utilised in the floor system significantly impacts performance and composite action as the use of grout is concluded to increase initial-, secondary stiffness and load carrying capacity of the connection. However, restricting the use of grout can promote circular construction practices.

In this research the behaviour of steel-CLT composite beams is predicted by the use of a numerical finite element model with shell elements and an analytical approach based on the simplified analysis of Eurocode 5(EN1995-1-1): Mechanically jointed beams.

The analytical method can predict the bending stiffness with a margin of error just slightly above 10%. However, it should be noted that the analytical method incorporates an incomplete representation of the composite connection used in the beam. On the other hand, the finite element model is able to accurately capture the pre-plasticity behaviour of the steel-CLT composite beam. This is achieved by incorporating the complete load-slip behaviour of the shear connection.

A parametric study was conducted to assess the importance of closely spacing composite shear connections in a steel-CLT composite beam to achieve a higher level of composite action. The study also demonstrates that by utilising connections with higher initial stiffness, secondary stiffness, and ultimate capacity, this effect can be further strengthened. As a result, the force resisted at the serviceability limit state experiences a notable boost due to the implementation of both a stronger and stiffer connection, as well as their close spacing. Shear connection position optimisation by concentration of connectors near the supports showed to have a small positive effect on beam deflection.

After evaluation of steel-CLT floor systems the research concludes that a steel-CLT composite floor system can be successfully constructed, offering environmental benefits and reduced structural weight while achieving the required structural performance for the set design conditions.