Short report for the research project

Two-way Spanning Timber-Concrete-Composite-Slabs – Development of construction and design methods for two-way spanning Timber-Concrete-Composite constructions

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1 Objective and initial situation of the research project

The timber-concrete-composite (TCC) construction represents a system with a good combination in load-bearing capacity, sound insulation and fire-safety. Until now, this construction method is limited to one-way spanning systems. With cross-laminated-timber (CLT), large plane timber elements with a biaxial load-bearing potential are available. The advantages of both construction methods will be combined in the presented system (Figure 1).

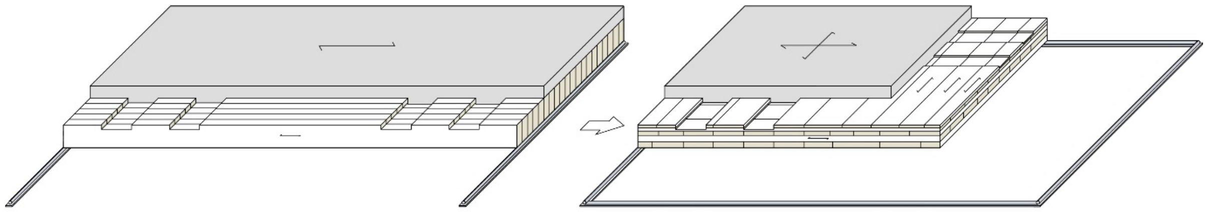

Figure 1: Transferring the one-way into a two-way spanning construction

2 Realization of the research project

The objective of this project was the feasibility and applicability of TCC-constructions as a two-way spanning system. In experimental tests and FEM simulations, the load-bearing behavior was examined. Proposals for design and construction methods were acquired. The specific project objectives and conducted working steps are given in the following.

2.1 Shear connectors

Shear connectors, for which the load-bearing behavior in uniaxial TCC-systems is well known, are examined in a two-way spanning system – fully threaded screws applied at an angle of 45° and rectangular notches. With the aim to generate a uniformly distributed shear stiffness in both load-bearing directions, adequate construction and calculation methods were developed. They focus on the arrangement of the connectors in the slab, either orthogonal or following the direction of principal shear forces (Figure 2-4). In addition, the shear force transmission into the CLT-layer parallel and perpendicular to grain was investigated. The investigations were conducted via experimental tests, FEM simulations and spring models. Based on the results, design and construction methods were derived. The shear connecters were assessed and compared with each other in their load-bearing behavior.

Figure 2: CLT-element with notches as shear connectors

Figure 3: CLT-element with inclined screws as shear connectors. The screws are aligned along the expected principal shear forces.

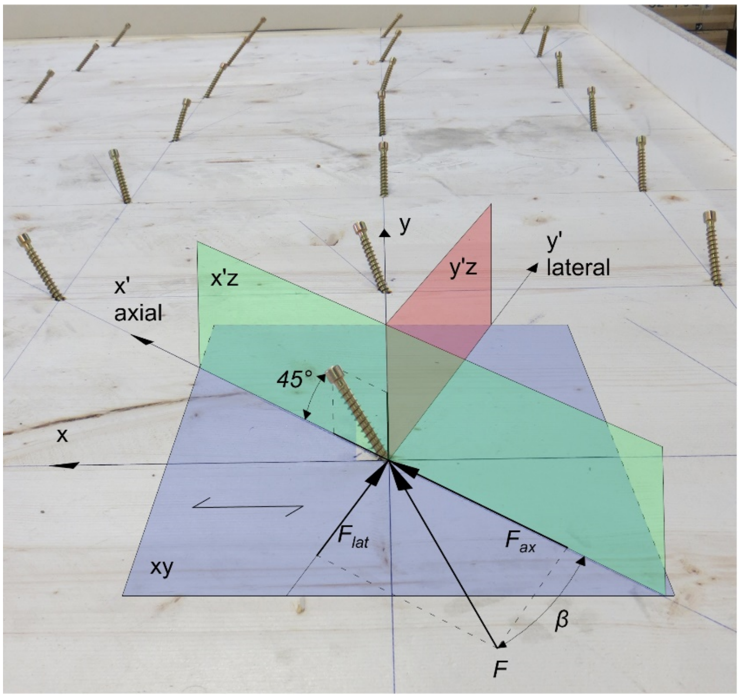

Figure 4: Principal shear force *F* in relation to the screw connection

2.2 Torsion

Torsion is an essential mechanism of the load bearing behavior of a plate. In experimental examinations regarding the torsion stiffness, the influence of different construction parameters such as CLT-layup or shear connectors was quantified. Further, to quantify the share and the influence of the torsional behavior on the overall load-bearing behavior, the shear modulus in plane was varied and compared for all layers.

2.3 Overall load-bearing behavior

In the examination of the overall load-bearing behavior, the findings from the investigations on the shear connectors and the torsion were combined. The overall load-bearing behavior was examined in a large-scale test in analogy to uniaxial four-point-bending tests (Figure 6). Apart from the individual failure mechanism and the maximum load-bearing capacity, the ductility and the overall stiffness in dependence on the deflection were evaluated. The tests were accompanied by FEM simulations, in which the influence of the different parameters, such as composite stiffness, torsion or CLT-layer configuration was determined. From these studies, construction principles could be derived. Further, the degree of the biaxial load-bearing behavior and the ratio between primary and secondary load-bearing axis were determined.

Figure 5: Building the concrete layer

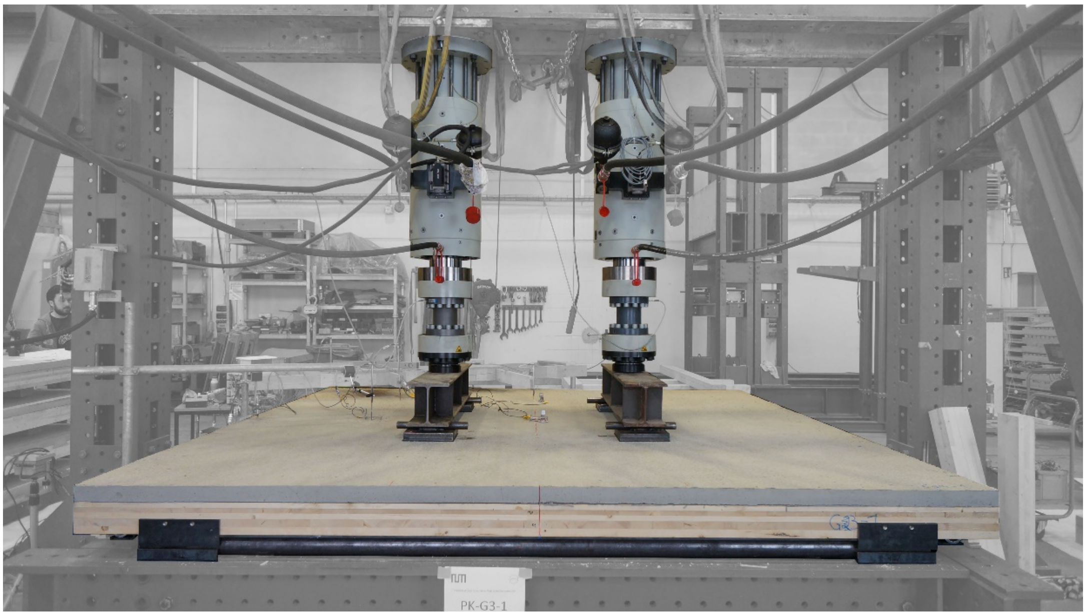

Figure 6: Force-deflection-test on an all sided simply supported TCC-element

2.4 Force-fitting element joint

Due to geometrical transportation and production limits of CLT-elements, a force-fitting element joint is necessary to activate the biaxial load-bearing capacity. Most important parameter is the effective bending stiffness of the joint connection. A loss in stiffness reduces the stiffness of the respective axis orthogonal to the joint line and therefore a balanced biaxial load-bearing behavior. Different connection types were compared regarding stiffness and buildability. The most promising connection type was tested experimentally in relation to a reference specimen without joint (Figure 7). From test results design and construction rules were derived.

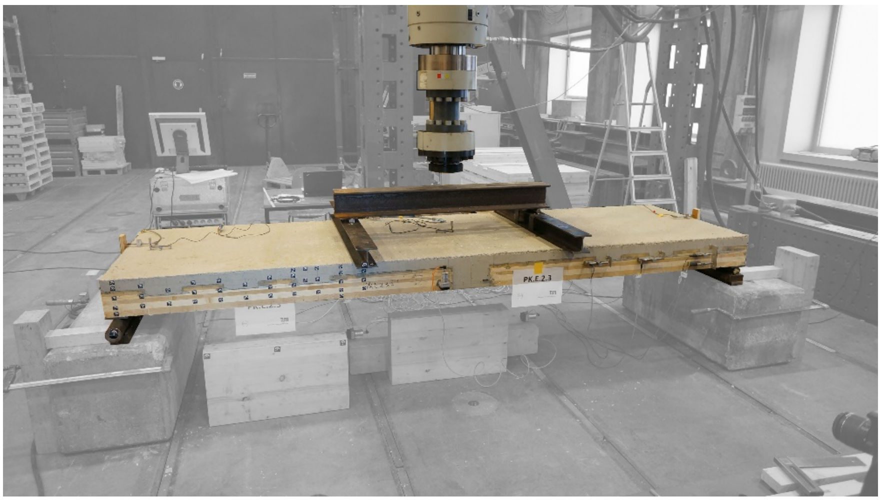

Figure 7: Force-deflection-test on a TCC-element, which is jointed force fitting in midfield.

2.5 Comparison to one-way spanning systems

To evaluate the potential of the newly developed two-way spanning TCC-slab, a comparison of the deflection behavior to one-way spanning TCC-slabs was conducted.

3 Conclusion

The applicability of the TCC-construction method for two-way spanning systems was demonstrated. Solutions for the arrangement of shear connectors and layers within the slab were found. The influences of torsion and material parameters on the overall load-bearing behavior were determined. With glued-in reinforcement bars, a connection was developed, which meets the requirements of stiffness and practical buildability. The elements can be joined with barely any loss in stiffness. A comparison with one-way spanning TCC-slabs shows distinct material reduction potentials.

4 Basic data

Short title: Two-way Spanning Timber-Concrete-Composite-Slabs
Researcher: Dipl.-Ing. Stefan Loebus
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