TOWARDS THE PLASTIC DESIGN OF GLULAM CONCRETE COMPOSITE STRUCTURES

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Summary

Creating composite structures from existing structural materials offers great potential for innovation in new structural types and new approaches in structural design; this paper intends to promote composite structures of glued laminated timber (glulam) and structural concrete, providing remarkable potential for resource efficient structures with high environmental quality.

At Ultimate Limit State (ULS), pure glulam structures are usually designed elastically, reinforced concrete structures according to limit analysis. Experiments show, however, that glulam exhibits a significantly ductile behavior in compression, potentially allowing a partial application of limit analysis approaches. This ductile behavior is the basis for the development of a new type of shear connector for glulam concrete composite structures, formed by relatively large-scale reinforced concrete corbels intruding into the glulam section at the interface.

Keywords: Glued laminated timber (glulam), structural concrete, composite structures, full-scale testing, shear connector, serviceability behavior, limit analysis, ductility, bending, compression.

Experimental and Theoretical Investigations

To analyze the general applicability of the new shear connector (Fig. 1) to composite structures, the following phases are followed:

Stage 1 – Push-out tests to determine the behavior of the notches in pure shear and define its constitutive law (force-slip).

Fig. 1: Notch type shear connector.

Stage 2 – Full-scale single-span beam tests to determine the contribution of notches to overall stiffness and failure loads.

Stage 3 – Full-scale two-span beam tests to determine the limits of plastic rotations in the negative moment area.

The full paper presents the results obtained from three series of push-out tests and compares them to a plastic failure model (Fig. 2). The stiffness at Serviceability Limit State (SLS) K_{ser} of common steel connectors is compared to the one of the new type of shear connectors.

Furthermore, single-span beam tests with notch type shear connectors are presented (Fig. 3) and the correlation of experimental and theoretical results (“M-model”) are discussed (Fig. 4).

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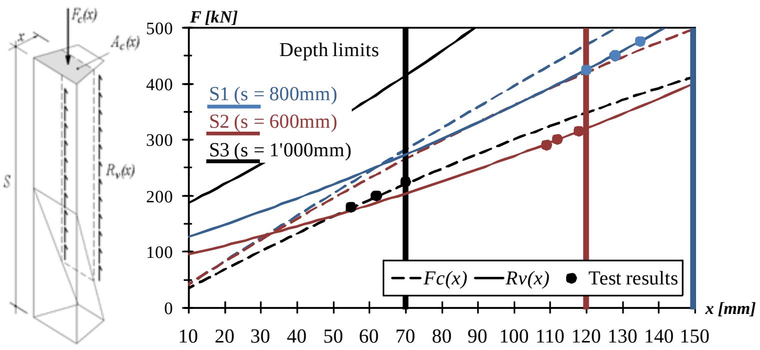

Fig. 2: Plastic failure model (left) and correlation of test and theoretical results (right).

Conclusions

The theoretical and experimental results presented here confirm that the new notch type shear connector exhibits a very high load bearing capacity and an enormously stiff behavior at SLS. This resistance is due to the exploitation of the glulam compression strength parallel to the grains $f_{c,0}$ on rather large bearing areas *BA*. Thus, the spacing of the connectors can be increased and their number reduced, respectively.

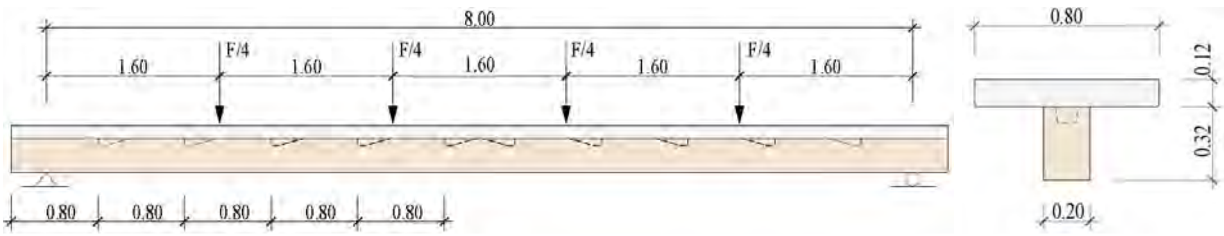

Fig. 3: Loads and structural scheme of four point bending tests [m].

Owing to the very high ductility of the connectors due to the crushing parallel to the grains, their necessary number at ULS can be determined by assuming a plastic behavior, hence a uniform distribution of the connectors along the beam. This ductility generally increases structural safety of the structure since it shows an “announcement” of failure.

The theoretical and test results confirm that the section loss due to the notches cannot be neglected. The decrease in bending and normal force resistance of the glulam depends on the size of the notch, more exactly on the section ratio between glulam beam and notch. Moreover, if a notch is in a highly loaded area of the structure, its influence becomes more important. Such effects should be consequently considered in the design.

Time-dependent effects such as shrinkage and creep should be taken into account in the design of such timber-concrete composite structures. When the reinforced concrete slab retracts after concreting, the friction forces between both components prevent this longitudinal deformation; some cracks may appear in the slab, demanding for a minimum reinforcement. The consequence is a decrease of the overall flexural stiffness. Furthermore, shrinkage of the concrete slab induces stresses in the glulam section, leading to a reduction of the total resistance of this part of the composite section, mainly of the bending resistance.

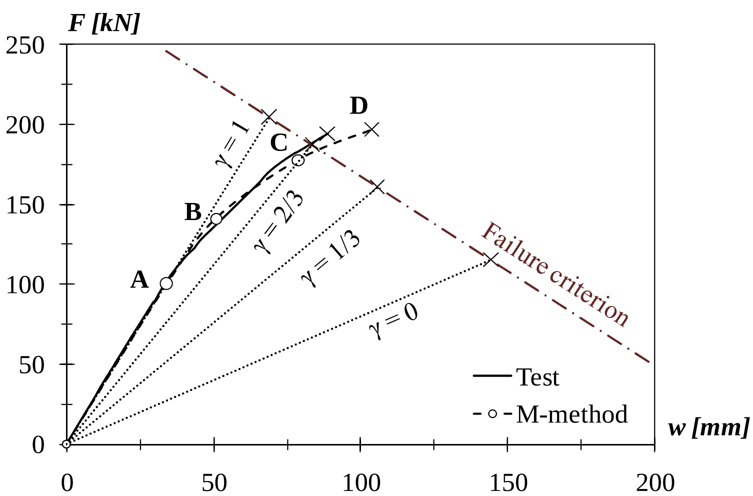

Fig. 4: Theoretical and experimental results.