PRECAST TIMBER-CONCRETE COMPOSITE FLOOR STRUCTURES FOR SUSTAINABLE BUILDINGS – EXPERIMENTAL VERIFICATION

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Summary

An effort to use renewable materials leads to broader utilization of timber structures also for multi-storey buildings. However, wider application of timber floor structures in multi-storey buildings is limited by lower lateral rigidity, worse acoustic and fire safety parameters in comparison to concrete floor structures.

The composite floor structures based on high performance silicates and wood represent the beneficial alternative to the modern timber floor structures. Proposed timber-concrete composite floor structure benefits from lower weight of slender HPC or UHPC deck (compared to common RC slab) while improving acoustic parameters and fire safety of the structure (compared to timber floor structure). Experimental verification proved that effective mechanical connection can be ensured by gluing.

Keywords: timber-concrete, high performance concrete, floor structures, experimental verification, glued connection

1 Introduction

Traditional timber-concrete floor structures consist of timber beams that are connected with concrete slab placed on the top of them. Shear composite action is usually ensured by various types of pinned connection (nails, bolts, pins or screws), newly also by steel multi-tooth connector plates [1]. The upper concrete slab is usually reinforced by reinforcing mesh in one or two layers. Minimal slab thickness is 50 mm due to required concrete cover of reinforcement, but more often the thickness is higher with respect to structural reasons. Timber-concrete composite floor structures are implemented in new buildings as well as in reconstructions of existing buildings. Disadvantage of common solution can be the substantial weight of concrete slab requiring the bigger dimensions of timber beams.

Concrete slab thickness can be diminished to 25–30 mm by utilizing high performance concrete (HPC) or ultra high performance concrete (UHPC) reinforced by dispersed steel microfibers [2]. However, at such thickness ordinary mechanical kinds of connection cannot be used. The experimental investigation performed at the Czech Technical University in Prague verified that a slender prefab deck can be connected to timber beams by gluing (Fig. 1, Fig. 2). The advantage is to avoid a wet process in timber--concrete floor structure implementation and the possibility of utilization of very thin prefab slabs from HPC or UHPC.

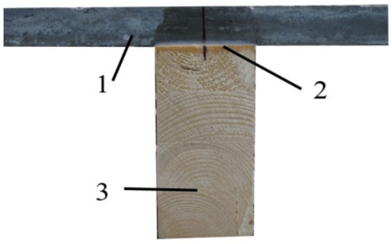

Fig. 1 *Cross-section: 1 – UHPC slab, 2 – glued connection, 3 – glued laminated timber beam*

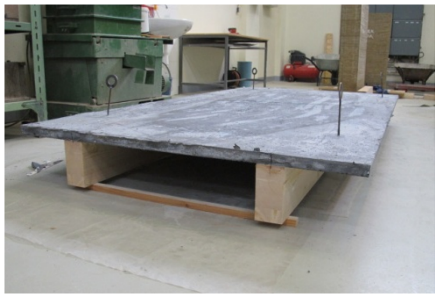

Fig. 2 *Segment of timber-UHPC floor structure*

2 Experimental verification of glued connection

Specific UHPC mixture was developed at the CTU in Prague from materials available in the Czech Republic. A broad spectrum of cements, superplasticizers, microsilicas and sands from various producers were tested. Only Stratec fibres were imported from Germany. The mixture used in these experiments has a compressive strength of 160 MPa tested on cubes a = 100 mm, flexural strength of 22 MPa (three-point bending test on single-edge notched beams 100/100/400) and modulus of elasticity in compression is 49 GPa.

The shear test was selected for verification of glued connection between timber and UHPC. Both sides of concrete prism 100/100/400 were glued to two timber prisms 80/160/320. The arrangement of the test is apparent from figure 3.

Two types of concrete (OPC – ordinary Portland cement concrete C30/37 and UHPC 160) and three various glues based on epoxy resins (Sikadur 30, Sikadur 330, SikaFloor 156) were used and tested in the first set of experiments. Timber prisms were from glued laminated wood. Even though, there were quite high variances in the results, the trend was obvious. The difference between OPC and UHPC timber composites was in the kind of a failure – the rapture in timber-OPC composites was mainly in concrete (Fig. 4) while in UHPC-timber composite the rapture was in the timber (Fig. 5). The best results were achieved with SikaFloor 156 although it has the worst workability as this type of glue is too liquid for such a purpose. Therefore, for the second set of experiments specific filler (3 % and 5 % by mass) was introduced into the SikaFloor 156. The glue with 5 % of filler performed well both from the point of workability and shear strength.

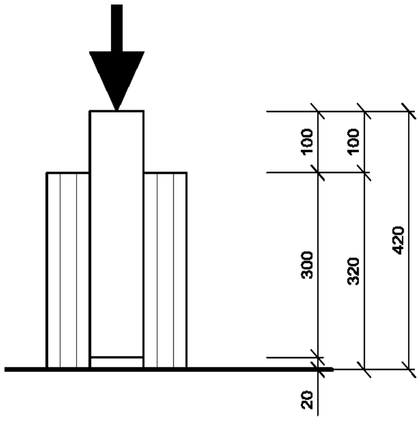

Fig. 3 *Shear test arrangement*

Fig. 4 *Timber-OPC sample failure*

Fig. 5 *Timber-UHPC sample failure*

3 Experimental verification of representative segment of timber-UHPC composite floor structure

Tested element comprised of slender UHPC slab 1.2 x 2.4 m with thickness of only 30 mm and two glued laminated timber beams 80/160 mm. Width between timber beams was 0.7 m. Connection between timber beams and UHPC slab was ensured by epoxy resin based glue Sikafloor 156 with 5 % of specific filler by weight. Composite segment was tested by four-point bending test (Fig. 6). The load was applied in steps by 10 kN with subsequent unloading to 1 kN. Maximal achieved load was 155 kN in average. With given theoretical span of 2.2 m, the limit deflection L/300 = 7.3 mm was achieved under load of 98 kN. That represents 5 times higher load than common load in residential buildings (converted into area 7–8 kN/m^2, i.e. dead load (floor, partitions) and live load). The experiments proved that glued connection between timber beams and UHPC deck is suitable for this type of application. Rapture always appeared after reaching the maximal load-bearing capacity of timber beams (Fig. 7).

Fig. 6 *Tested segment of timber-UHPC floor structure*

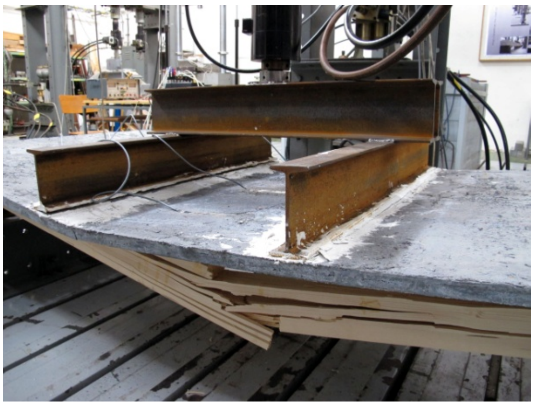

Fig. 7 *Failure of the tested composite segment*

4 Conclusions

Experimental verification of timber-UHPC composite floor structure proved the feasibility of the concept. Timber beams can be successfully connected to concrete slab by epoxy resin based glue. However, due to low melting point of epoxy resin based glue, it is necessary to protect glued connection against fire action.

Timber-UHPC floor structure benefits from lower weight of slender UHPC slab when compared with timber-concrete composite from common concrete (e.g. C30/37). Proposed solution improves acoustic parameters in comparison with timber floor structures. Life cycle assessment studies presented in [3], [4] showed that timber-UHPC composite floor structure has almost 25 % lower environmental impact in comparison with timber-OPC floor structure and 50 % lower environmental impact when compared with full reinforced concrete slab (concrete C30/37).

Acknowledgement

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