FIRE TEST OF TIMBER-FIBRE CONCRETE COMPOSITE FLOOR

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Abstract

Furnace test was performed on one full-size floor specimen at the Fire testing laboratory PAVUS. Floor specimen was 4.5 m long and 3 m wide, consisting of 60 mm fibre concrete topping on plywood formwork, connected to GL floor joists. It was subjected the standard fire for over 150 min. The membrane effect of the floor was progressively activated. The project is part of the experimental research that deals with the effect of membrane action of composite steel fibre reinforced floor slabs exposed to fire and continuous on previous research on steel fibre reinforced concrete slabs. The main objective of the project is the preparation of the analytical prediction model for the fire resistance of the steel-concrete and timber-concrete slab with steel fibre concrete.

Keywords: timber, fibre reinforced concrete**,** fire test, furnace

INTRODUCTION

The use of timber-concrete structures has considerably increased especially in case of reconstructions and constructions of prefabricated residential houses. For this reason it is necessary to gain a deeper knowledge of the behaviour of timber-concrete structures in fire, to remove all unknown and to ensure safe use for the intended purpose.

In the concrete slab of the timber-concrete composite floor is necessary reinforcement for restrain caused by shrinkage of concrete and to obtain a sufficient resistance against tensile forces around the shear connectors. Consider the amount and the position of the reinforcement in the slab the thickness of the slab results in a minimum of about 60 mm which leads to an unnecessary high dead load of the composite floor, see Holschmacher, 2002. For this reasons several research studies during the last decades have been conducted, with focus on new timber-concrete composite floor. One of the new kinds of such floor is that the usual reinforced concrete is replaced by steel fibre reinforced concrete (SFRC). This innovative concrete with specific hardened concrete properties and fresh was developed to reduce the slab thickness and to help the construction procedure. With the use of fibres the experiment shows that the behaviour is more ductile and redistribution of stresses is better.

One of the most important requirements of floor structure is its fire resistance. The fire resistance of timber-fibre concrete composite elements is mainly influenced by the timber, the connectors and mixture of fibre concrete. The temperature inside the timber member depends particularly on the cross-sectional dimensions, on the density and moisture content of wood and on the fire load and temperature development during the fire. The temperature development in the place of the shear connection can be governed by the cross-sectional dimensions, particularly by the width, and by the sort of fire scenario. It is possible to use nominal, parametric or natural fire scenario. Fire resistance of SFRC can be increased by adding of plastic fibres (polypropylene, polyester) because the plastic fibres evaporate in temperature of 100 °C and rise continuous water pore to escape from concrete in case of fire. The results indicate that the influence of steel fibres on the mechanical properties is relatively greater than the influence on the thermal properties and is expected to be beneficial to the fire resistance of structural elements constructed of fibre-concrete. Experimental and theoretical studies shows that the compressive strength at elevated temperatures of fibre-reinforced

concrete is higher than that of plain concrete. The presence of steel fibres increases the ultimate strain and improves the ductility of fibre-reinforced concrete elements, see Kodur, 1996.
The experimental work of testing a composite timber-fibre concrete floor in fire is described in this report. For the experiments were made material properties tests at ambient and elevated temperature. There were detected tensile strength and ductility of fibre reinforced concrete. Thermal and mechanical properties of fibre reinforced concrete at elevated temperature and numerical modelling of timber-fibre concrete composite floor in fire will be the subject of further author´s works and papers. The results obtained in the numerical simulations will be compared with results obtained from furnace tests, which were performed on one full-size floor specimens in the Fire testing laboratory PAVUS in October 2012. On the evaluating of results and comparing results and simulations author currently works.

1 TEST AT ELEVTED TEMPERATURE

The full scale floor specimen was designed to span 3,5 m by 4 m according to the furnace interior dimensions. The composite timber-concrete floor was composed of timber frame, two secondary beams and a 60 mm thick floor slab connected to glue laminated floor joists. Concrete slabs with a strength class 45/55 were reinforced by steel fibre only without added steel bars. The fibre content was 70 kg/m^3 with type of fibres HE 75/50 Arcelor. As connectors were used TCC screws inclined 45 degrees to the beam axis in two rows, distance of screws in one row is 0,1 m. The timber frame was fire protected and the secondary beams in the centre of the floor slab were left unprotected. The design fire used in the tests was the standard fire. The mechanical load during fire was created by concrete blocks uniformly distributed over the floor. The arrangement of the test specimen is shown in Fig. 1.

Fig. 1 Fire test set-up

The behaviour of the composite slabs in the furnace was recorded by 27 thermocouples and 13 deflectometers. 13 thermocouples were concreted in the composite slab at 3 separate points across the slab, 4 were located on timber beams and 10 recorded the gas temperature in the furnace and were located just below the floor. Seven deflectometers measured the vertical deflections and six measured the horizontal deflections.

2 EXPERIMENTAL RESULTS

During the heating phase of this test, the standard fire curve was followed which lasted for 150 mins. After that, burners were turned off and the furnace was cooled down naturally. The unprotected timber beams located at the middle of the floor were heated up to 250 °C. The maximum recorded temperature occurred after 45 mins at the centre span of beam. Then the secondary beams failed, see Fig. 2. Integrity of this slab was maintained during the first 100 mins, when the first crack opened. The full collapse of the test was reached at 154 mins due to damage of the fire protection of edge beams, see Fig. 2.

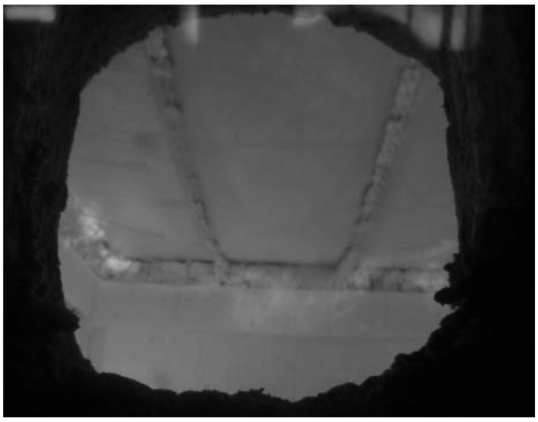

Fig. 2 Floor during the fire test from bottom

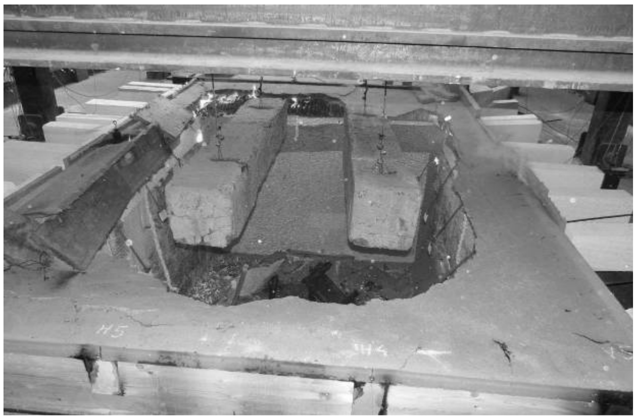

Fig. 3 Collapse of the composite slab

The temperature in the concrete slab continues to rise after the maximum atmosphere temperature, which occurred at 150 mins. The maximum temperature reached 845 °C in the middle of the slab 20 mm from the bottom surface of the slab. The temperature rise at the unexposed face of the composite slab after 150 mins of fire was slightly above 350 °C. The limit of 140 °C that defines the insulation criterion was exceeded at 52 mins.

At low temperatures, less than 400 °C, the beam deflection is predominantly due to thermal bowing. At higher temperatures, mechanical deflection will dominate and the deflection increases at a faster rate. At 150 minutes of fire, the total deflection of the floor reached 220 mm. Their flexural load bearing capacity with this level of heating would no longer allow them to bear the applied load alone. In consequence, the slab and membrane effect of the floor was progressively activated, to maintain the global resistance of the floor.

The supported concrete slab was not horizontally restrained around its perimeter and the supporting protected perimeter beams maintained their load carrying capacity. They were subjected to small vertical displacements and allowed membrane action to develop with the in-plane forces in the central region of the slab going into tension and in-plane equilibrium compressive forces forming in the slab around its perimeter.

Based on the experimental results, behaviour of timber-concrete floor in fire may be divided into three stages, as shown in Fig. 4. In the initial stage of fire, when the temperature is not very high, the slab carried applied load in a bending mechanism with small deflections (Stage 1). In addition to the thermally induced downward deflection, the unprotected beam was losing strength and stiffness due to the increasing temperatures from fire. With increasing temperature, between 30-45 mins, the strengths of timber and concrete of the slab were reduced, and the slab behaviour formed in the slab (Stage 2). The temperatures reached in the timber beam by the end of Stage 2 are in excess of 250 °C. When the temperature of the slab increased further (after 46 mins), the bending capacity of the slab was not enough, and the deflection of the slab had to be further developed, which created additional load-bearing capacity under membrane mechanism to maintain the resistance of the slab (Stage 3). How the deflection of the slab was larger, the tensile membrane action is higher. Finally, most of the vertical load on the slab was carried by membrane action.

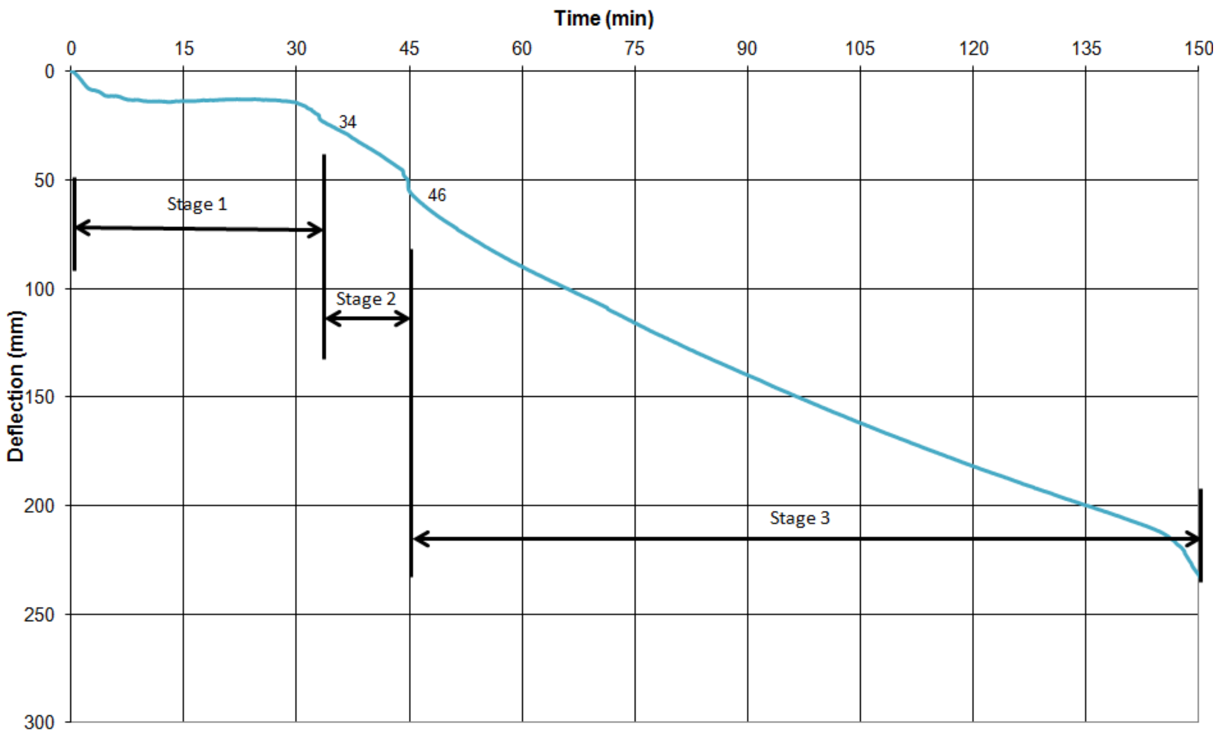

Fig. 4 Stages of timber-concrete composite floor during fire test

3 SUMMARY AND ACKNOWLEDGMENT

The timber-concrete slab performed well supporting the applied load for the duration of the test and pointed out the strength in the system due to membrane action. Due to membrane action, the existence of secondary timber beams to support the slab is not necessary in the fire condition and these beams can be left unprotected.

Based on current knowledge and the performed tests the analytical model is prepared for the fire resistance of the timber- concrete slab with steel fibre concrete.

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REFERENCES

Bailey C.G., Moore D.B., The structural behaviour of steel frames with composite floors slabs subject to fire - part 1 theory, Struct Eng, Vol. 78(11), pp. 19–27, 2000.

Bednář J., Wald F., Vodička J., Kohoutková A., Membrane Action of Composite Fibre Concrete Slab in Fire. Procedia Engineering [online]. 2012, Vol. 40, no. 40, p. 498-503. Internet: http://www.sciencedirect.com/science/article/pii/S1877705812025180. ISSN 1877-7058.

Vassart O., Zhao B., Fire Resistance Assessment of Partially Protected Composite Floors, FRACOF+, 2011, http://fire.fsv.cvut.cz/fracof.

Holschmacher K., Klotz S., Weise D., Application of steel fibre reinforced concrete for timber-concrete composite constructions, Lacer No. 7.2002: 161-170, 2002.

Kodur V.K., Lie T.T., Thermal and mechanical properties of steel-fibre-reinforced concrete at elevated temperatures, Can. J. Civ. Eng. 23:511-517, 1996.

Guo-Qiang Li, Shi-Xiong Guo, Hao-Sheng Zhou, Modeling of membrane action in floor slabs subjected to fire, Engineering Structures, Vol. 29, pp. 880–887, 2007.