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Munich Fire Tests on Membrane Action

of Composite Slabs in Fire – Test Results and Recent Findings

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Research Project

To enable the utilisation of membrane action in Germany the research project "Utilisation of membrane action for design of composite beam-slab-systems in fire" (AiF-No. 16142) was initiated. Main objective of the project is to understand the behaviour of intermediate beams between two slab panels. Two large scale fire tests have been performed in Munich (Fig. 1) to analyse this issue, to calibrate numerical models and to validate analytical assumptions.

Fig. 1. Munich Fire Tests

Test Arrangement

The test arrangements should represent office buildings and similar multi storey structures. The specimens both consisted of two slab panels with overall dimensions of 5.0 m by 12.5 m (Fig. 2). They were supported by hot rolled I-beams and six reinforced concrete columns. All edge beams were protected with intumescent coating for a fire resistance of 60 minutes. The secondary beams were left unprotected. Only the orientation of the secondary beams, the flooring system and the intumescent coating system has been varied. The first specimen was built with a lattice girder precast slab and the second one with a profiled steel sheeting composite slab.

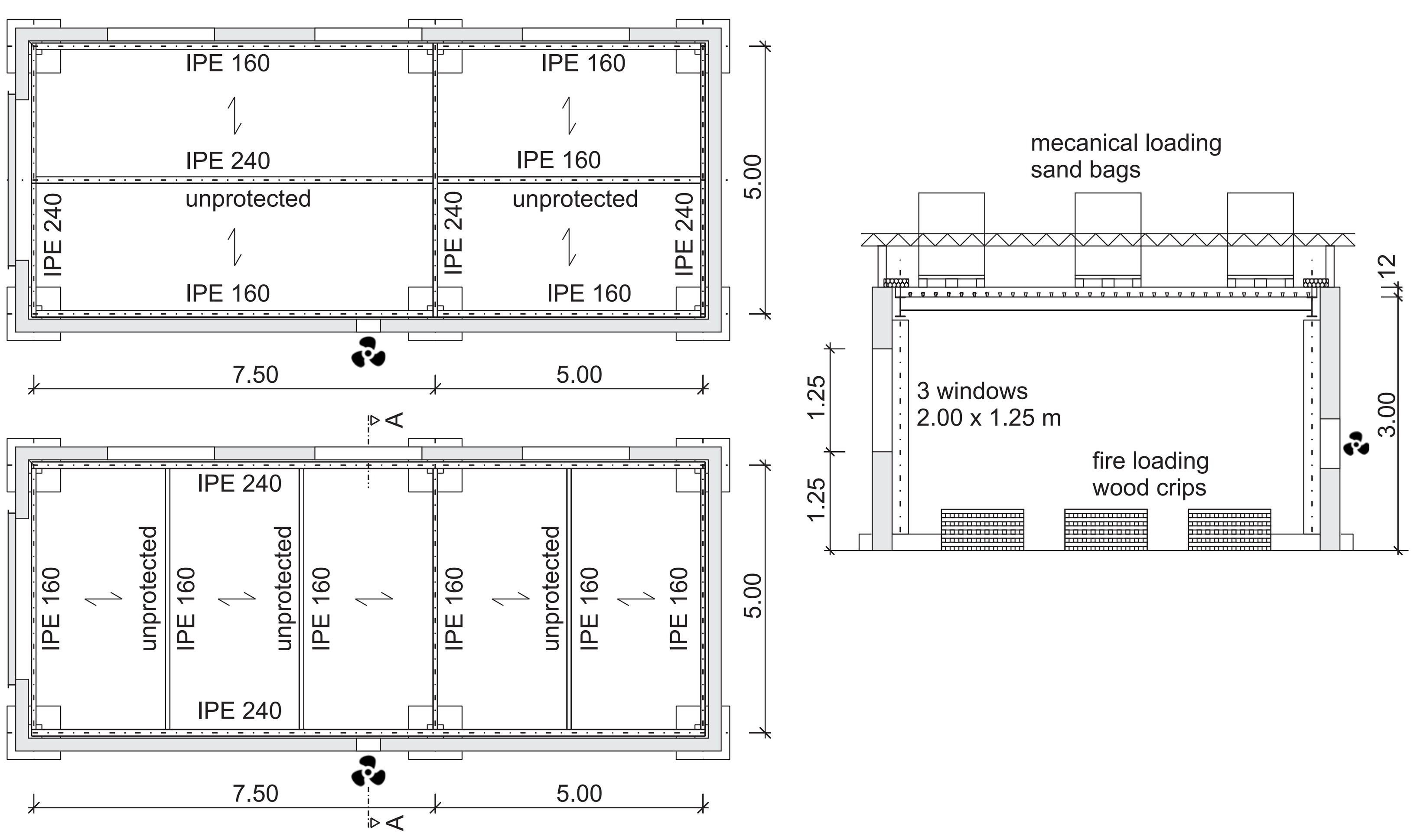

Fig. 2. Plan views and section of test arrangement

The fire exposure of the slabs was intended to follow as close as possible the ISO 834 fire curve. The edge beams have been inside the furnace to be able to deform freely and to investigate the influence of the edge beams on membrane action. The loading should be representative for office buildings. To ensure these boundary conditions a 3.0 m high temporary furnace was built by aerated concrete bricks. Sandbags were placed on top of the slab to simulate a uniform distributed load of 2.1 kN/m². Wood cribs consisting of 4.9 m³ spruce timber constituted the fire load. Three windows in one wall provided natural ventilation and a fan was installed in the opposite wall to readjust the ventilation.

Test Results

The gas temperatures in both tests exceeded 900°C (Fig. 3). The unprotected secondary beams heated up to 900°C. The temperature in the edge beams remained below 500°C. Partially the intumescent coating detached from the lower flange. Therefore the lower flange of the intermediate beam reached almost gas temperature. The larger panel reached a maximum deformation of 260 mm after 60 minutes and the shorter panel about 200 mm. At test 1, after 19 minutes a huge crack appeared in the smaller panel close to the intermediate beam. The upper reinforcement layer ruptured completely in this crack and smoke passed through the gap. The slab did not collapse during the whole test but it lost its integrity and insulation (criterion "E" and "I"). At test 2 also a crack occured above the intermediate beam but all three criterions (REI) for fire resistance were kept during the whole test.

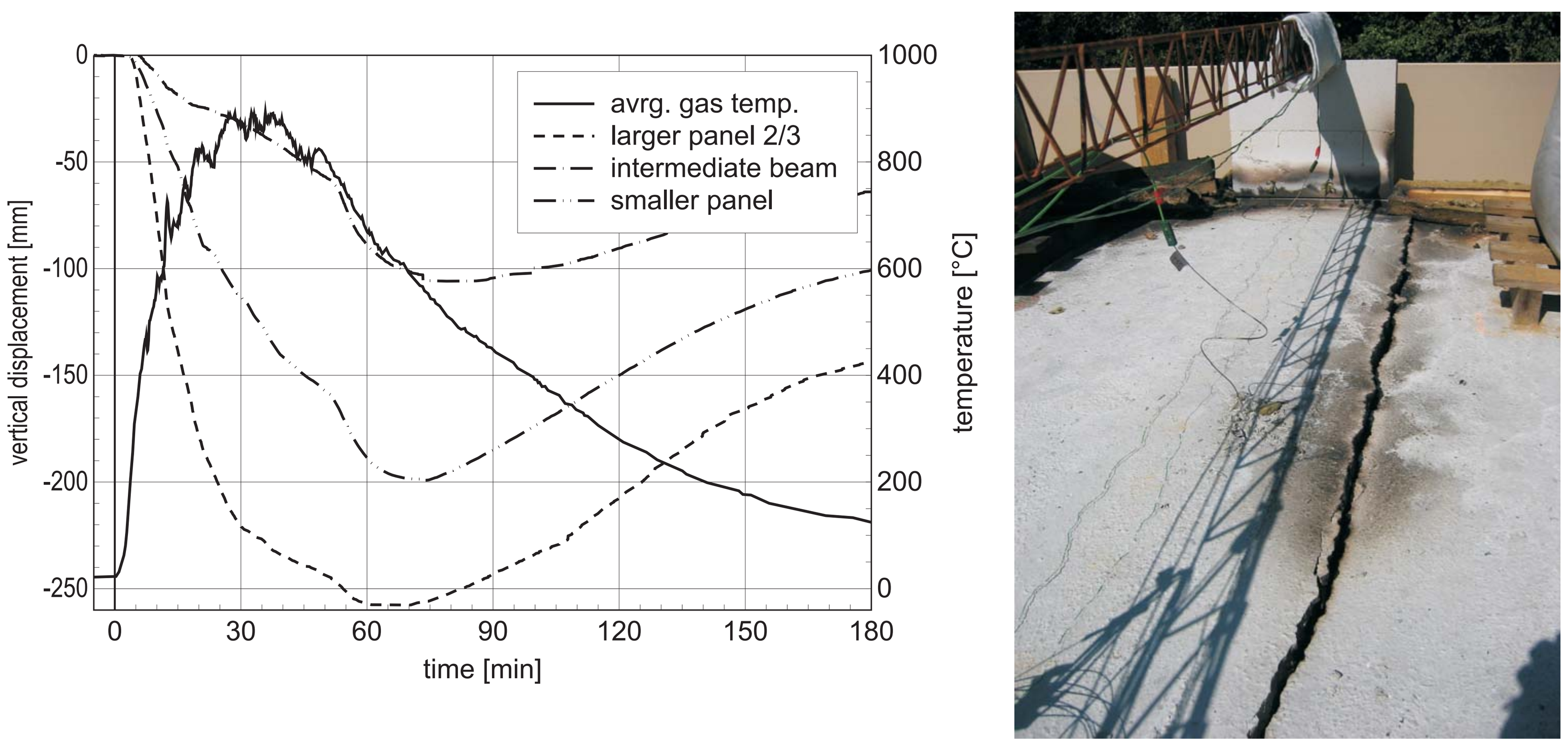

Fig. 3. Gas temperature, vertical displacements and crack above intermediate beam at test 1

Shear Crack

The tensile forces in the reinforcement above the intermediate beam are mainly caused by the hogging moment. This can be shown by considering the stresses in the top layer of the slab (Fig. 4). Material nonlinearities reduce these stresses but even a bending hinge above the intermediate beam is not sufficient. The tensile forces are reduced but do not disappear. The slab acts like a three times supported cable in longitudinal direction. This led to cracking of the concrete above the intermediate beam, yielding and finally even to rupture of the reinforcement in the crack. With the ruptured reinforcement in the tension-zone the slab was not able to bear shear forces anymore and a huge shear crack was formed close to the intermediate beam. After that all the constraint forces have been removed and the slab again got into equilibrium with a different force distribution.

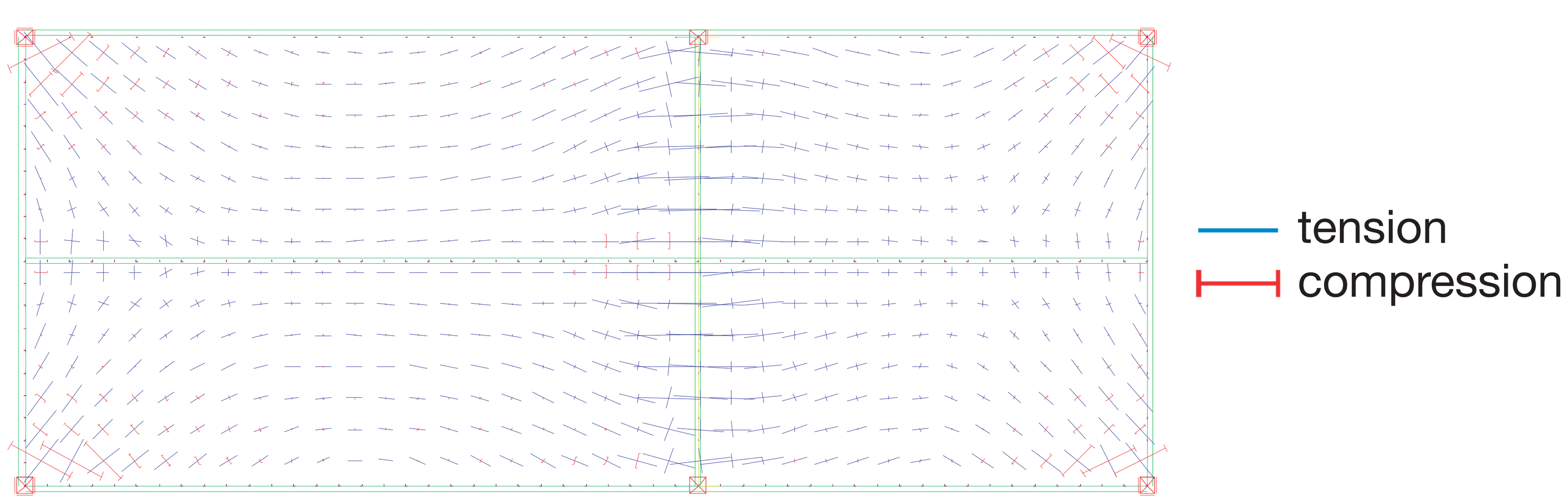

Fig. 4. Principal stresses top layer of slab, uncracked concrete

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