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COST Action TU0904 Integrated Fire Engineering and Response

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FIRE ENGINEERING RESEARCH - KEY ISSUE FOR THE FUTURE II

TIMBER-FIBRE CONCRETE STRUCTURES IN FIRE

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Contents

Introduction

- Ph.D. student at the **Czech Technical University in Prague**
- Research is focused on **modeling of membrane action of timber-fibre concrete composite floors exposed to fire**
- The aim is the preparation of the **analytical prediction model** for the fire resistance of the timber-fibre concrete composite floors
  - Based on tests at ambient and elevated temperature and FE modeling
- Short Term Scientific Mission at The Institute of Structural Engineering ETH Zurich ⟶ Numerical modeling of timber-fibre concrete composite floor
- Scientific internship at Blaise Pascal University in Clermont-Ferrand ⟶ Analytical model of timber-fibre concrete composite floor in fire

Timbre-Fibre Concrete Structures

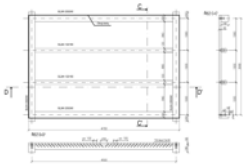
- Effective method for refurbishment of existing timber floors and for floors of new multi-storey timber houses
- Increase of the load bearing capacity
- Reduction of the deflection
- Better vibration behaviour of the ceiling
- Improvement of sound insulation and fire resistance
- Fire resistance is one of the most important questions
- Perception of the public is, that timber is combustible material → it is necessary to gain a deeper knowledge of the behaviour of timber-fibre concrete structures in fire
- The fire safety of timber-concrete structures can **match or even succeed** that of other structural materials

Timbre-Fibre Concrete Structures

- Reinforcement of the concrete slab leads to a large slab thickness and disadvantages during the execution of construction work ⟶ reasonable to replace the conventional reinforcement by steel fibres

- Steel fibres increase the ultimate strain and improves the ductility of fibre-reinforced concrete elements
- The fire resistance of the timber-fibre concrete structure was **not published yet**

Experimental Programme



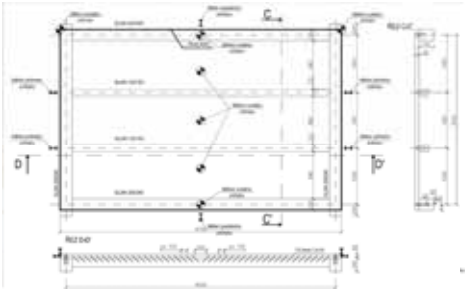
- timber frame GL24h 200/240 mm and two secondary beams 120/160 mm
- 60 mm thick floor concrete slab
- steel fibres 70 kg/m³ HE 75/50 Arcelor
- polypropylene fibres 1,5 kg/m³
- TCC screws Ø 7,3 mm inclined 45° to the beam axis in two rows

Experimental Programme

- Furnace test of timber-fibre concrete structure was performed on one full-size floor specimen at the Fire testing laboratory
- Mechanical load was created by concrete blocks

Experimental Programme

- Timber frame was fire protected and the secondary beams were left unprotected
- Recorded by 27 thermocouples and 13 deflectometers



Experimental Results

- Standard fire for over 150 mins
- Unprotected timber beams were heated up to 250 °C
- The full collapse of the test was reached at 154 mins → damage of the fire protection of edge beams
- The membrane effect of the floor was progressively activated

Floor during the fire test from bottom

Collapse of the floor

Numerical Simulations

- Mechanical behavior of the timber-concrete composites in fire is very complex transient thermo-mechanical problem
- This problem can be solved as one-way coupling between thermal analysis and mechanical analysis

Nonlinear transient heat flow

- Thermal load (fire) as radiation and convection
- Thermal material properties depend on time (nonlinear analysis)
- Timber charring effects

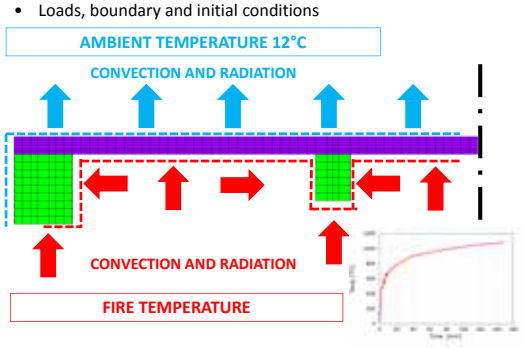
→

Nonlinear structural analysis

- Structure loaded by mechanical loads and by thermal strain due to nonlinear thermal expansion
- Nonlinear behavior of fibre reinforced concrete and timber with temperature effects
- Model of timber-concrete connection
- Timber charring effects

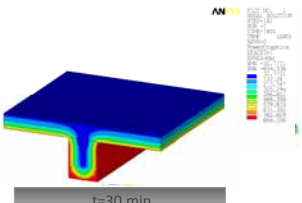
Transient thermal analysis

- Loads, boundary and initial conditions

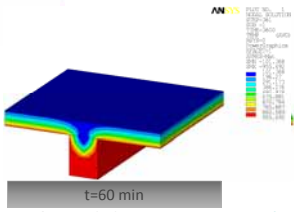


Numerical Simulation

- Temperature development



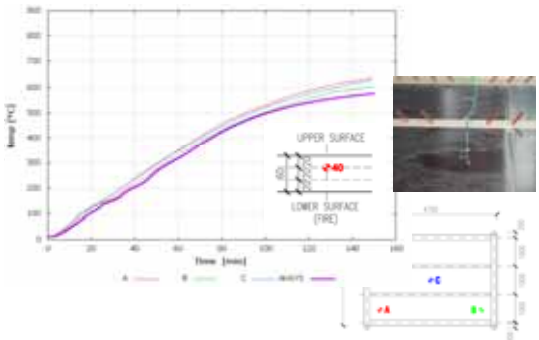
t=30 min



t=60 min

Numerical Simulation

- The comparison of numerical model with results from the test



Research Objectives

- Preparation of the analytical prediction model
  - Initialization and development of the plastic yield lines
  - Development and progress of membrane behaviour
  - Achievement of the ultimate limit state

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Model will facilitate the increase of the fire resistance of the multi-storey building

by optimal structural solution for reconstructions and new structures

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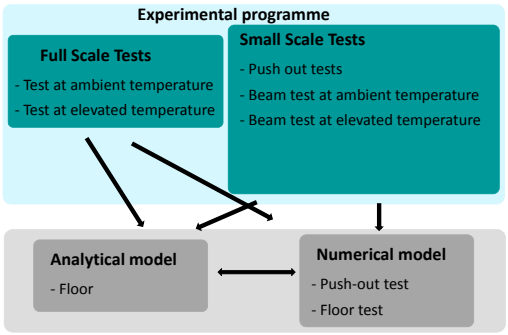
background material for the update of the European structural fire safety standards scheduled to 2015

Method



Conclusion

- State of The Art ✓
- Experimental programme ✓
  - Test at ambient temperature ✓
  - Test at elevated temperature ✓
  - Material tests ✓
- Numerical model of push out test ✓
- Transient thermal analysis ✓

- Beam test at ambient temperature (11/10/2013)
- Beam test at elevated temperature (11/10/2013)
- Test at elevated temperature (9/10/2013)
- Nonlinear structural analysis
- Analytical model

THANK YOU FOR YOUR ATTENTION

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