A Structural Fire Engineering Prediction for the Veselí Fire Tests, 2011

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1. Background

When a fire occurs in a building the internal forces in the joints change substantially during the course of the fire, even though the external forces applied to the structure remain unchanged. This results mainly from restraint to thermal deformations and degradation of the mechanical properties of the building materials at high temperature. These phenomena were observed in both full-scale tests (Newman et al, 2004) and accidental fires (NIST 2005, 2008). Because current design methods for connections are solely based on ambient-temperature behaviour, the additional forces and rotations generated by restrained thermal expansion of beams in fire are not taken into account in design. If, at any stage of fire exposure, a connection does not have sufficient resistance to accommodate large rotations and co-existent forces, fracture will occur, which may lead to extensive damage or progressive failure of the structure. However, a more effective way of ensuring robustness may be to provide sufficient inherent ductility in the connections to accommodate much of the thermal expansion of members, and thus reduce the restraint forces. Therefore, how the joints perform in a building fire will be critical to whether it would be able to survive the fire attack.

2. Objectives

The Structural Fire Engineering Research Group of the University of Sheffield is participating in the European-funded project COMPFIRE (RFCS 2008), a collaboration between research teams at universities in Manchester, Coimbra, Luleå and Prague, Desmo Ltd in the Czech Republic, and TATA Steel RD&T. The objective of this project is to investigate the behaviour and robustness in fire of practical connections between steel beams (both composite and non-composite) and two types of composite columns - concrete-filled tubular (CFT) and partially-encased H-section columns. Two natural fire tests on a full-scale composite structure are planned to take place in Veselí, in the Czech Republic (Wald and Jána 2011). One task of the Sheffield research team has been to predict the structural behaviour of the tests before they are conducted. The assessment was conducted using the specialist structural fire engineering FEA program *Vulcan* (VSL), and this paper reports the results of this predictive analysis.

3. Test Description

Objectives:

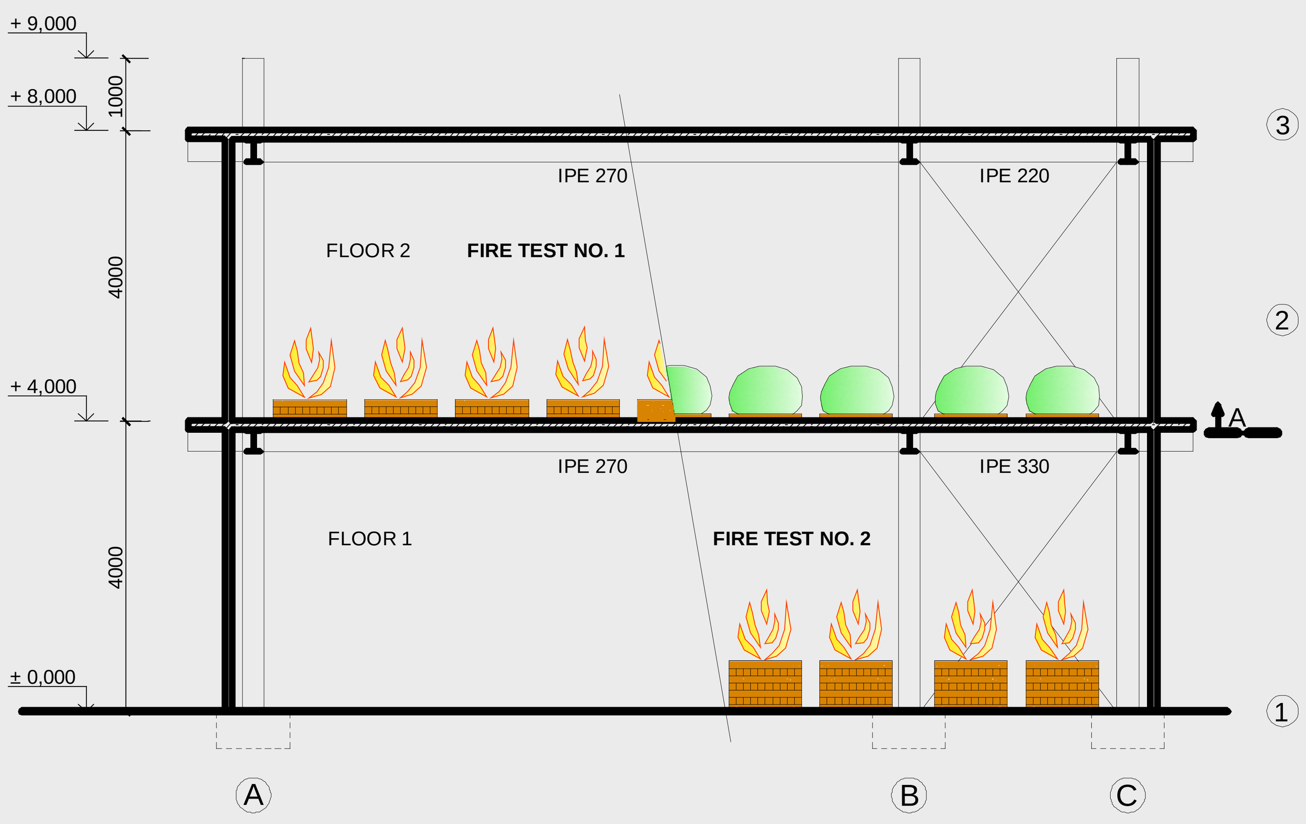
- Provide experimental data on the response of composite frames to a natural fire
- Demonstrate the impact of improved detailing of joints on structural robustness in fire

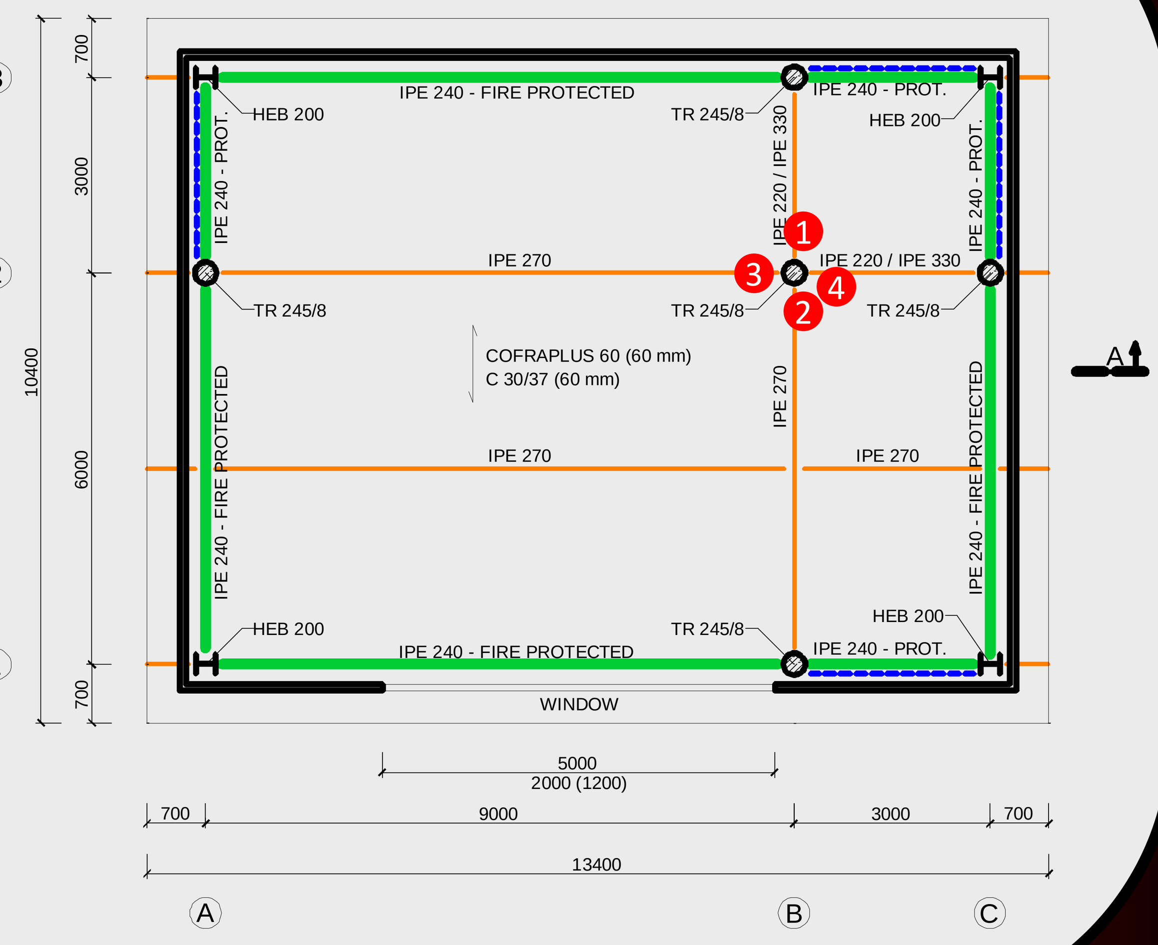
Dates: 6th and 15th September 2011

Designed by: Department of Steel and Timber Structures of the Czech Technical University

Two tests planned:

- Test 1 – thermal test in upper storey to obtain temperature data
- Test 2 - lower storey subject to both mechanical and fire loading, to demonstrate the robustness in fire of the joints

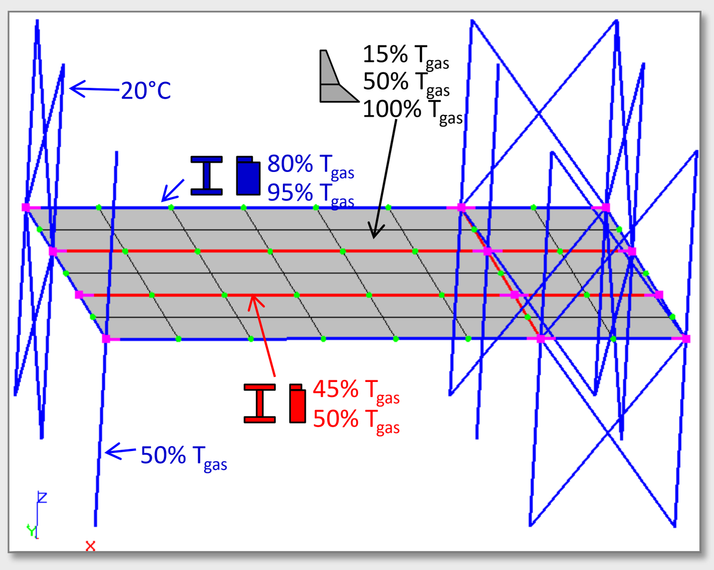




Characteristic design loads:

- Dead - Slab 2.35 kN/m^2; Flooring 0.5 kN/m^2
- Live – Imposed load 3.0 kN/m^2; Partitions 0.5 kN/m^2

4. Pre-Test Modelling Using *Vulcan*



Mechanical loading

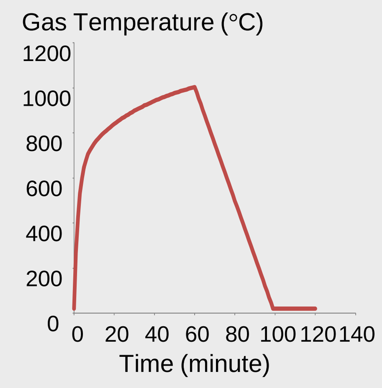
- Area load on slab - 6.35 kN/m^2
- Point loads on column tops - 2.85 kN/m^2

Boundary conditions

- Column base - fixed
- Top ends of upper-floor columns - restrained laterally but not axially

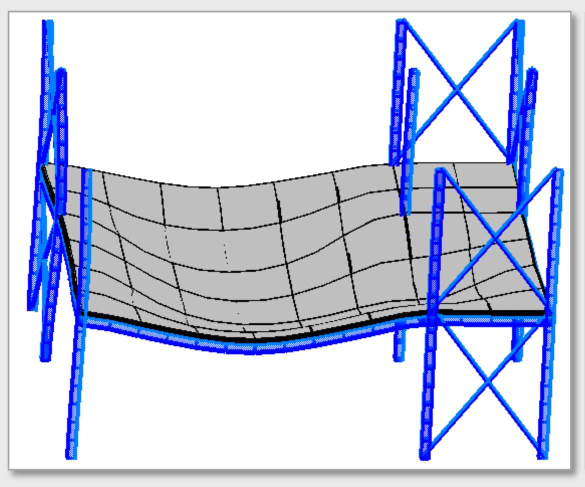
Temperature distribution

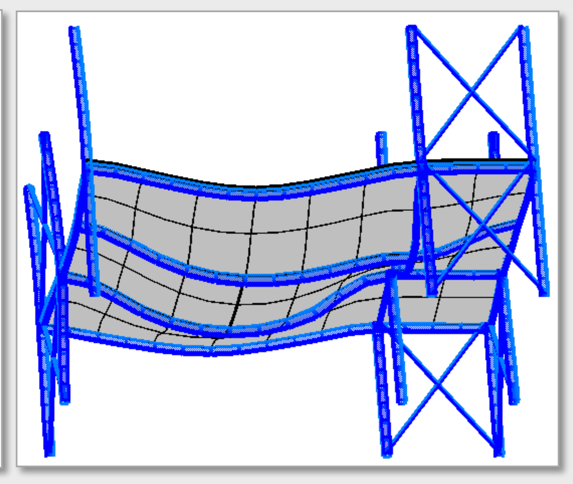
- While waiting for the actual temperature data, the first predictions were made by relating the beam, column and slab temperatures to a Eurocode 1: Part 1.2 (CEN 2002) type of fire curve which reaches 1000°C at 60 minutes.

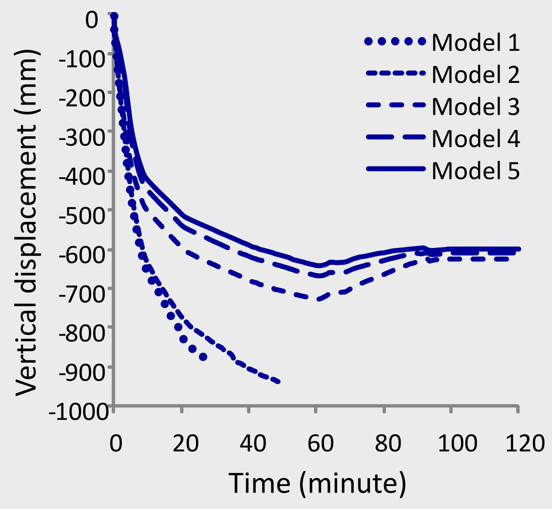


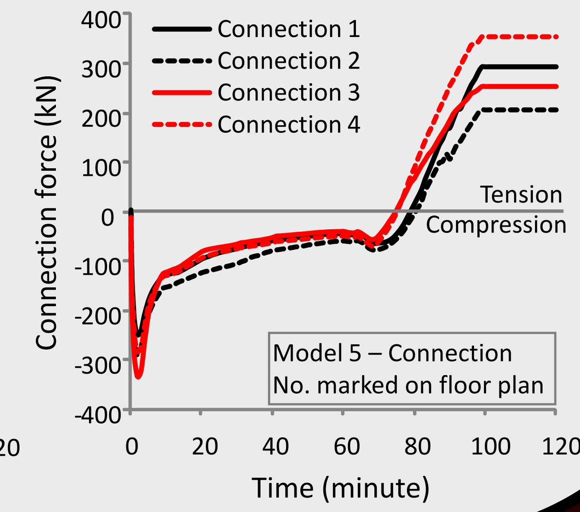
Model No.	Connection Rigidity	Rotational Spring Stiffness (Nmm/rad)
1	Pinned	100
2	Semi-rigid	5x10^5
3	Semi-rigid	1x10^9
4	Semi-rigid	1x10^{10}
5	Rigid	1x10^{12}

- Five models with different connection rigidities were analysed by varying the rotational stiffnesses of the connection (spring) elements









5. Conclusion

- The deformation shapes of the five models of different connection rigidities are similar;
- The effect of connection rotational stiffness on the fire resistance and deformability of the structure is considerable;
- The fire resistance of the structure is enhanced by increasing the rotational stiffnesses of the connections.

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