FracoF

FIRE RESISTANCE ASSESSMENT OF PARTIALLY PROTECTED STEEL-CONCRETE COMPOSITE FLOORS

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  - Mechanical principle
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Background

Large scale fire tests conducted in a number of countries and observations of actual building fires have shown that the fire performance of composite steel-framed buildings with composite floors is much better than indicated by standard fire resistance tests on isolated structural elements.

The first relevant experimental evidence is the fire test campaign which was completed in the UK at the Building Research Establishment’s Cardington Laboratory in 1995-1996. The tests were carried out on an eight storey composite steel framed building that had been designed and constructed as a typical multi-storey office building. The purpose of the tests was to investigate the behaviour of a real structure under real fire conditions.
Background

The Cardington tests demonstrated that modern steel frames acting compositely with steel deck floor slabs have a coherence that provides a resistance to fire far greater than that normally assumed. In all tests, the structure performed very well and overall structural stability was maintained.

Analysis reveals that this excellent fire performance is due to the development of tensile membrane action in the reinforced concrete slab and the catenary action of steel beams. As a result, a new fire design concept for modern multi storey steel framed buildings was developed in UK.
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Concept

Test on whole floor

Unprotected Element

Protected Element

$R_{\text{(single element)}} < 30$

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FRACOF Concept
Structural grid

**Fracof test**

(16 / 01 / 2008)

**Cossfire test**

(16 / 01 / 2009)
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- **Naked** central beams
- **Protected** surrounding beams

Dimensions:
- 9m
- 7m
Composite slab

Steel deck: COFRAPLUS60 – 0.75 mm
Concrete: C30/37

Reinforcing mesh

Mesh size: 150x150
Diameter: 7 mm
Steel grade: S500
Axis distance from slab top:
• 50 mm FRACOF
• 35 mm COSSFIRE
## Connections

<table>
<thead>
<tr>
<th>Beam to column</th>
<th></th>
<th>Beam to beam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Secondary beam</td>
<td>Primary beam</td>
<td>Double angle web cleats</td>
</tr>
<tr>
<td>Double angle web cleats</td>
<td>Flexible end plate</td>
<td>Double angle web cleats</td>
</tr>
</tbody>
</table>

Grade of steel bolts: 8.8
Diameter of steel bolt: 20 mm
Loading

Surfacic load for office buildings: \(1.25 \text{kN/m}^2 + 0.5 \times 5.00 \text{kN/m}^2 = 3.75 \text{kN/m}^2\)

FRACOF

15 sand bags of 1512 kg
Equivalent uniform load: 390 kg/m\(^2 = 3.90 \text{kN/m}^2\)

COSSFIRE

20 sand bags of 1098 kg
Equivalent uniform load: 393 kg/m\(^2 = 3.93 \text{kN/m}^2\)
FRACOF TEST
about 80 people from Authorities
Test results: \( R > 120 \) minutes
Results – Fracof (2008) and Cossfire (2009)

Before the fire

After 120 of fire

Max. deflection 46 cm

Max. deflection 55 cm

Extrapolated results

FRACOF

COSSFIRE
Numerical simulation of the Fracof test

27 October 2010

Slab

Beam
Measured deflections during the Fracof test

Protected beams

Exposed beams
Results of the numerical simulation
München natural fire tests
(07/07/2010 + 03/09/2010)

In the scope of german AIF project “Nutzung der Membranwirkung von Verbundträger-Decken-Systemen im Brandfall”, pictures from first test.
Ulster natural fire test
(27/02/2010)

In the scope of european RFCS project FICEB+ “Fire resistance of cellular beams made of hot-rolled profiles”.

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Method developed by **Prof. Colin Bailey** University of Manchester, formerly Engineer Building Research Establishment (BRE).

Starting point is the robust *tensile membrane action* behaviour of the composite slab which was firstly observed at the Cardington tests.
Behaviour of slab and beam during a fire

Composite slab is one-way spanning onto unprotected beam
Behaviour of slab and beam during a fire

Plastic hinge forms in unprotected beam - yield line forms in slab.
Behaviour of slab and beam during a fire

Strength of composite beam continues to decrease resulting in the slab yield pattern shown.
Behaviour of slab and beam during a fire

With increasing loss of mechanical properties of the beam, the slab behaviour tends towards a yield line pattern given for the slab acting without the beam.
Load carrying capacity

Beam temperature

Strength of slab based on lower bound assuming no beam strength

Tension

Compression ring
Possible failure modi

Fracture

Horizontal movement

Compression failure

Compression failure
Model validation

Bailey conducted additionally 26 cold and 22 fire tests on slab in his laboratory to validate the plate theory based on tensile membrane action.
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The Fracof software is a simple design tool for the assessment of the fire resistant of partially protected composite floors according to the Bailey method. It has been realised in the frame of Steel Alliance by cooperation of SCI and CTICM.

It is freely downloadable under: www.arcelormittal.com/sections
Design philosophy

Protected elements

Unprotected elements

FRACOF software
Floor slab is adequate if load-carrying capacity $> \text{loads}$

Temperature evolution

Load-carrying capacity evolution
Aknowledgements:

- Prof. Colin Bailey (UMIST)