Fracof

FIRE RESISTANCE ASSESMENT OF PARTIALLY PROTECTED STEEL-CONCRETE COMPOSITE FLOORS

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  - New fire tests
  - Mechanical principle
  - Design software

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

2nd corner test: fire load (above) and during the test

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.

2nd corner test: remaining deformed shape after fire

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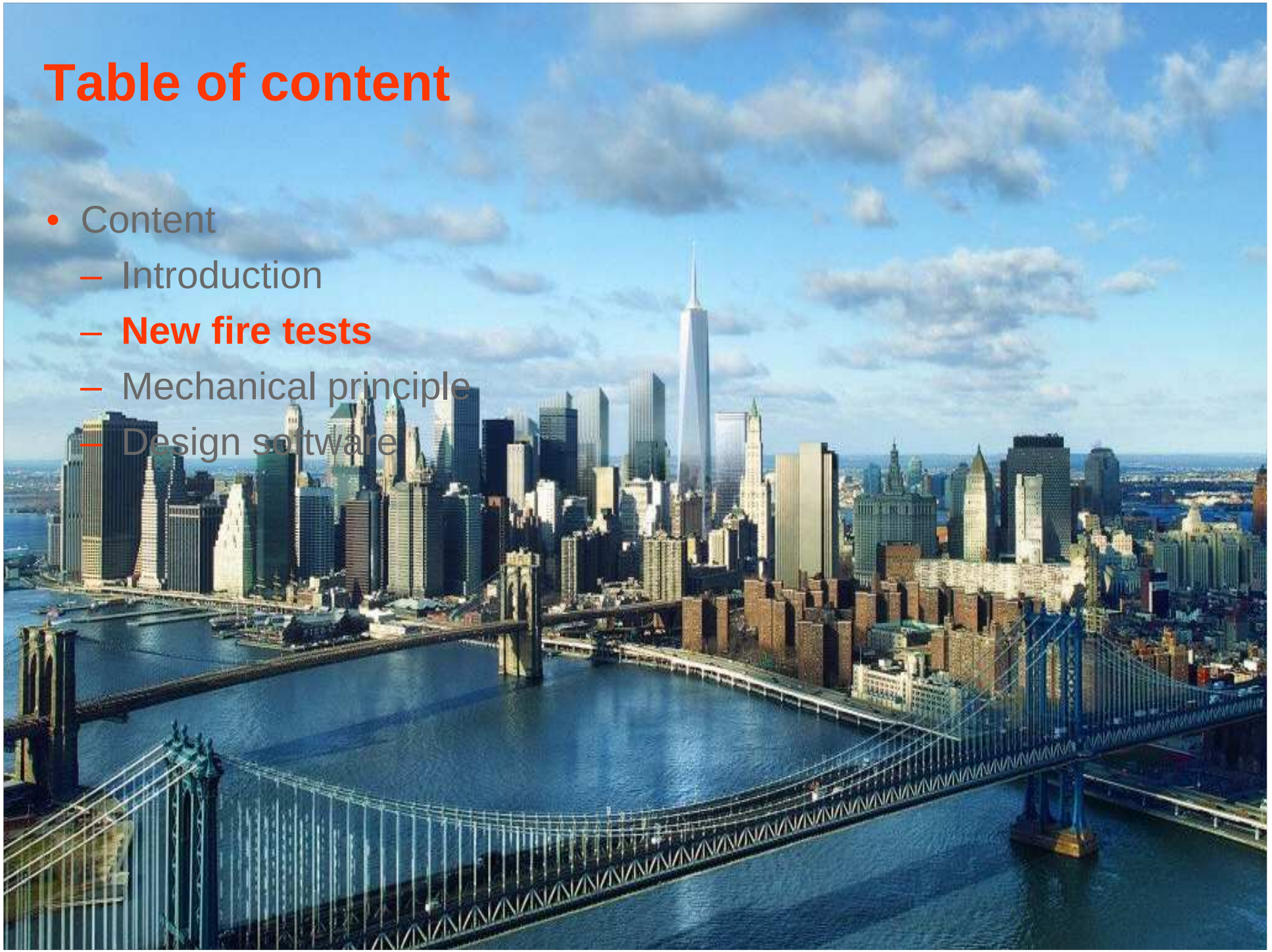

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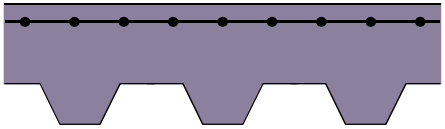
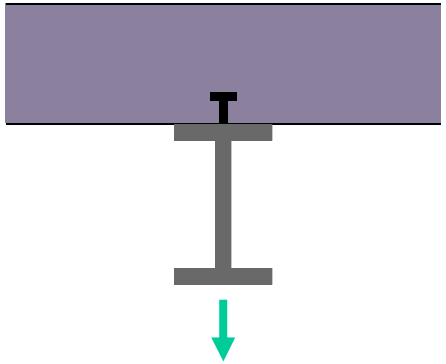
  - **New fire tests**
  - Mechanical principle
  - Design software

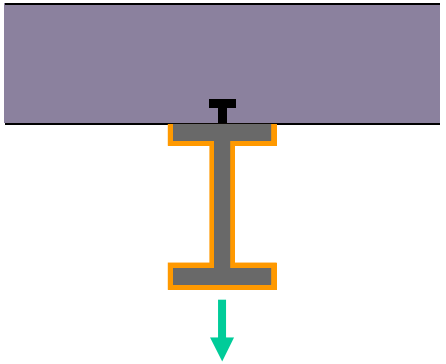
Concept



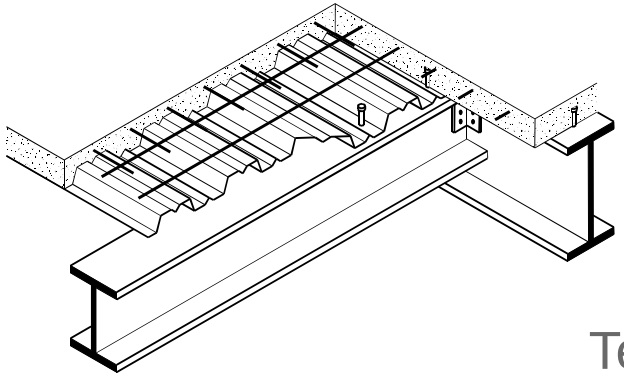


Unprotected Element

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

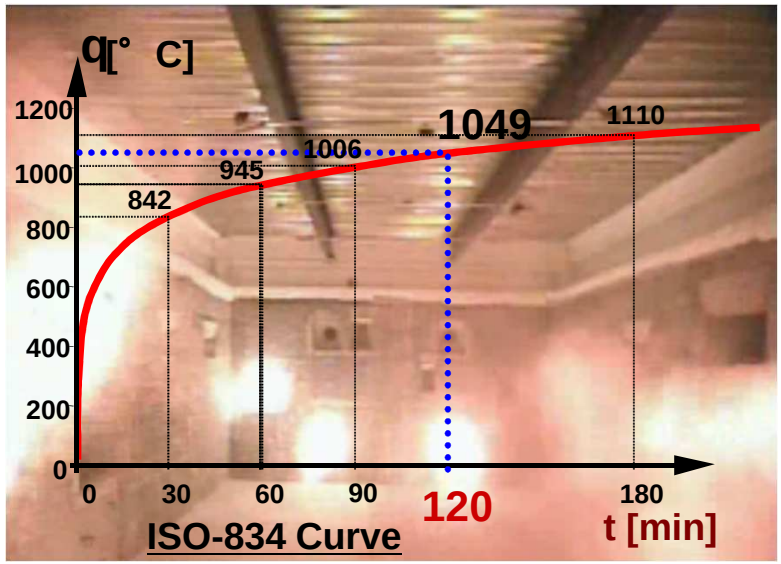


Protected Element



Test on whole floor

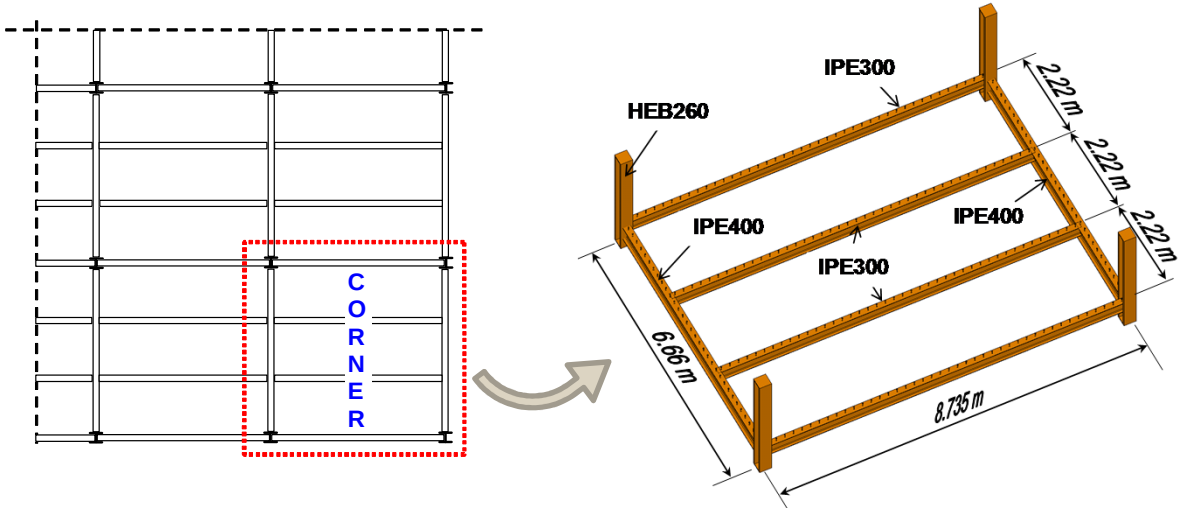
R = ?



Structural grid

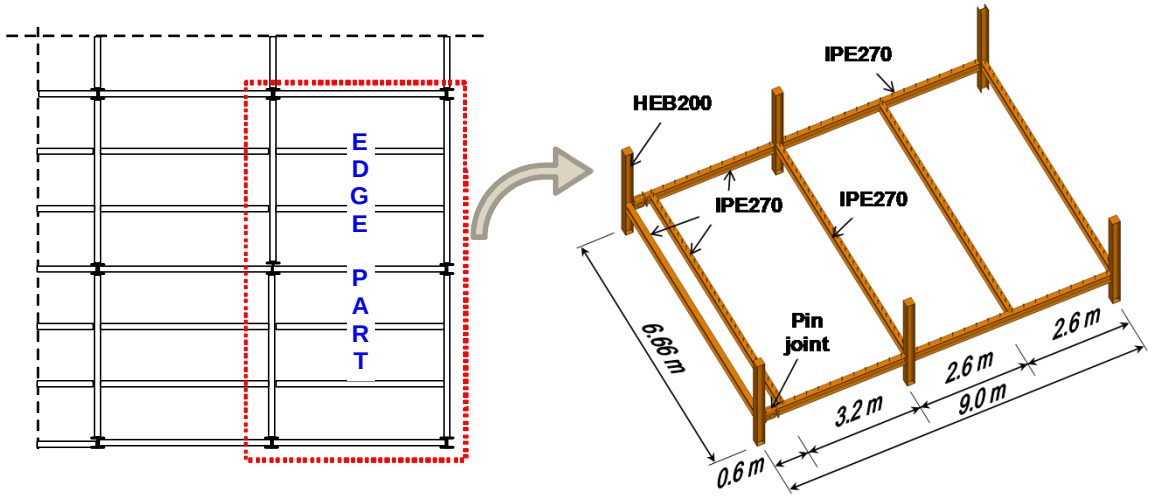
Fracof test

(16 / 01 / 2008)

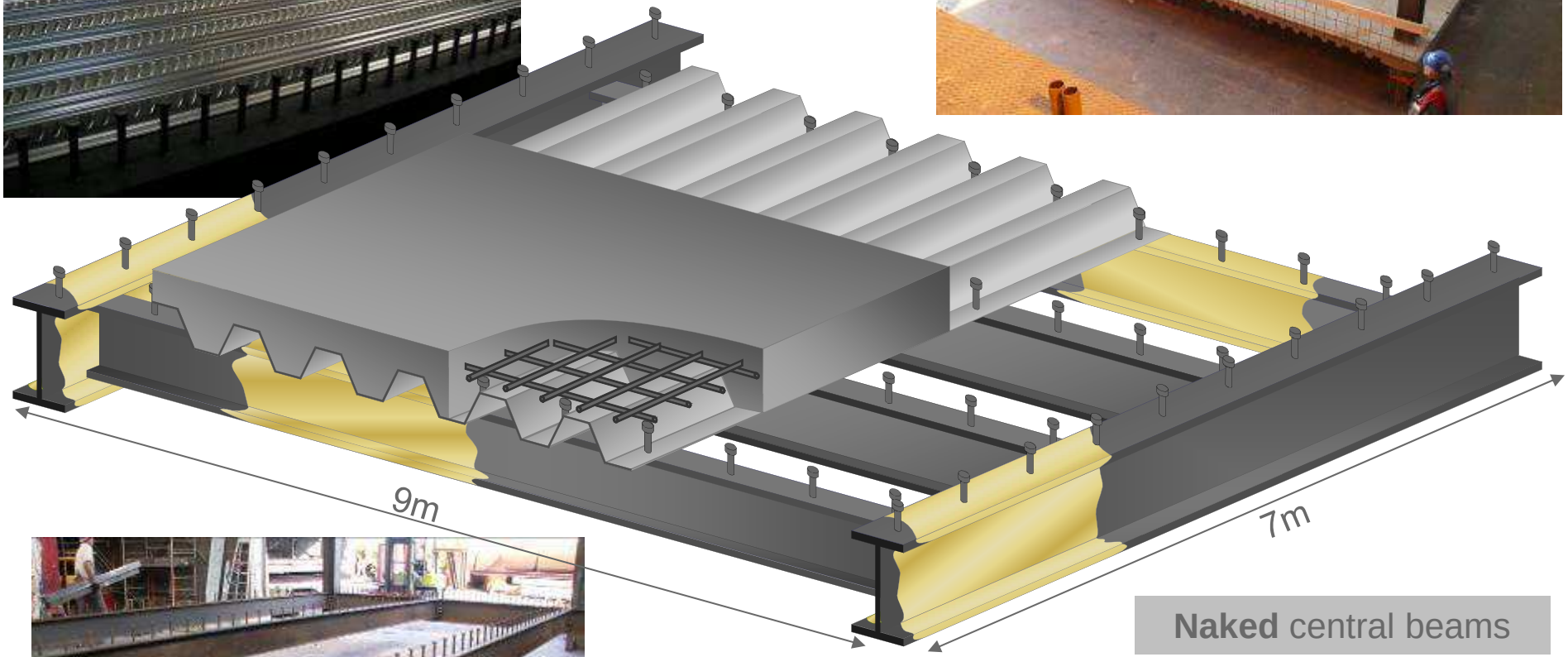


Cossfire test

(16 / 01 / 2009)



FRACOF

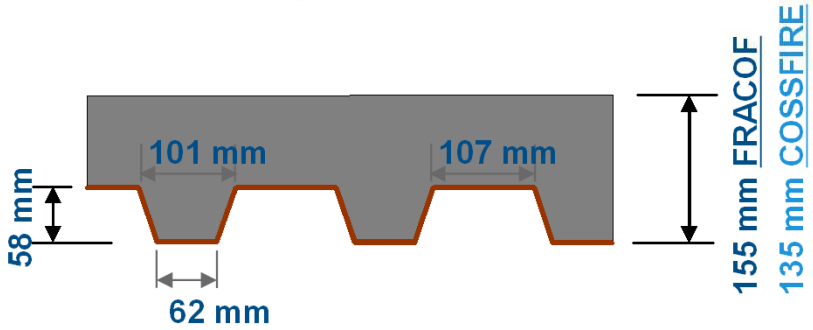


Naked central beams

Protected surrounding beams

Slab

Composite slab



Steel deck: COFRAPLUS60 – 0.75 mm

Concrete: C30/37

Reinforcing mesh

Mesh size: 150x150

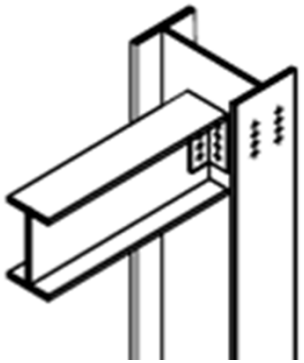
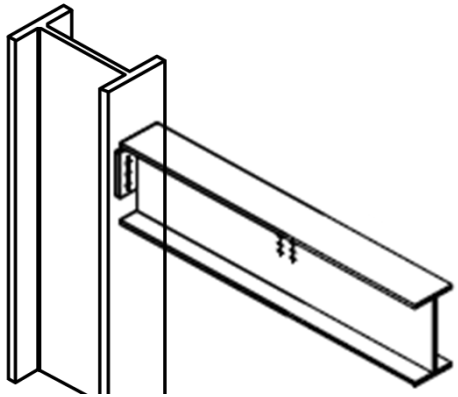
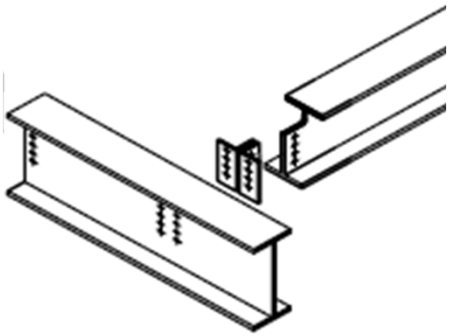
Diameter: 7 mm

Steel grade: S500

Axis distance from slab top:

- 50 mm FRACOF
- 35 mm COSSFIRE

Connections

Beam to column		Beam to beam
Secondary beam	Primary beam	
Double angle web cleats	**Flexible end plate**	**Double angle web cleats**
		

Grade of steel bolts: **8.8**

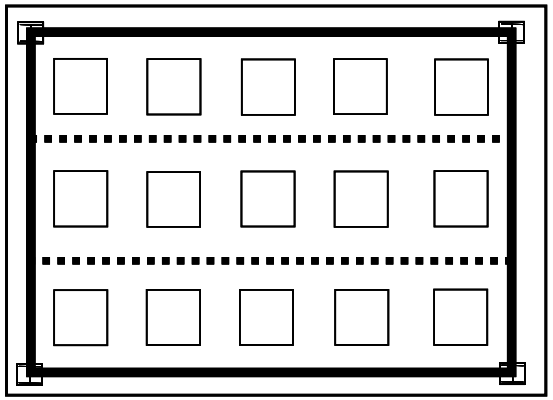
Diameter of steel bolt: **20 mm**

Loading

Surfacic load for office buildings: **1.25 kN/m² + 0,5 x 5.00 kN/m² = 3.75 kN/m²**

Partitions Ψ_1 Imposed Loads

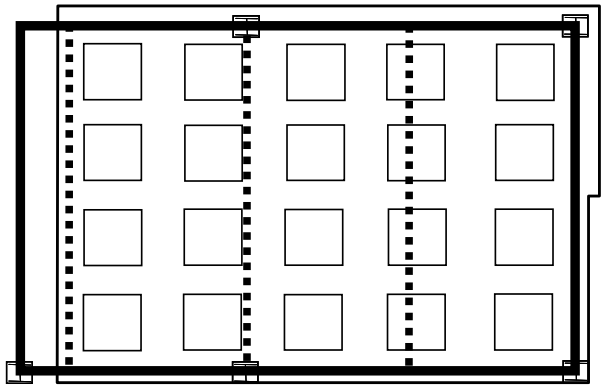
FRACOF



15 sand bags of 1512 kg

Equivalent uniform load:
390 kg/m² = 3.90 kN/m²

COSSFIRE

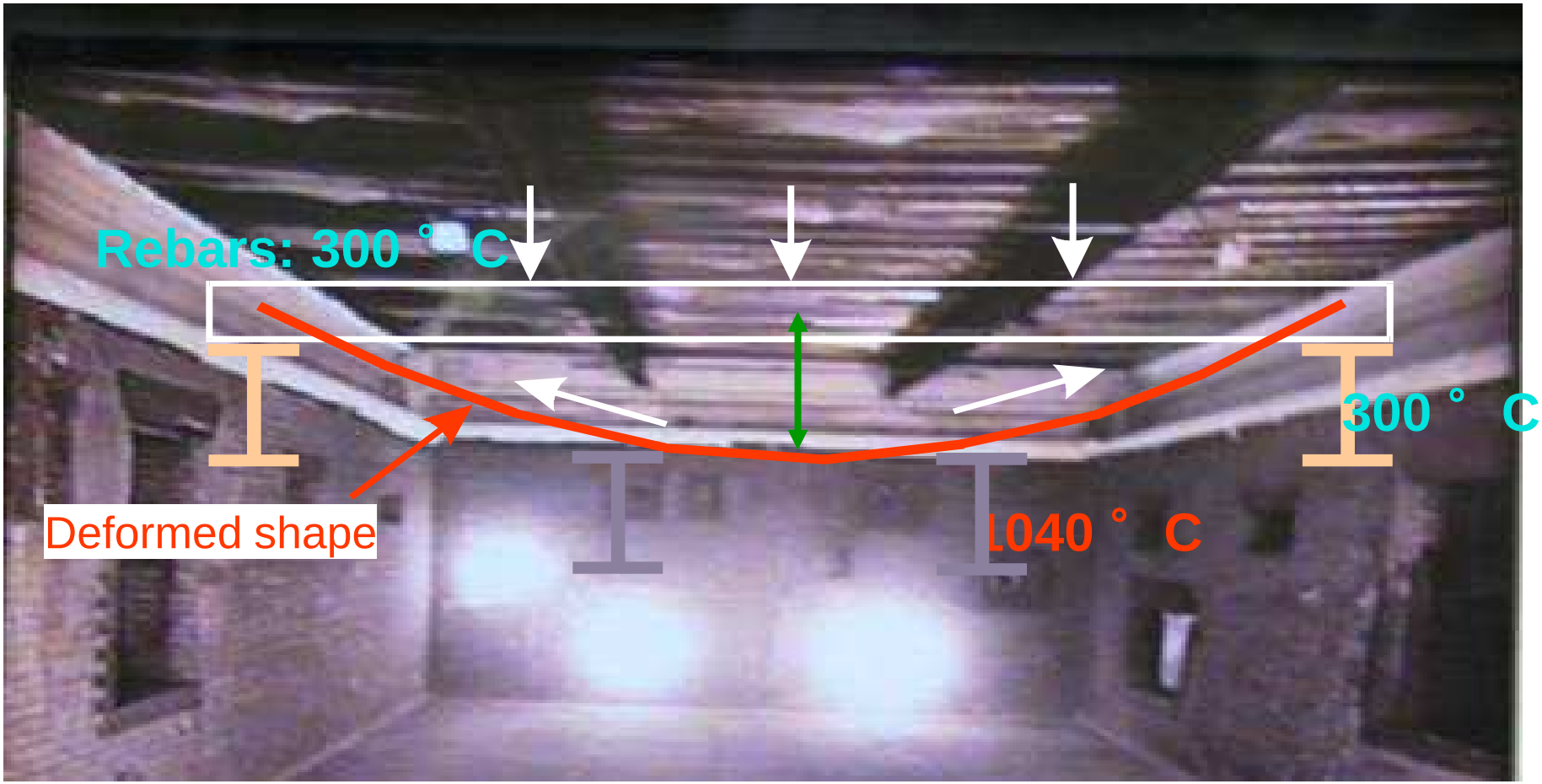


20 sand bags of 1098 kg

Equivalent uniform load:
393 kg/m² = 3.93 kN/m²

FRACOF TEST
about 80 people from Authorities

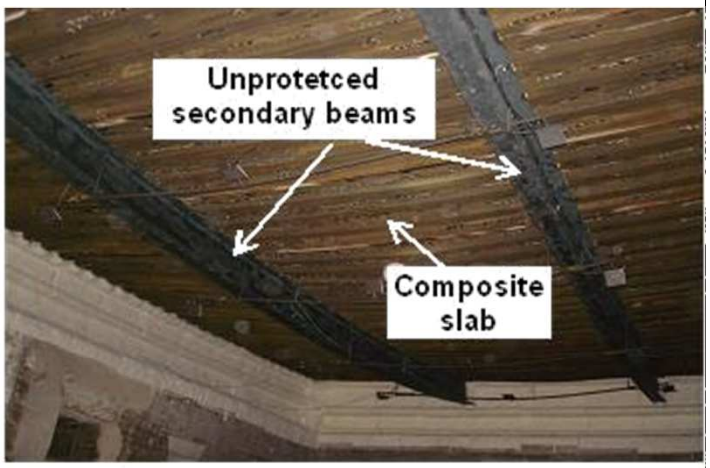
Test results: **R > 120 minutes**

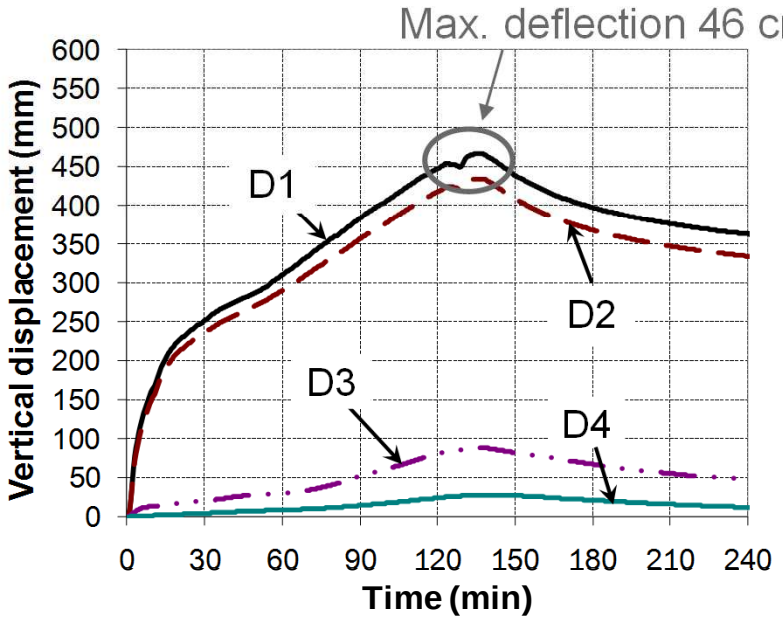


Results – Fracof (2008) and Cossfire (2009)

Before the fire

After 120 of fire





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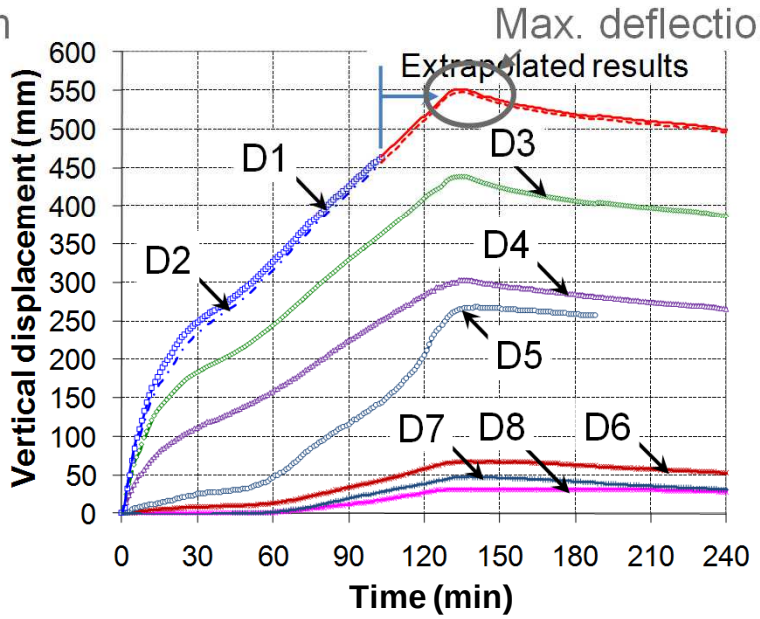
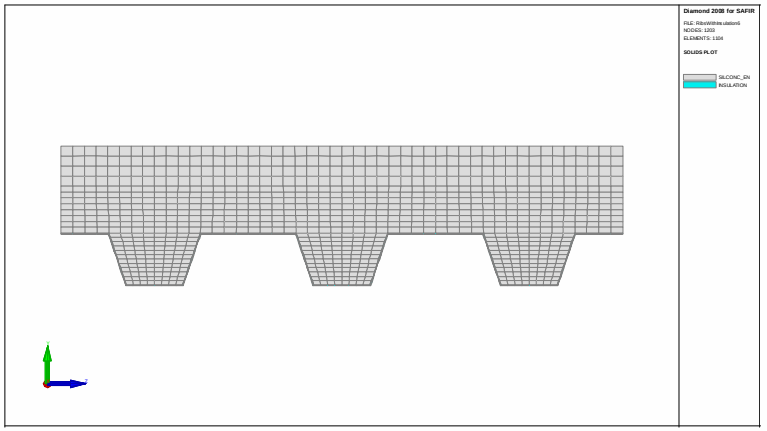


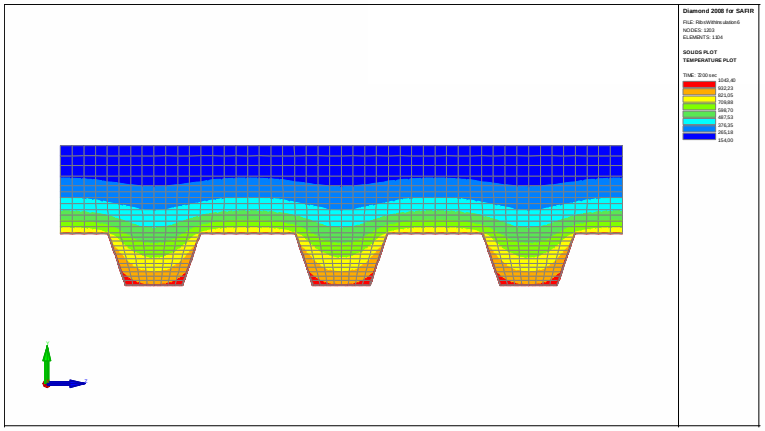
COSSFIRE

Numerical simulation of the Fracof test

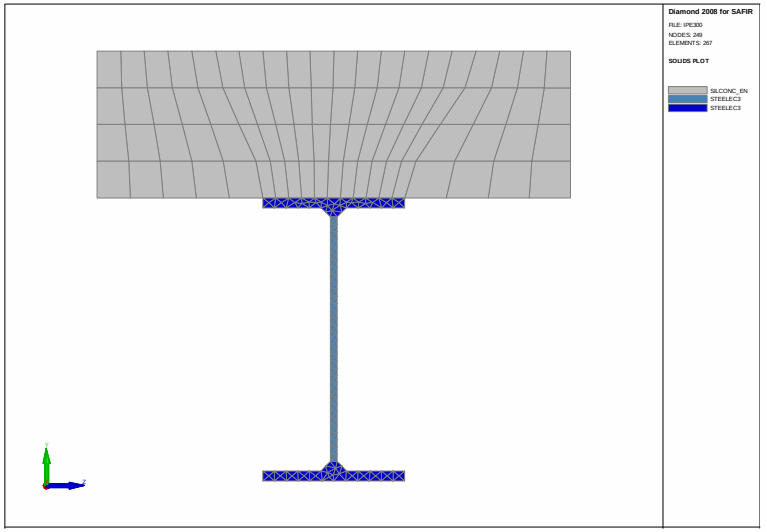
Slab



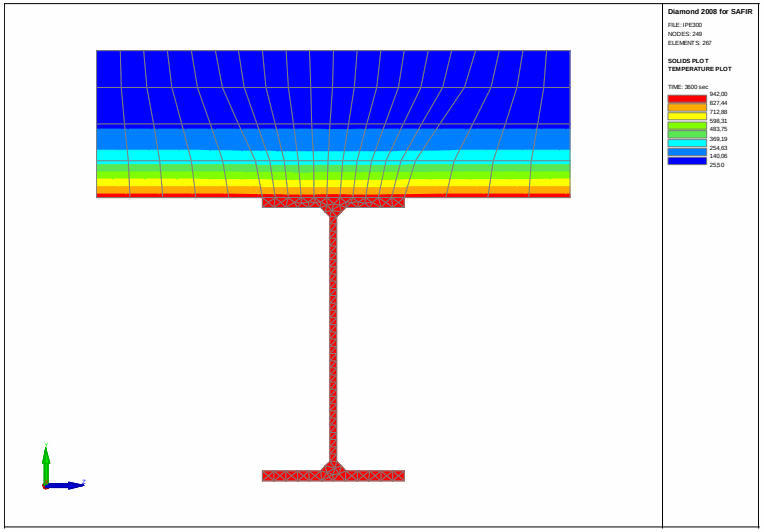
Fire exposure



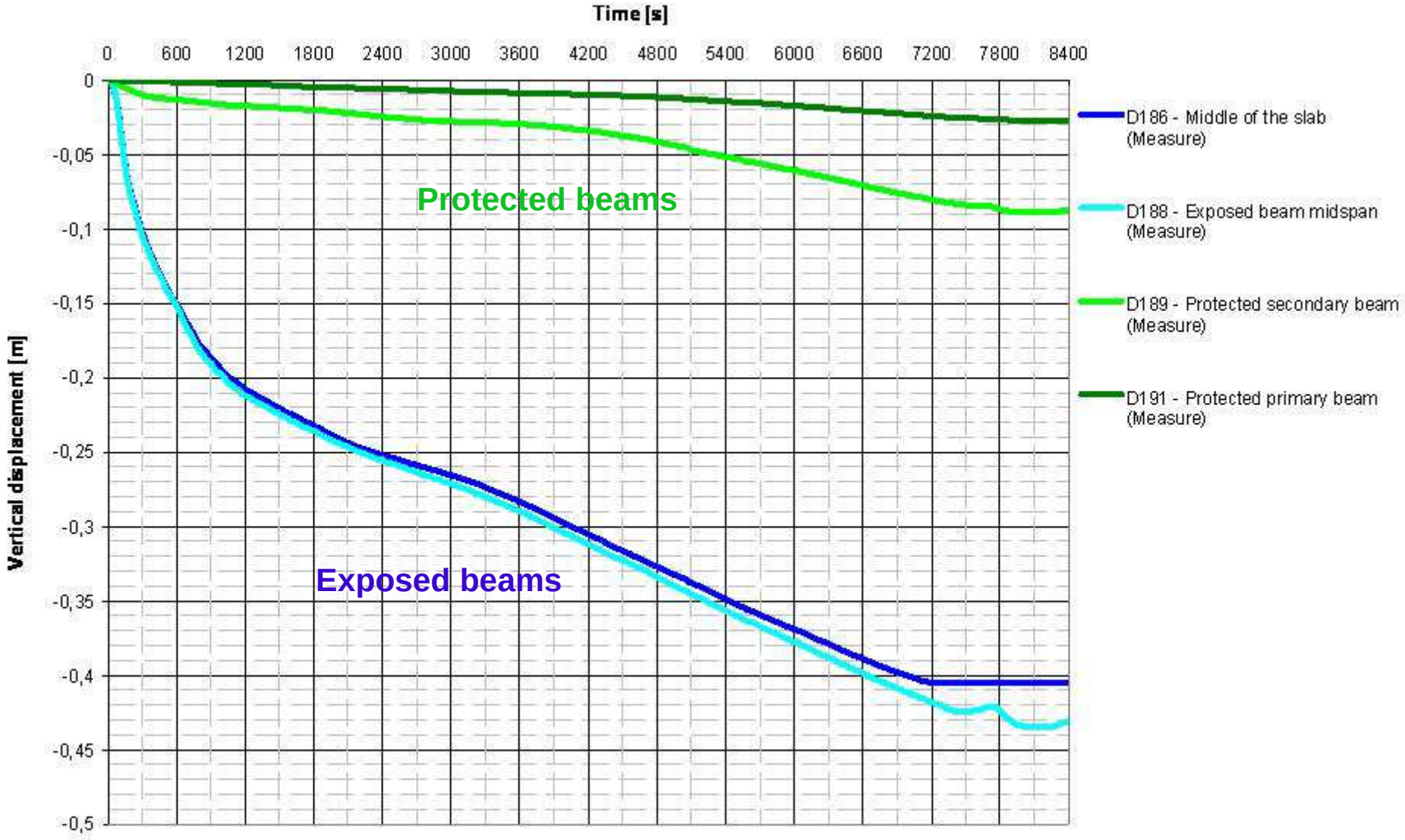
Beam



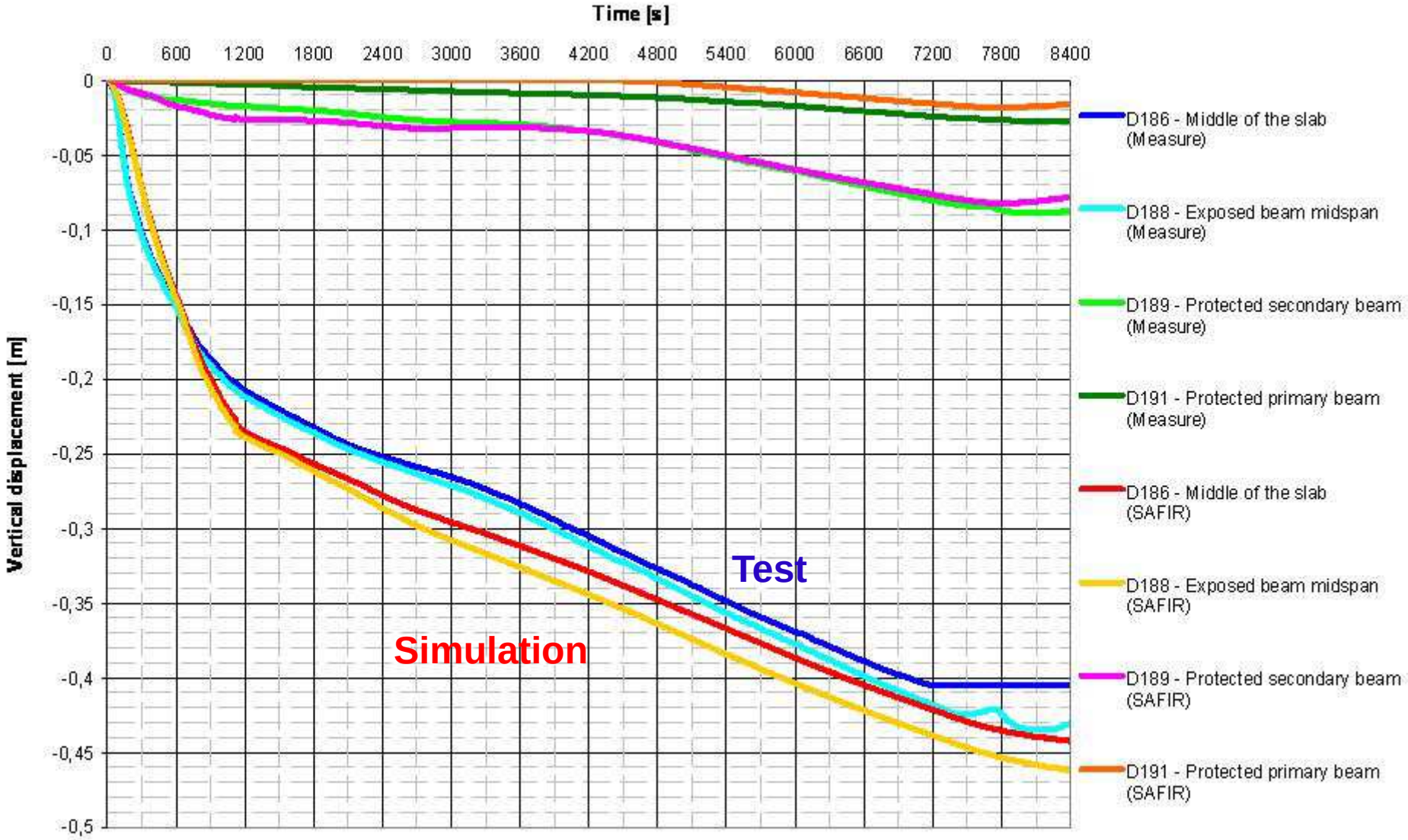
Fire exposure



Measured deflections during the Fracof test



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.


B6 Brandraum
T5_CH 14
1000
800
600
400
200
0
0
20
40
60
80
100
120
Zeit [min]

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*".


ZONE 4
B


00:31:24


01:21:28

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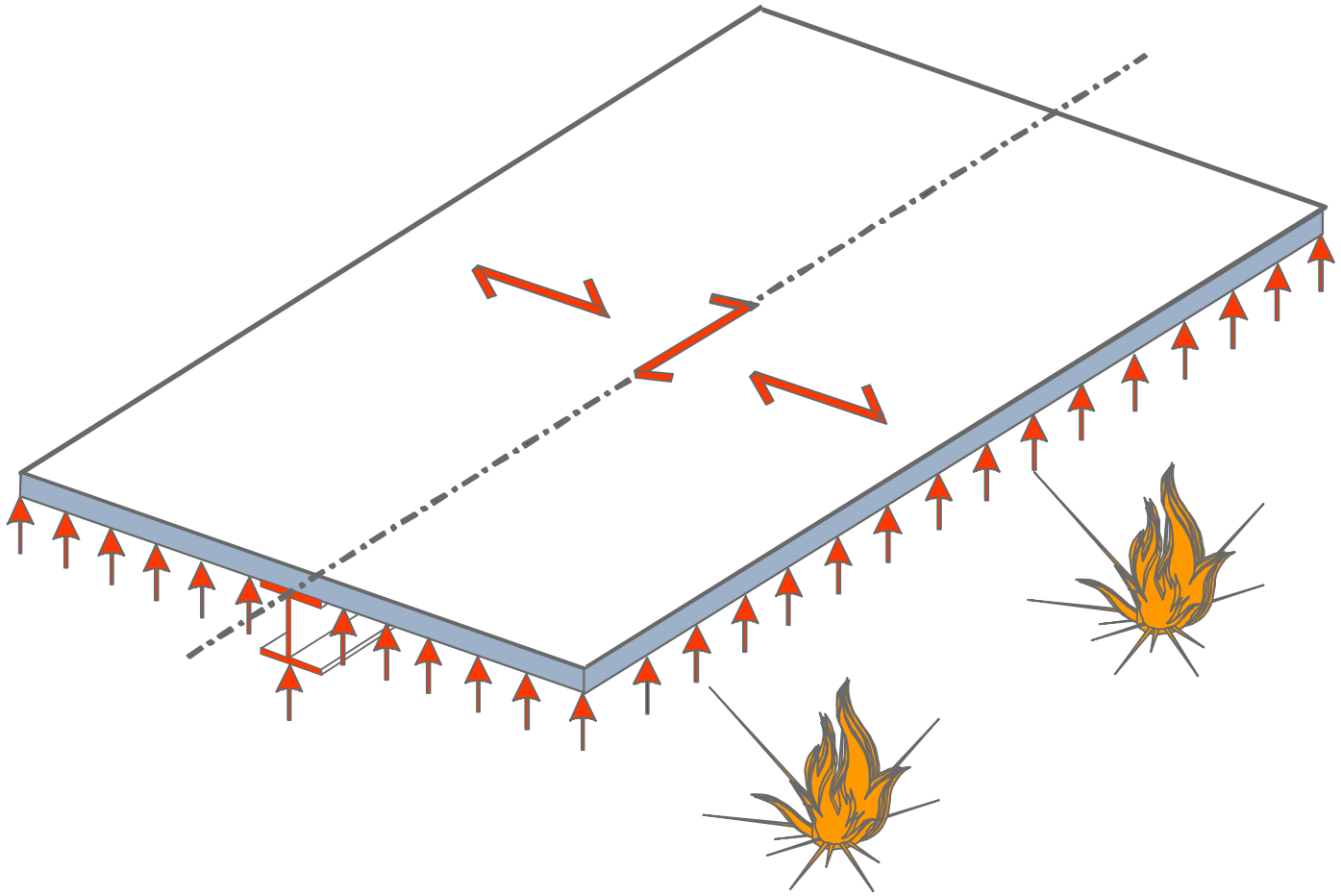
Concept

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

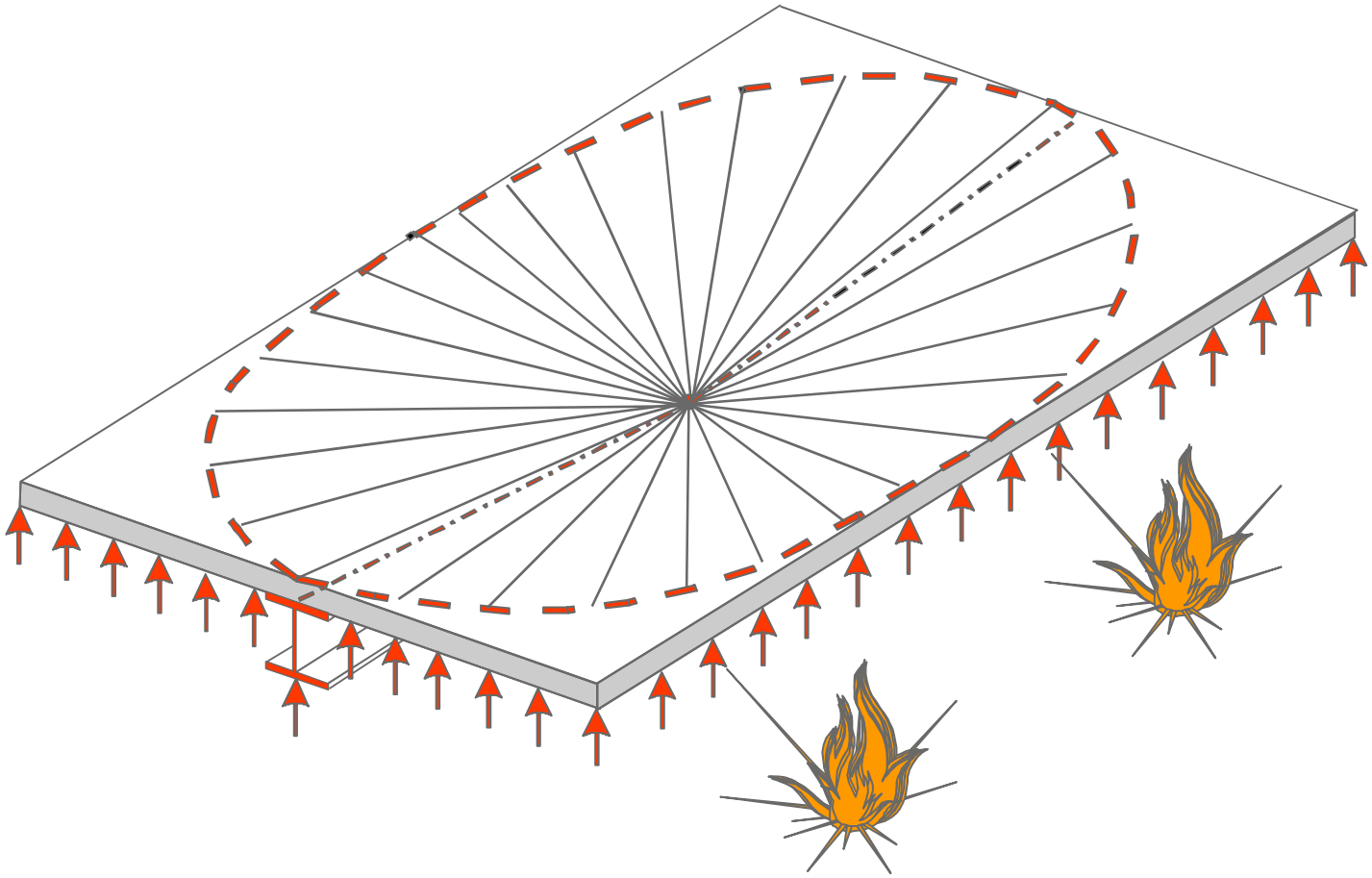
Starting point is the robust ***tensile membrane action*** behaviour of the composite slab which was firstly observed at the Cardington tests.

Behaviour of slab and beam during a fire



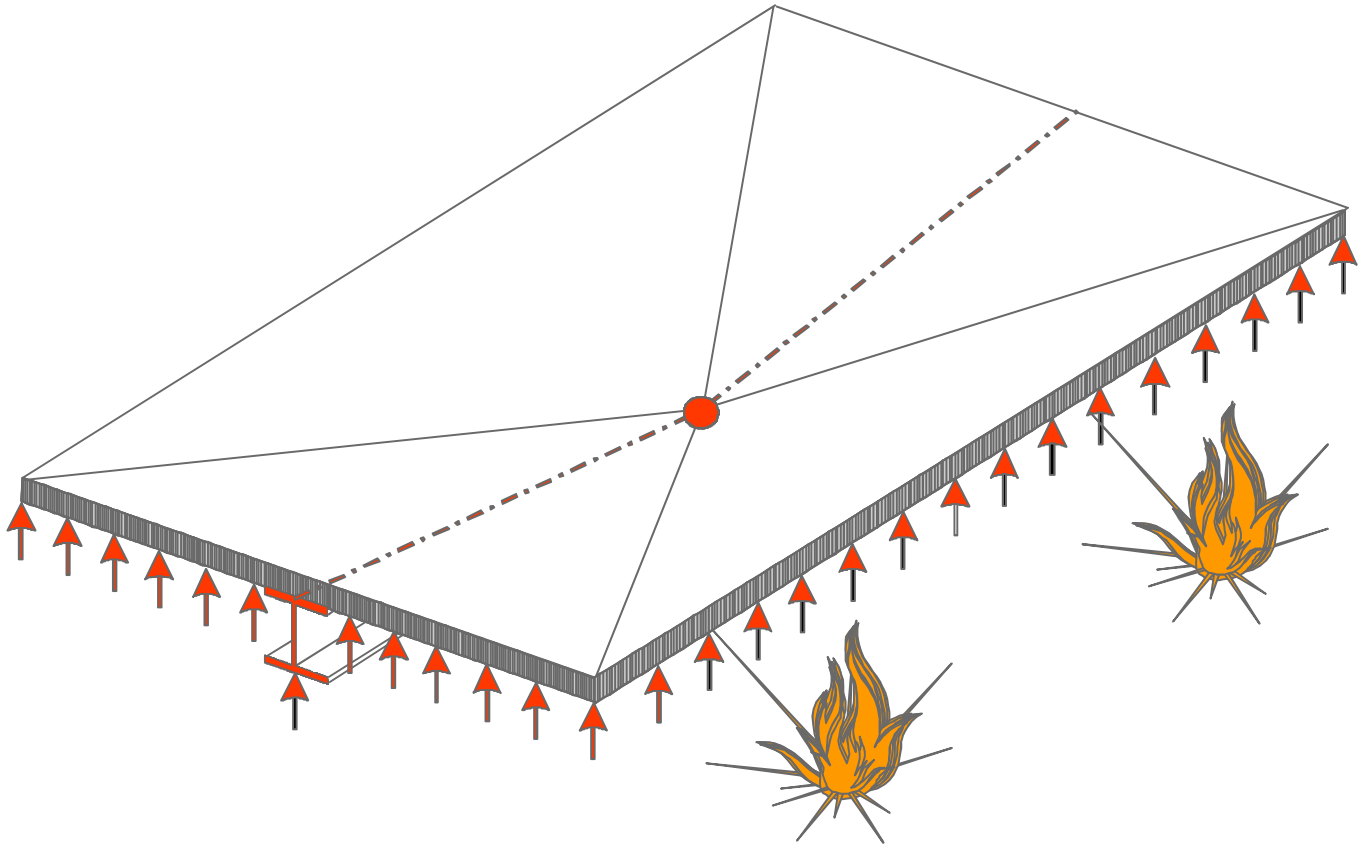
Composite slab is one-way spanning onto unprotected beam

Behaviour of slab and beam during a fire



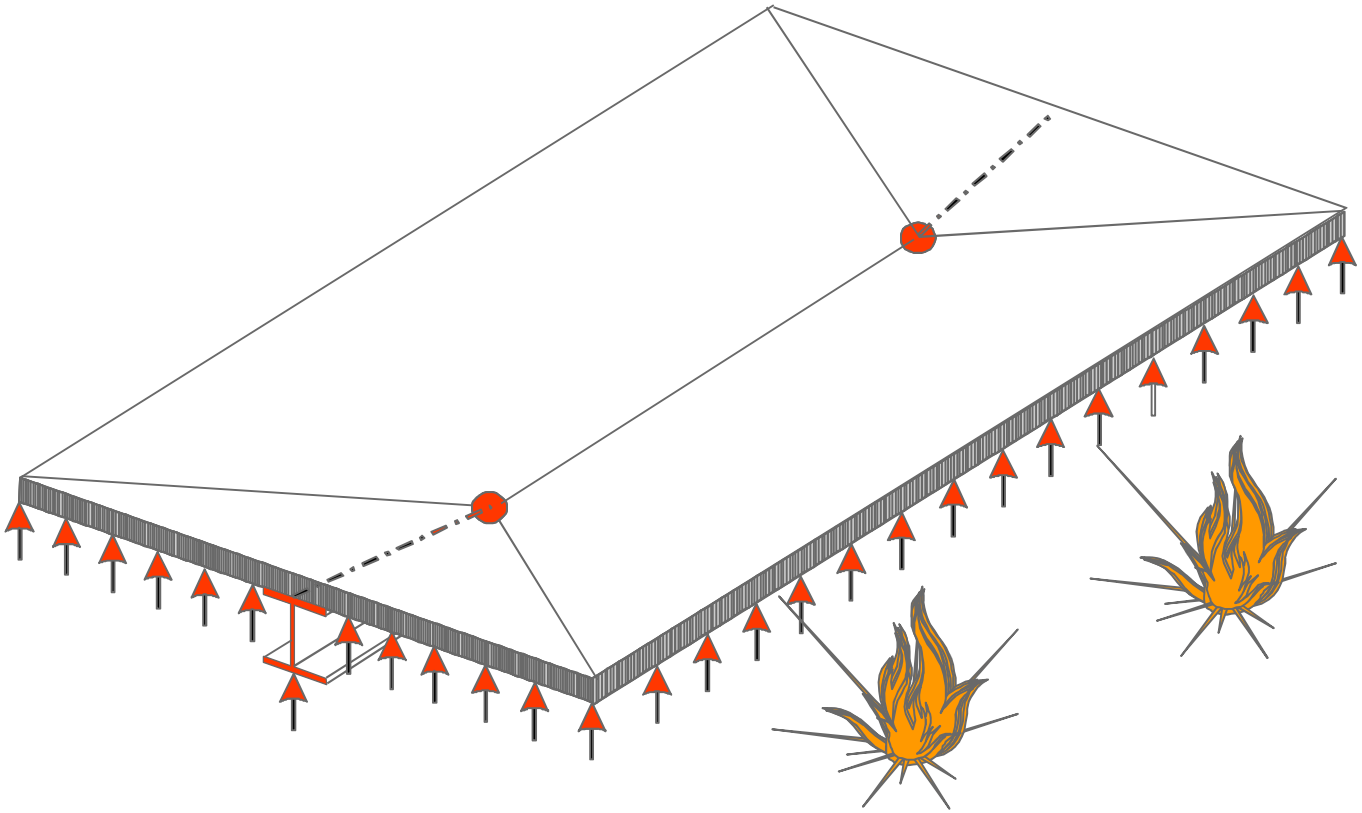
Plastic hinge forms in unprotected beam - yield line forms in slab.

Behaviour of slab and beam during a fire

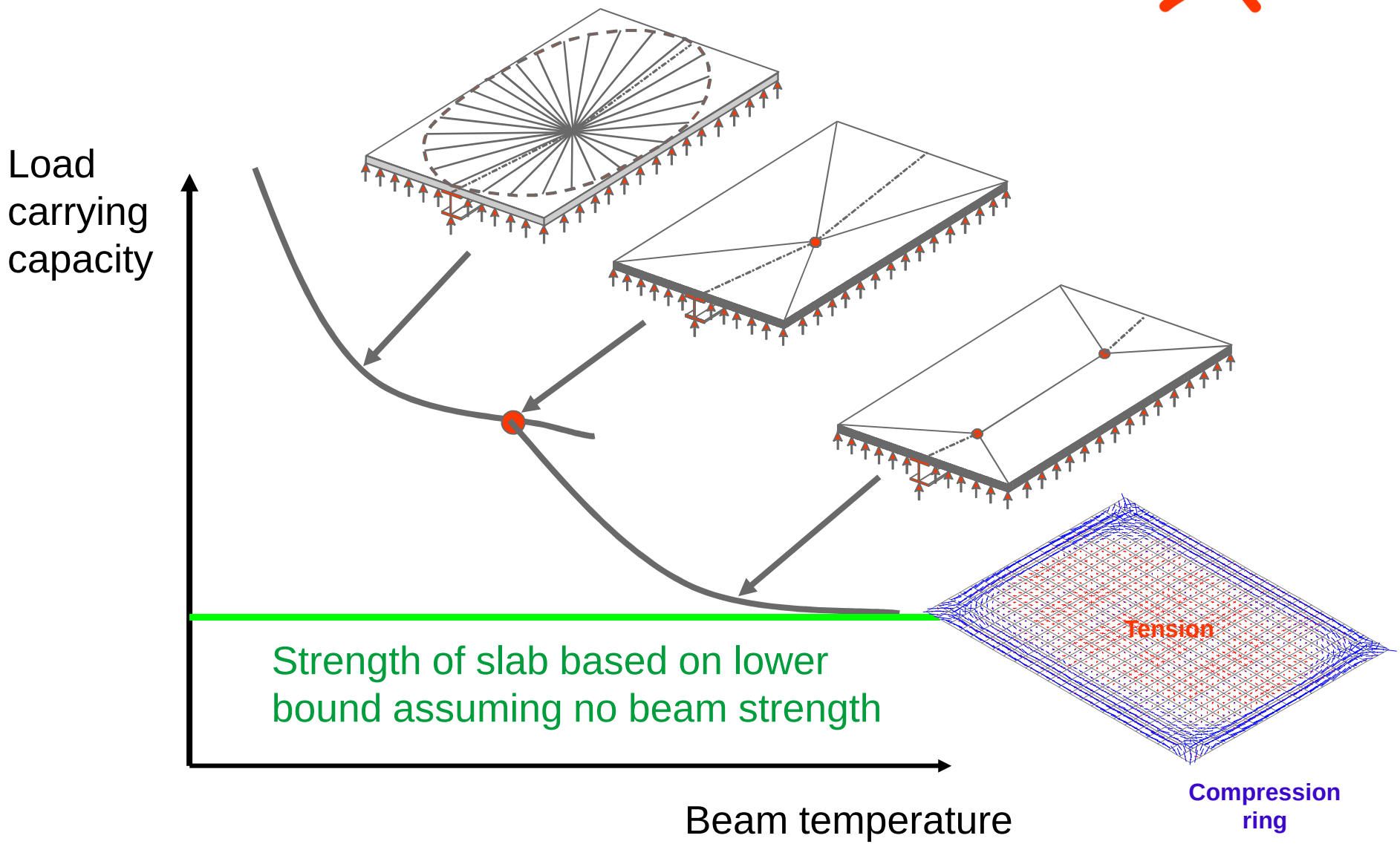


Strength of composite beam continues to decrease resulting in the slab yield pattern shown.

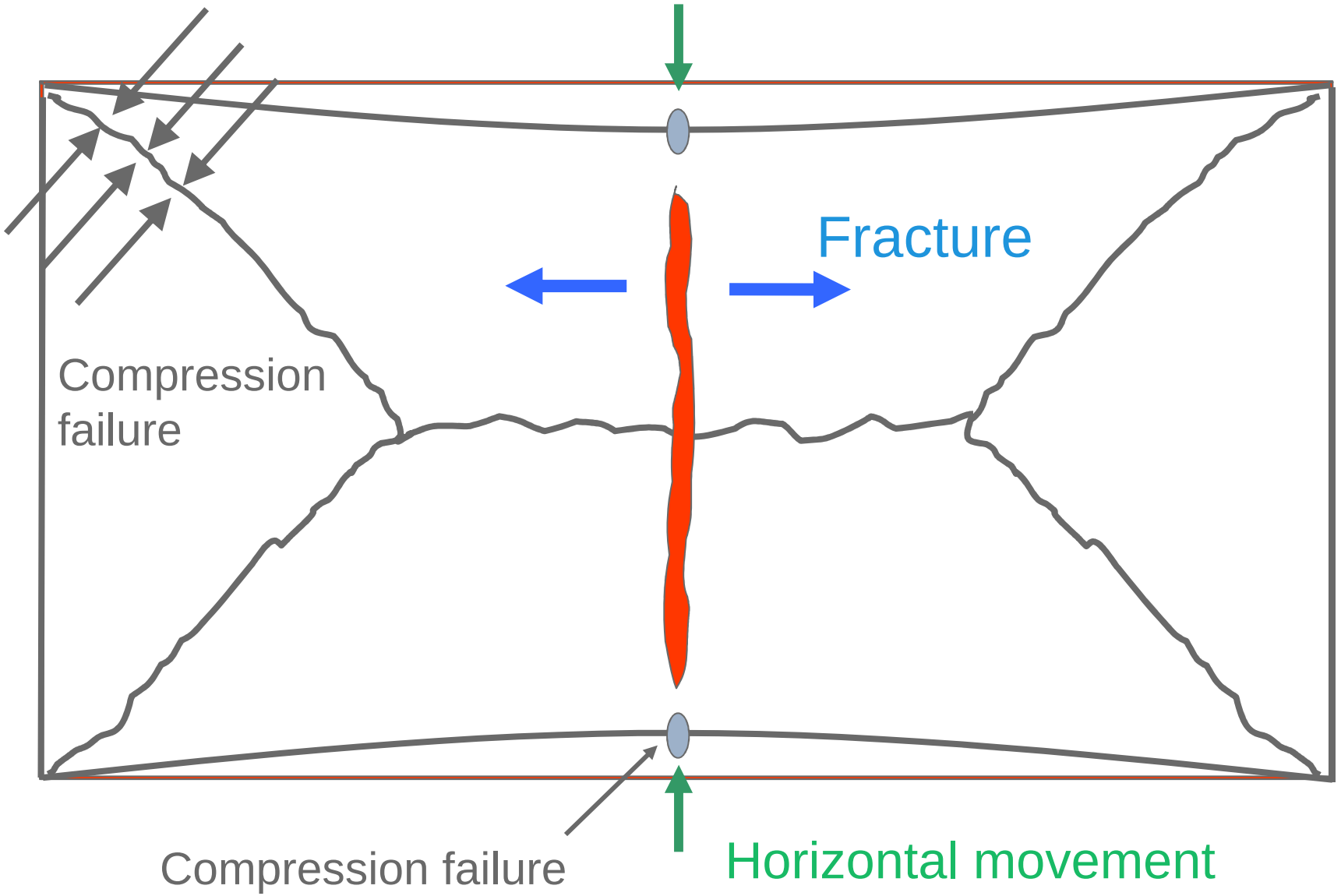
Behaviour of slab and beam during a fire



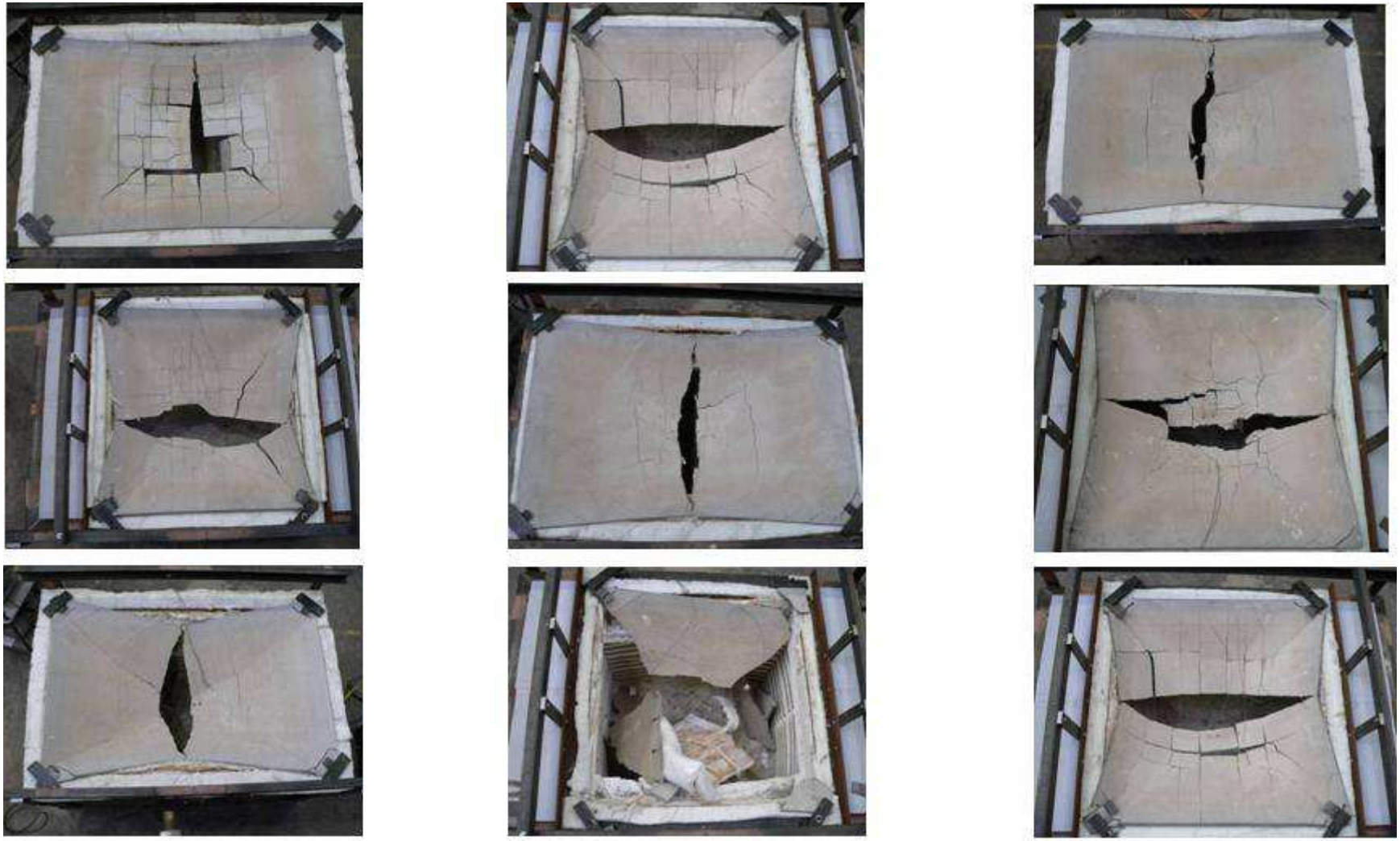
With increasing loss of mechanical properties og the beam, the slab behaviour tends towards a yield line pattern given for the slab acting without the beam.


Load carrying capacity
Strength of slab based on lower bound assuming no beam strength
Beam temperature
Tension
Compression ring

Possible failure modi



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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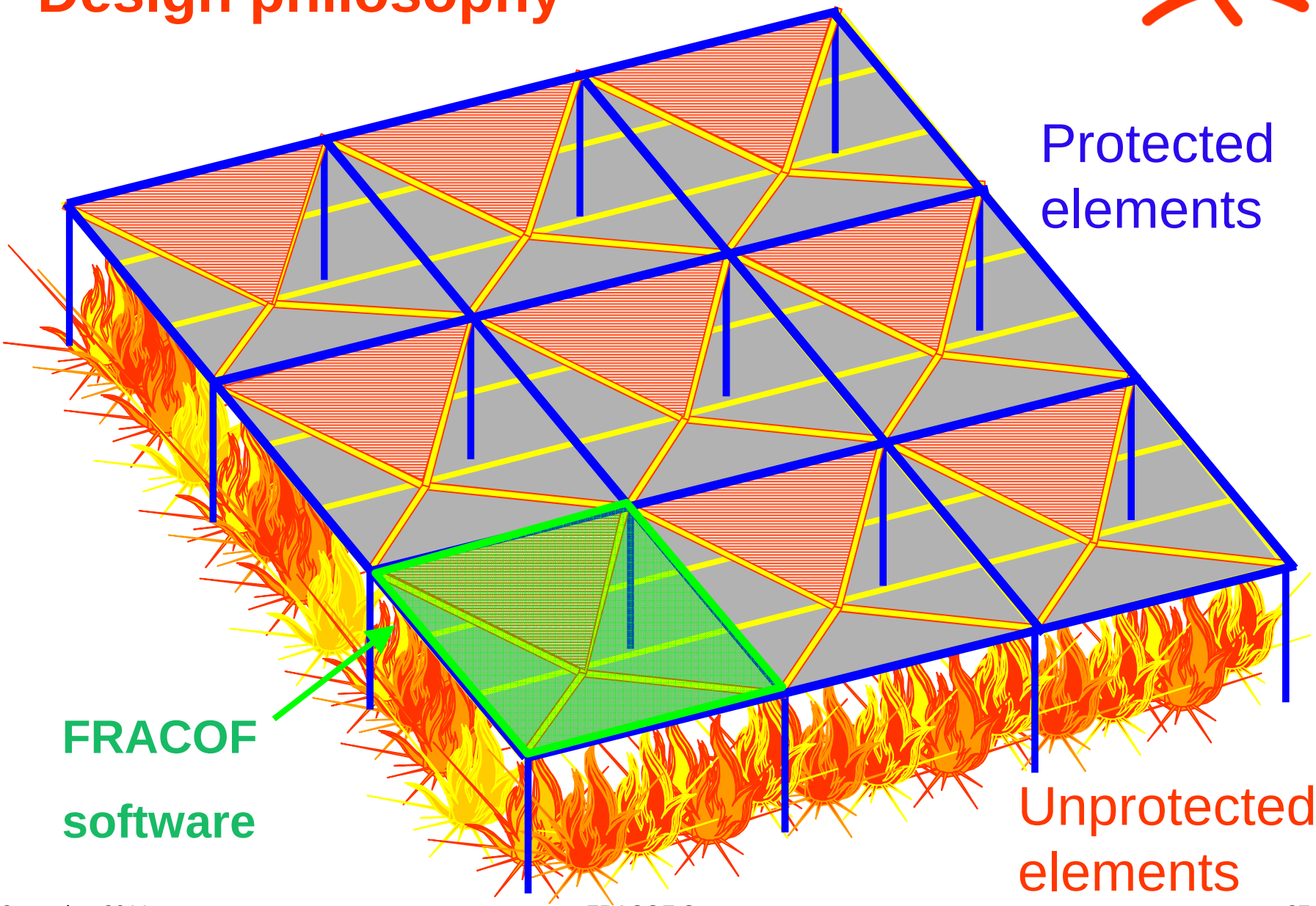
Fracof software

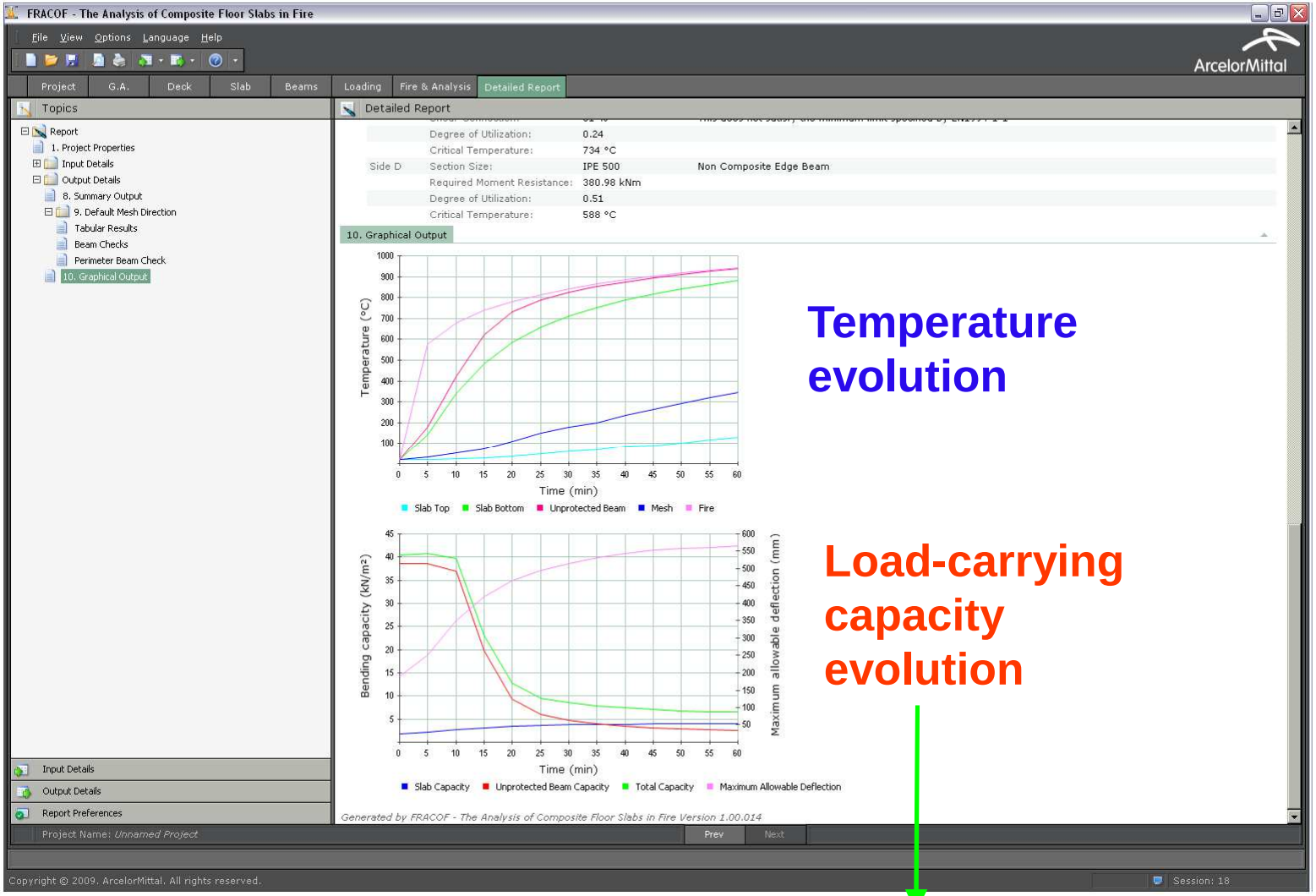
The Fracof software is a ***simple design tool*** for the assessment of the fire resistant of partially protected composite floors according to the Bailey method. It has been realised in the frame of Steel Alliance by cooperation of SCI and CTICM.

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

Design philosophy



Output



Temperature evolution

Load-carrying capacity evolution

Floor slab is adequate if **load-carrying capacity > loads**

Aknowledgements:

- Prof. Colin Bailey (UMIST)