Education and Culture DG

Lifelong Learning Programme
LEONARDO DA VINCI

1&4 ANEFORE

Fire Behaviour of Steel and Composite Floor Systems

New Experimental Evidences

Olivier VASSART - Bin ZHAO

Oct. 2010

Content of presentation

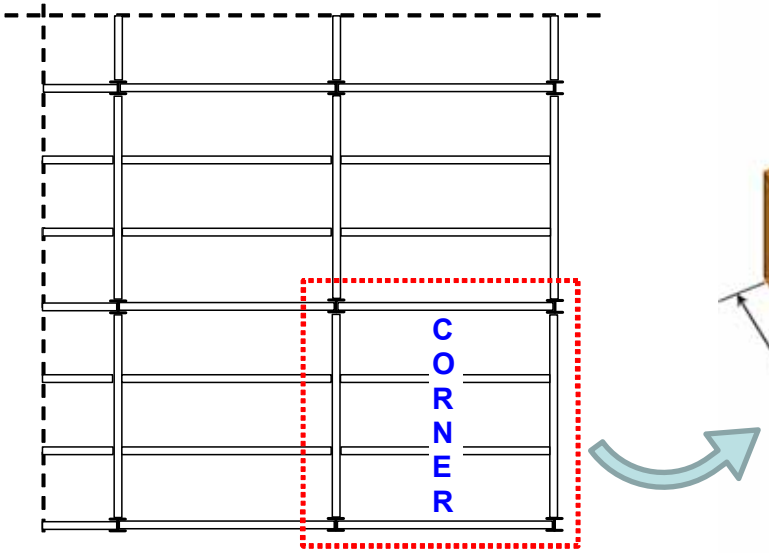
- Objectives of new fire tests
- Full scale fire tests within the projects of
  - FRACOF
  - COSSFIRE
- Test set-up
- Experimental results
  - Temperature
  - Displacement
- Observation and analysis
- Comparison with simple design methods
- Conclusion

Why more fire tests

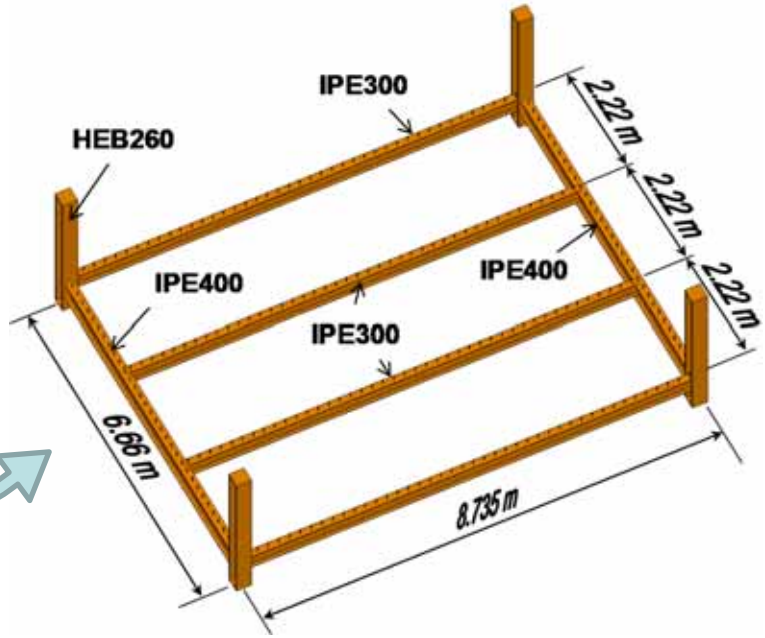
- **Background**
  - **Cardington fire tests**
    - **Excellent fire performance under natural fire condition**
    - **Max θ of steel $\approx$ 1150 °C, fire duration $\approx$ 60 min (> 800°C)**
    - **UK construction details**
- **Objectives**
  - **To confirm same good performance under long fire duration (at least 90 minutes of ISO fire)**
  - **To investigate the impact of different construction details, such as reinforcing steel mesh and fire protection of edge beams**
  - **To validate different fire safety engineering tools**

Design of test specimens

- **FRACOF test**



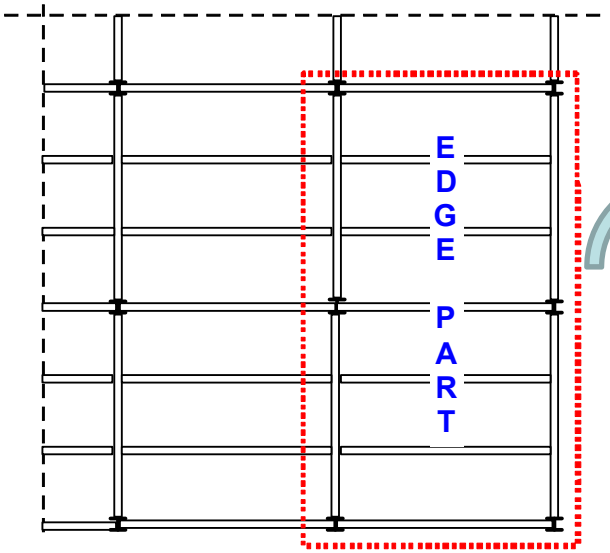
Structure grid of a real building



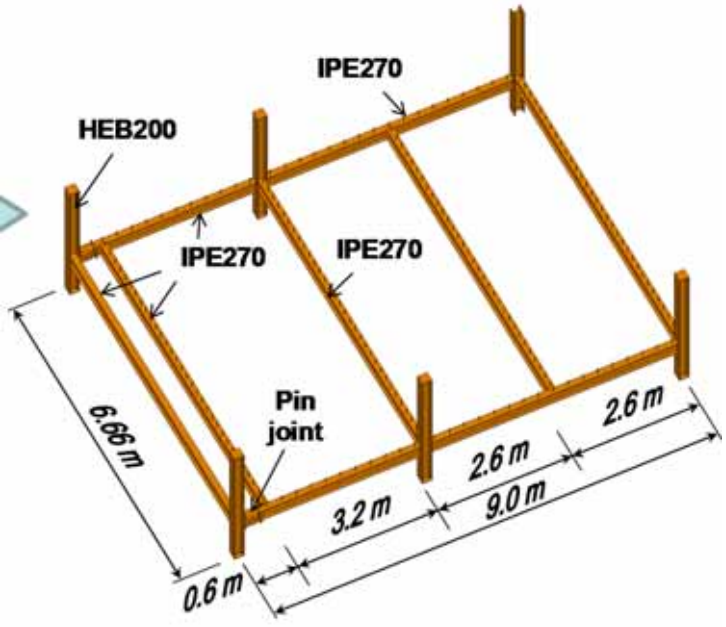
Adopted steel frames for FRACOF fire test

Design of test specimens

- **COSSFIRE test**



Structure grid of a real building

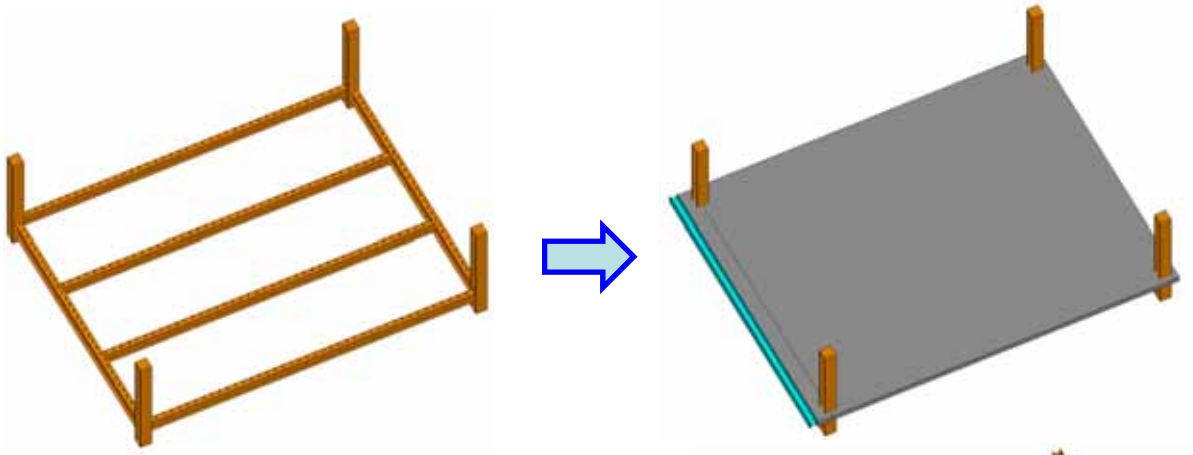


Adopted steel frames for COSSFIRE fire test

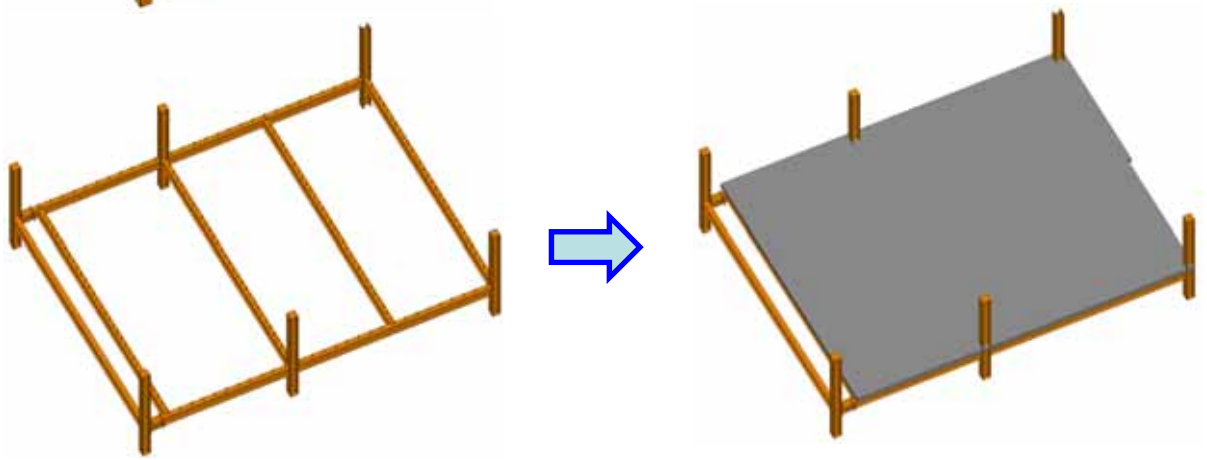
Design of test specimens

- **Final composite floor systems**

FRACOF



COSSFIRE



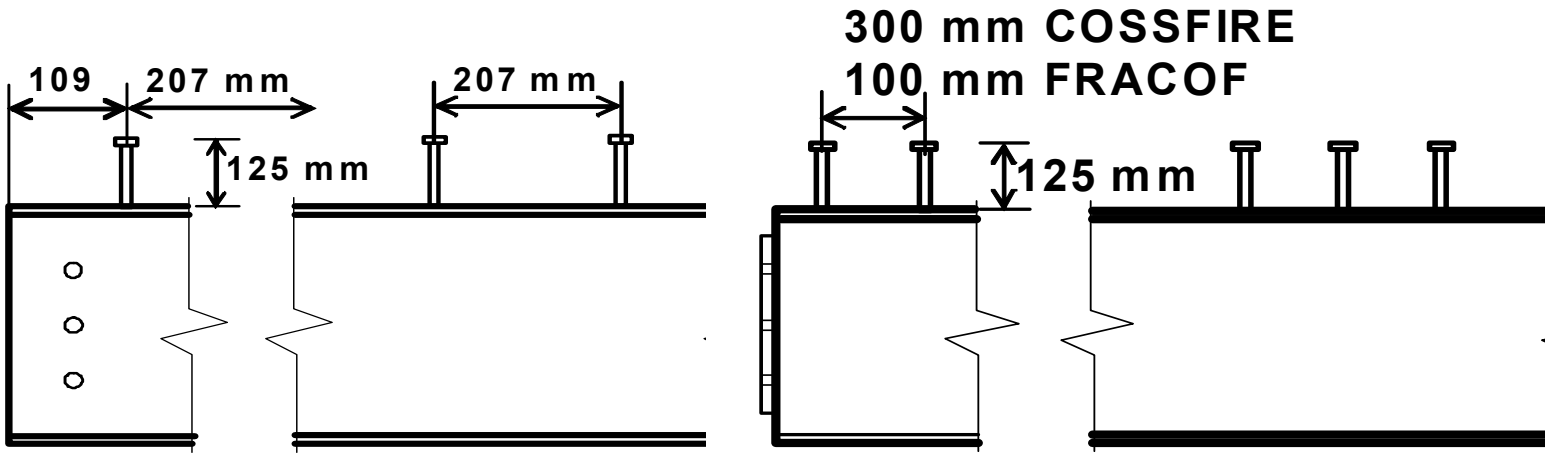
Design of structural members

- **Steel frame**
  - Steel and concrete composite beams
    - **According to Eurocode 4 part 1-1 (EN1994-1-1)**
  - Short steel columns

- **Composite slab**
  - Total depth
    - **According to Eurocode 4 part 1-2 (EN1994-1-2)**
  - Reinforcing steel mesh
    - **Based on simple design rules**

- **Steel joints**
  - Commonly used joints: double angle and end plate
    - **According to Eurocode 3 part 1.8 (EN1993-1-8)**

- **Arrangement of headed studs over steel beams**

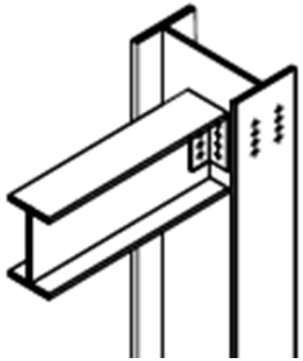
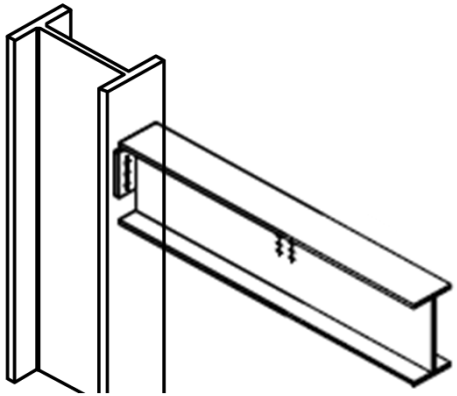
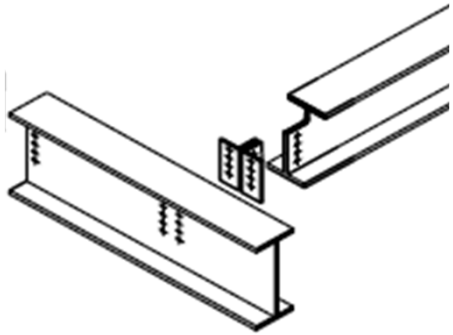


Secondary beams

Primary beams

- **Type of steel studs**
  - **TRW Nelson KB 3/4" – 125 (Φ = 19mm; h = 125 mm; f_y = 350 N/mm²; f_u = 450 N/mm²)**

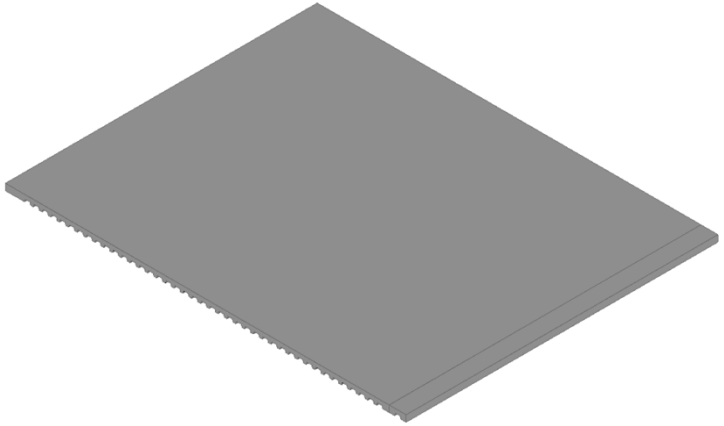
Steel joints

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

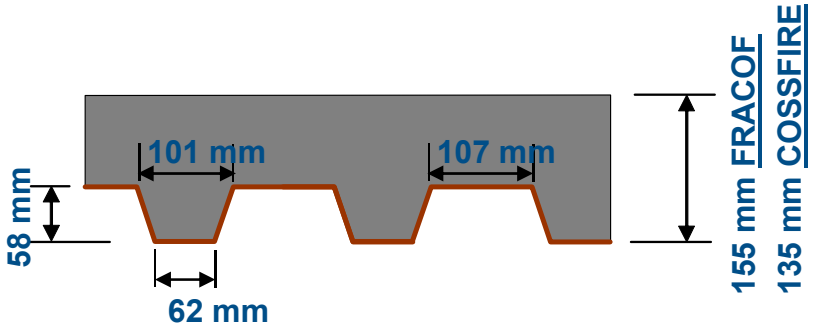
Grade of steel bolts: 8.8

Diameter of steel bolt: 20 mm

Sizes of structural members

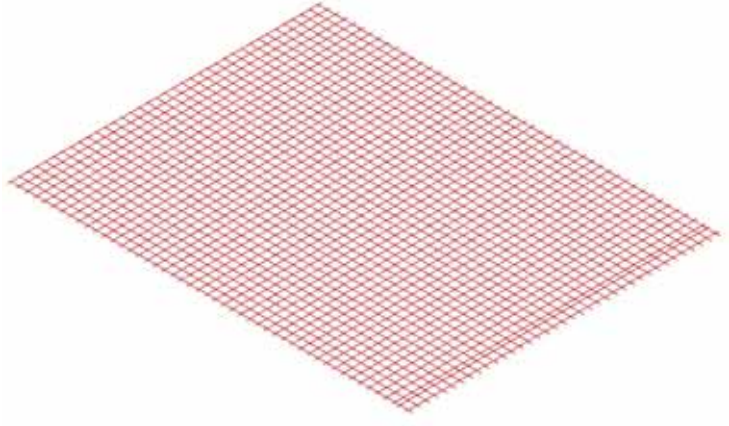


Composite slab



Steel deck: **COFRAPLUS60 – 0.75 mm**

Concrete quality: **C30/37**



Reinforcing steel mesh

Mesh size: 150x150

Diameter: 7 mm

Steel grade: S500

Axis distance from top of the slab:

- 50 mm FRACOF
- 35 mm COSSFIRE

Mechanical loading condition

Objectives

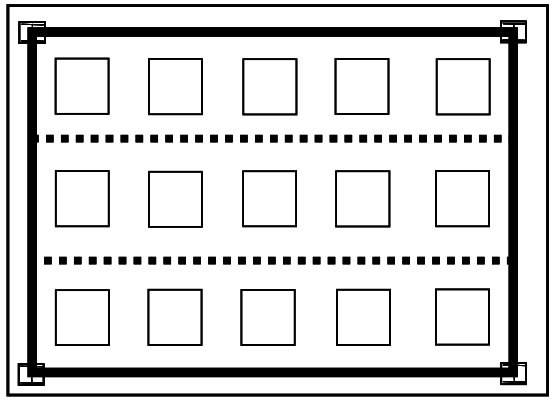
Test set-up

Experimental results & Observation

Comparison with simple design methods

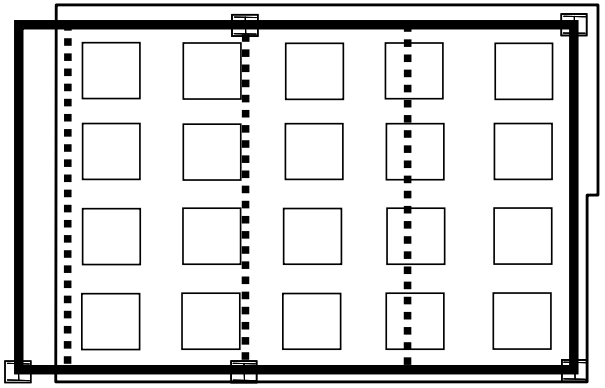
Conclusion

FRACOF



15 sand bags of 1512 kg

Equivalent uniform load: 390 kg/m²



COSSFIRE

20 sand bags of 1098 kg

Equivalent uniform load: 393 kg/m²

Preparation of FRACOF fire test

Objectives

Test set-up

Experimental results & Observation

Comparison with simple design methods

Conclusion

1

2

3

4

Behaviour of the floor during fire

Objectives

Test set-up

Experimental results & Observation

Comparison with simple design methods

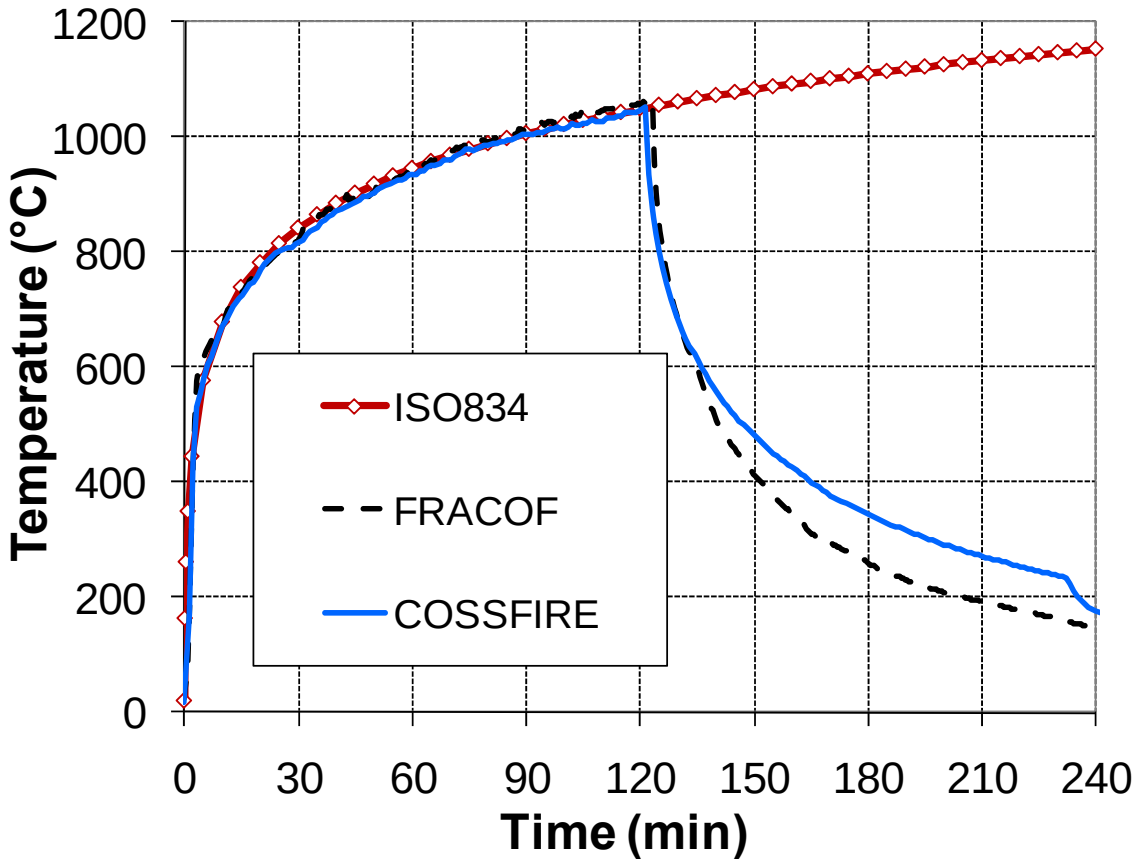
Conclusion

Experimental results

- **Fire temperature**
- **Heating of unprotected steel beams**
- **Heating of protected steel members**
- **Heating of composite slab**
- **Deflection of the floor**
- **Observations over the behaviour of composite floor systems**
  - **Concrete cracking and concrete crushing**
  - **Failure of reinforcing steel mesh during the test**
  - **Collapse of edge beams**

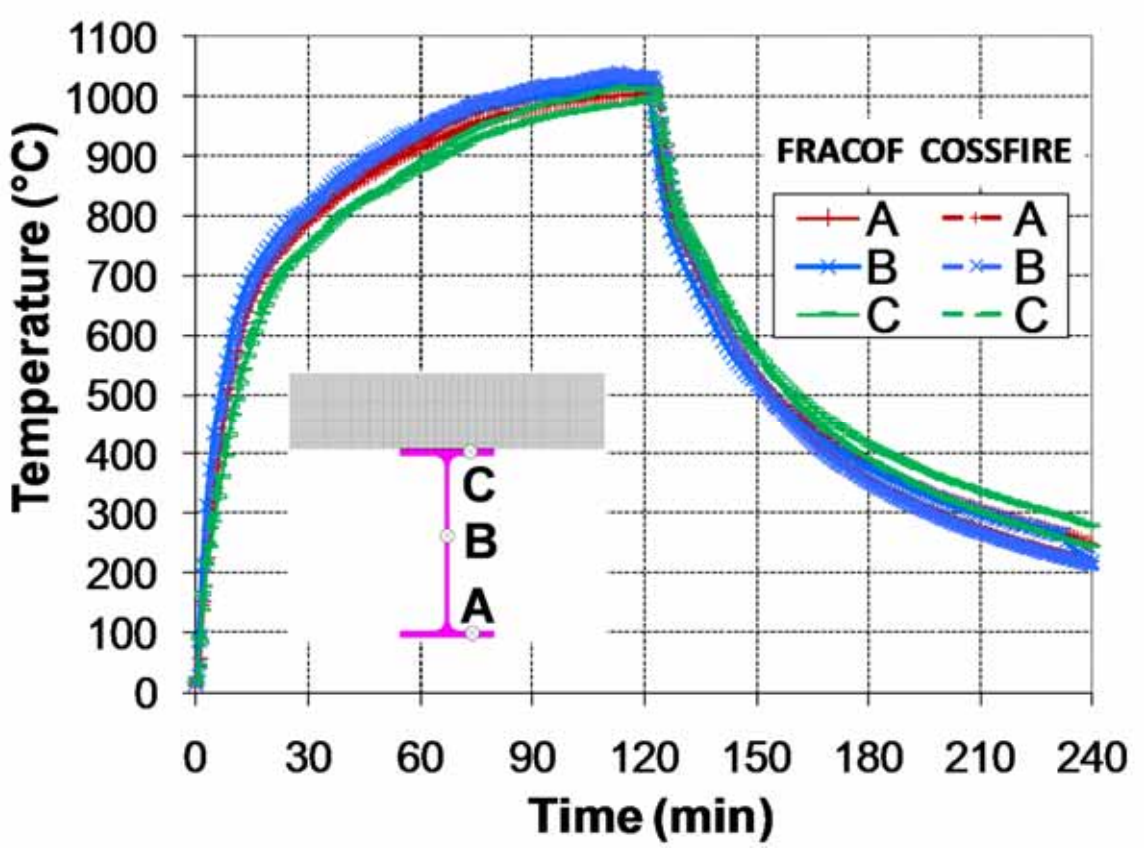
Experimental results

- **Fire temperature**



Experimental results

- **Heating of unprotected steel beams**



Objectives

Test set-up

Experimental results & Observation

Comparison with simple design methods

Conclusion

Experimental results

Objectives

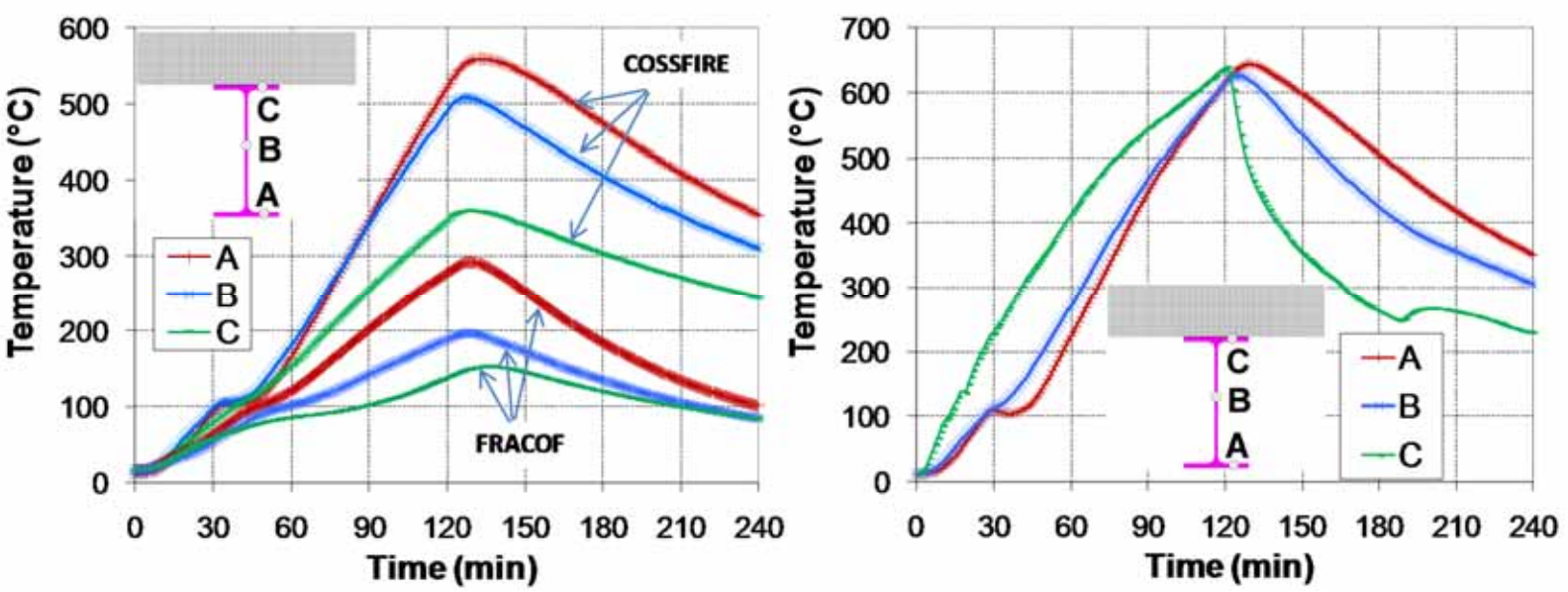
Test set-up

Experimental results & Observation

Comparison with simple design methods

Conclusion

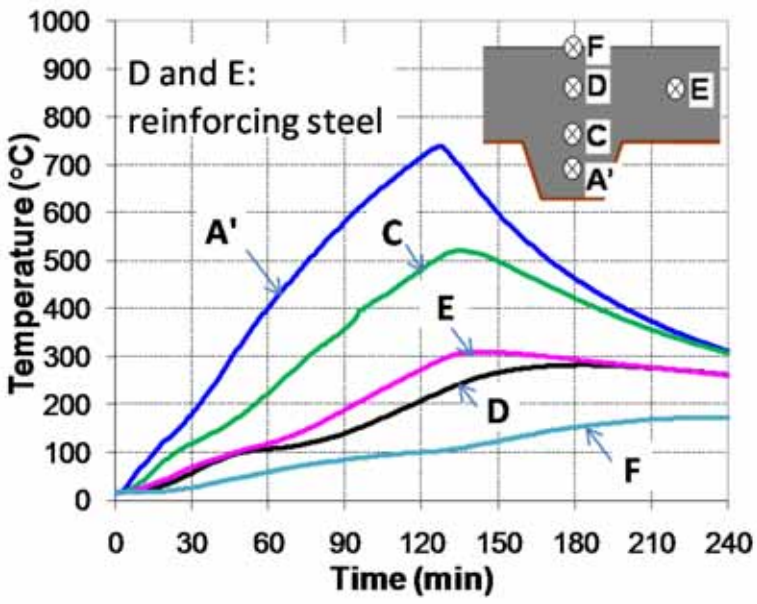
- **Heating of protected steel beams**



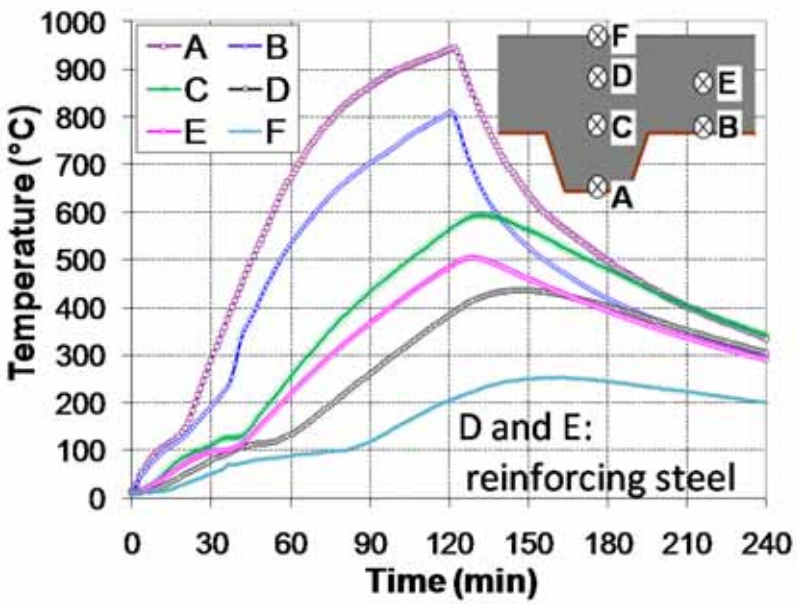
- **Observation**
  - **Much hotter beams in COSSFIRE test ≈ 550 °C and one edge secondary beam heated up to > 600 °C**

Experimental results

- **Heating of composite slab**



FRACOF



COSSFIRE

Experimental results

- **Displacement transducers for deflection**

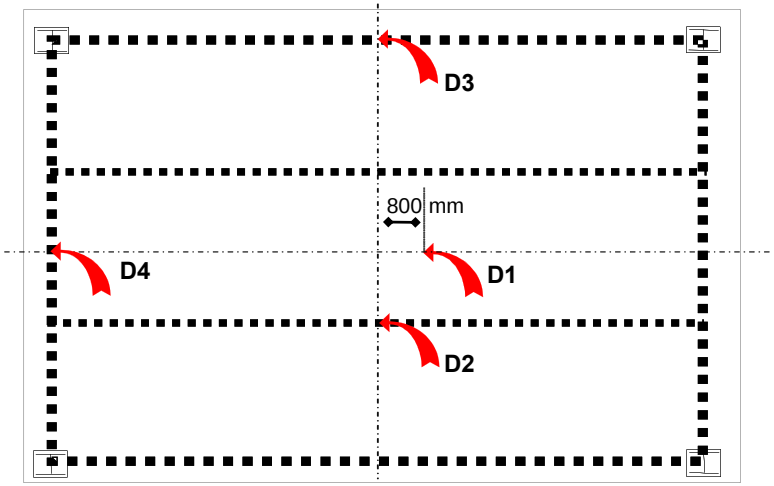
Objectives

Test set-up

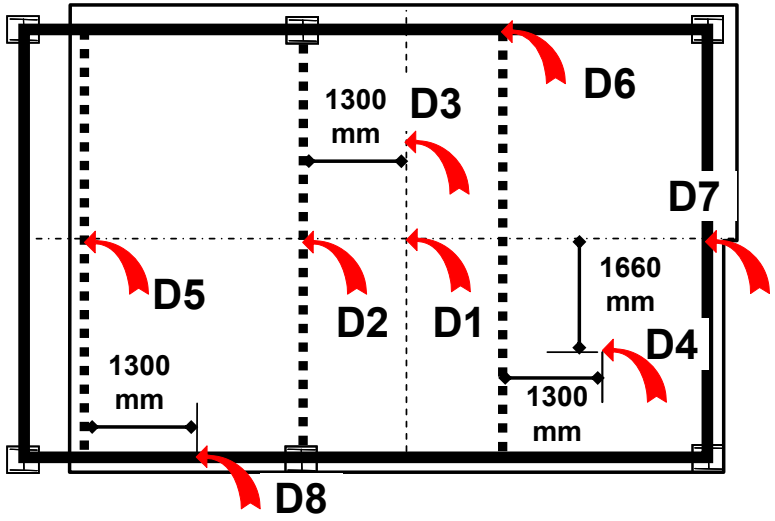
Experimental results & Observation

Comparison with simple design methods

Conclusion



FRACOF

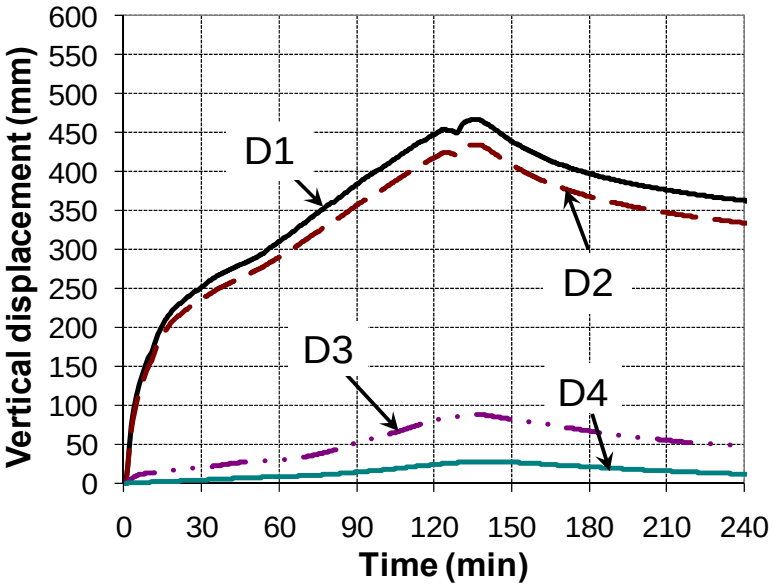


COSSFIRE

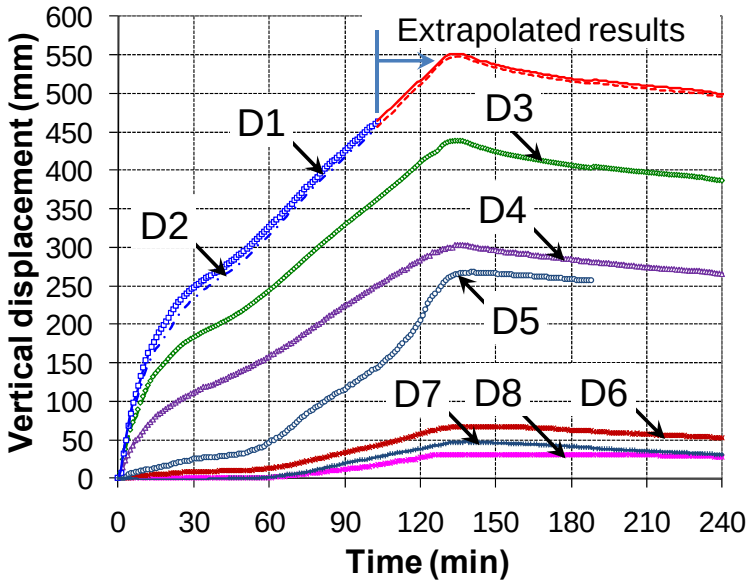
Experimental results

- Objectives
- Test set-up
- **Experimental results & Observation**
- Comparison with simple design methods
- Conclusion

• Deflection of the floors



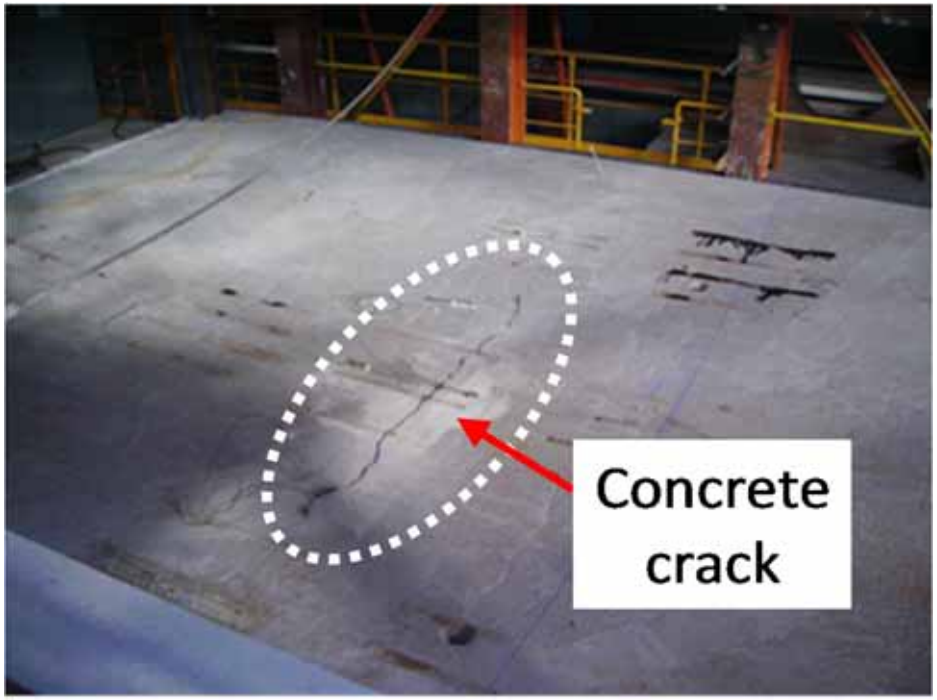
FRACOF



COSSFIRE

Experimental results

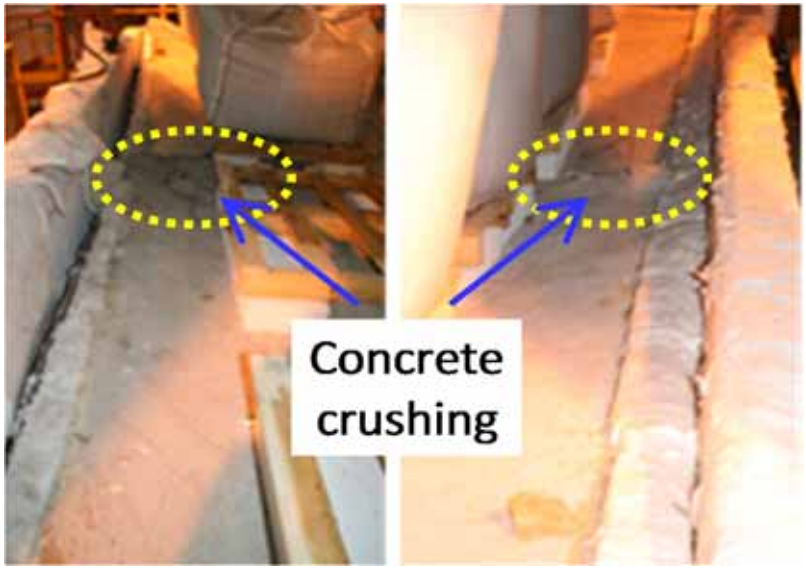
- **Cracking of concrete (FRACOF)**



- **Observation**
  - **Excellent global stability of the floor despite the failure of reinforcing steel mesh**

Experimental results

- **Crushing of concrete (COSSFIRE)**



- **Observation**
  - **Global stability of the floor maintained appropriately despite the failure of one edge beam**

Comparison with simple design rules

	FRACOF		COSSFIRE	
	Test	Simple design methods	Test	Simple design methods
Fire rating (min)	> 120	120	> 120	96
Deflection (mm)	450	366(*)	510	376(*)

- **Observation**
  - Experimental results:
    - **Fire rating > 120 minutes**

New experimental evidences

Objectives

Test set-up

Experimental results & Observation

Comparison with simple design methods

Conclusion

- **General conclusions relative to new fire tests**
  - **Excellent performance of the composite floor systems behaving under membrane action for long ISO fire exposure (>120 minutes)**
  - **High level of robustness of the composite floor system despite certain local failures**
  - **Specific attention to be paid to construction details with respect to reinforcing steel mesh in order to ensure a good performance of integrity criteria**
  - **Simple design method is on the safe side in comparison with test results**
  - **No sign of failure during cooling phase of the composite floor systems**