Education and Culture DG
Lifelong Learning Programme
LEONARDO DA VINCI

1&4 ANEFORE

Fire Behaviour of Steel and Composite Floor Systems

New Experimental Evidences

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26th of May 2011

Content of presentation

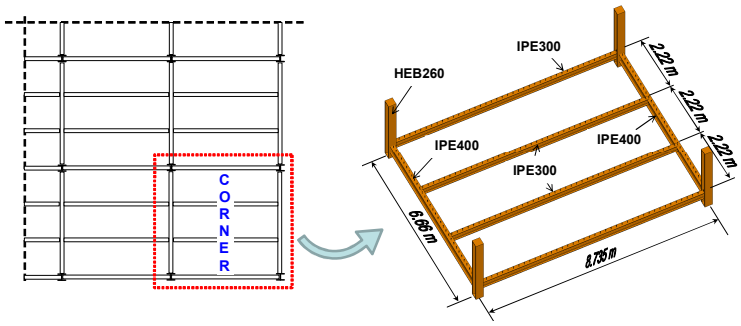
- Objectives of new fire tests
- Full scale fire tests within the projects of
  - FRACOF
  - COSSFIRE
- Test set-up
- Experimental results
  - Temperature
  - Displacement
- Observation and analysis
- Comparison with simple design methods
- Conclusion

Why more fire tests

- **Background**
  - Cardington fire tests
    - Excellent fire performance under natural fire condition
    - Max θ of steel ≈ 1150 °C, fire duration ≈ 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**



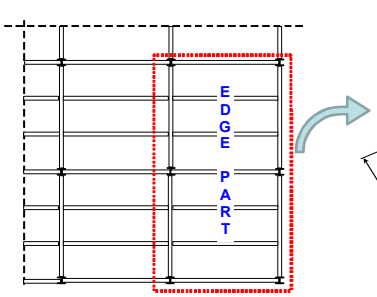
Structure grid of a real building

Adopted steel frames for FRACOF fire test

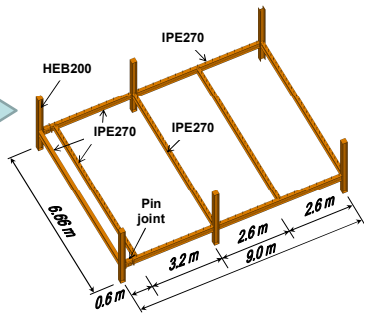
Design of test specimens

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

- **COSSFIRE test**



Structure grid of a real building



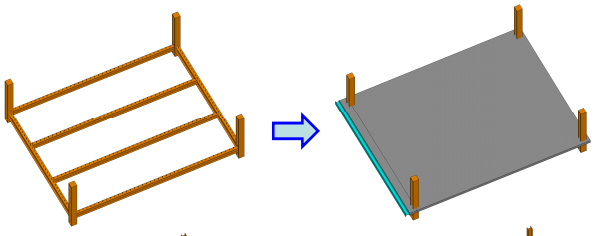
Adopted steel frames for COSSFIRE fire test

Design of test specimens

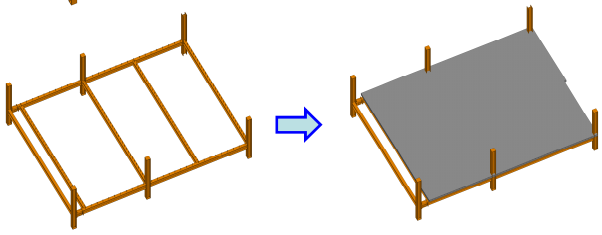
- Objectives
- **Test set-up**
- Experimental results & Observation
- Comparison with simple design methods
- Conclusion

- **Final composite floor systems**

FRACOF



COSSFIRE

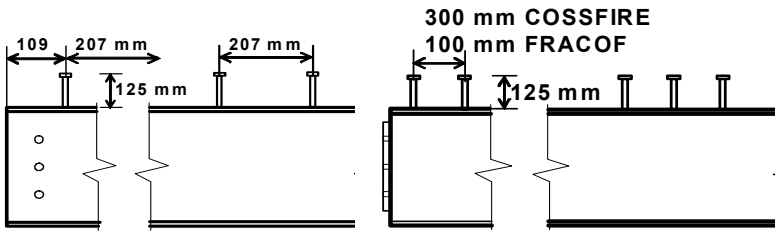


Design of structural members

- **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)**

Design of structural members

- **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)**

Objectives

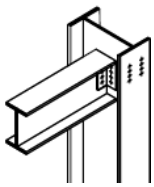
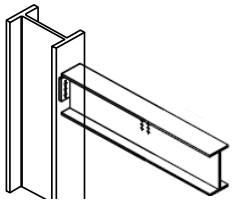
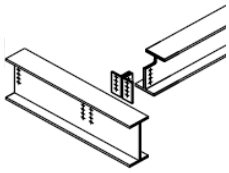
Test set-up

Experimental results & Observation

Comparison with simple design methods

Conclusion

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

Objectives

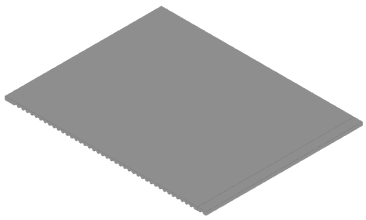
Test set-up

Experimental results & Observation

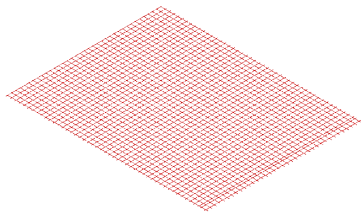
Comparison with simple design methods

Conclusion

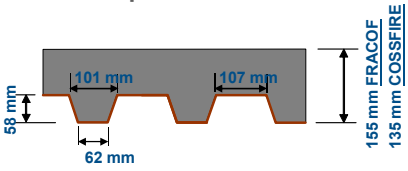
Sizes of structural members



Composite slab



Reinforcing steel mesh

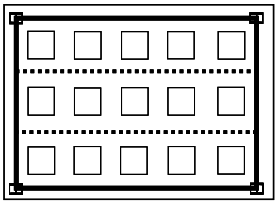


Steel deck: COFRAPLUS60 – 0.75 mm
Concrete quality: C30/37

Mesh size: 150x150
Diameter: 7 mm
Steel grade: S500
Axis distance from top of the slab:
- 50 mm FRACOF
- 35 mm COSSFIRE

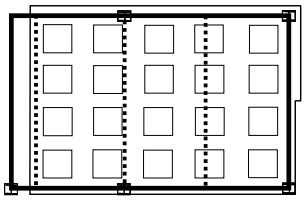
Mechanical loading condition

F R A C O F



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

1

2

3

4

Behaviour of the floor during fire

Objectives

Test set-up

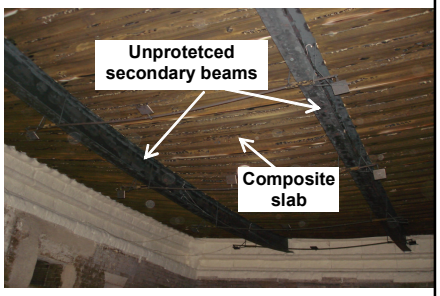
Experimental results & Observation

Comparison with simple design methods

Conclusion

Before the test

After the test



Behaviour of the floor during fire

Objectives

Test set-up

Experimental results & Observation

Comparison with simple design methods

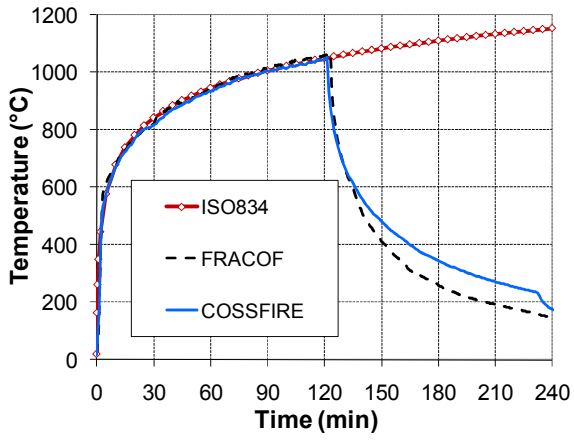
Conclusion

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**

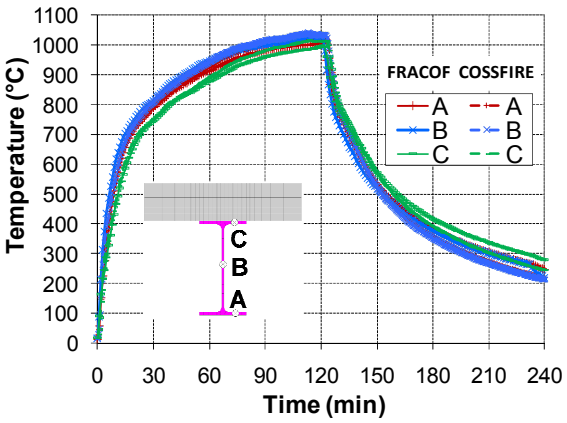
Experimental results

- **Fire temperature**



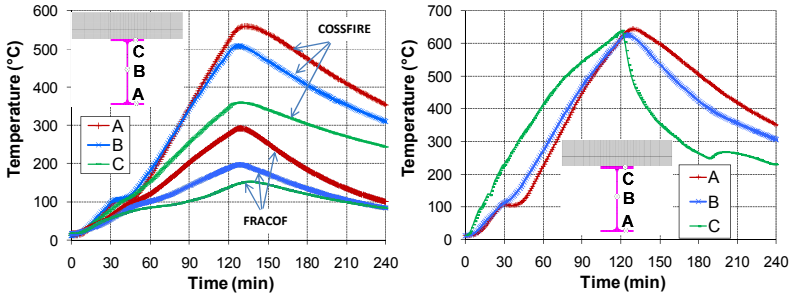
Experimental results

- **Heating of unprotected steel beams**



Experimental results

- **Heating of protected steel beams**



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

Objectives

Test set-up

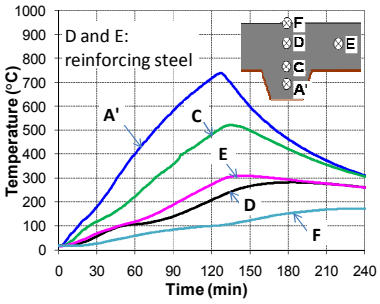
Experimental results & Observation

Comparison with simple design methods

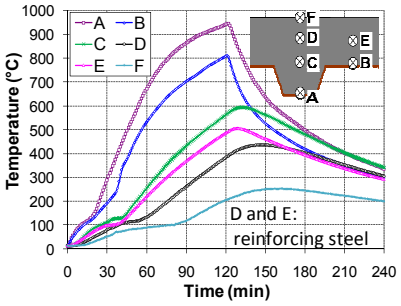
Conclusion

Experimental results

- **Heating of composite slab**



FRACOF



COSSFIRE

Objectives

Test set-up

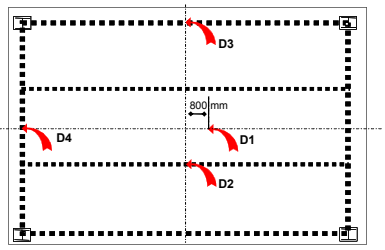
Experimental results & Observation

Comparison with simple design methods

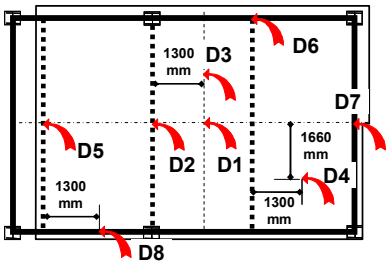
Conclusion

Experimental results

- **Displacement transducers for deflection**



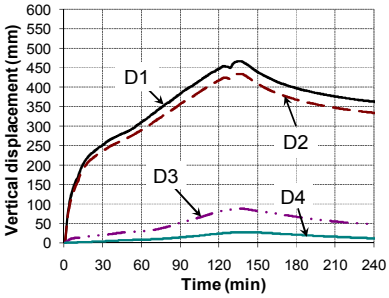
FRACOF



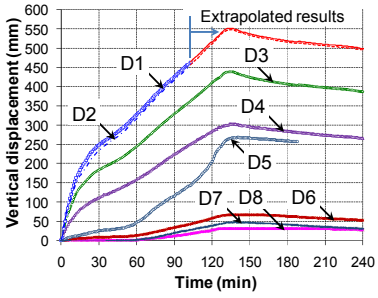
COSSFIRE

Experimental results

- **Deflection of the floors**



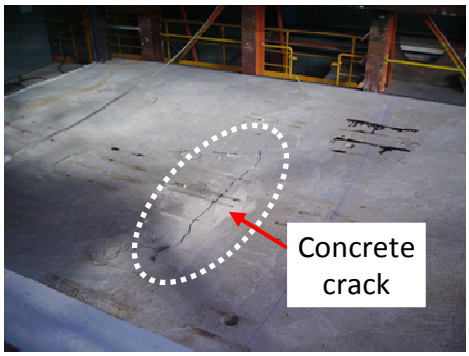
FRACOF



COSSFIRE

Experimental results

- **Cracking of concrete (FRACOF)**



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

Objectives

Test set-up

Experimental results & Observation

Comparison with simple design methods

Conclusion

Experimental results

- **Crushing of concrete (COSSFIRE)**

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

Objectives

Test set-up

Experimental results & Observation

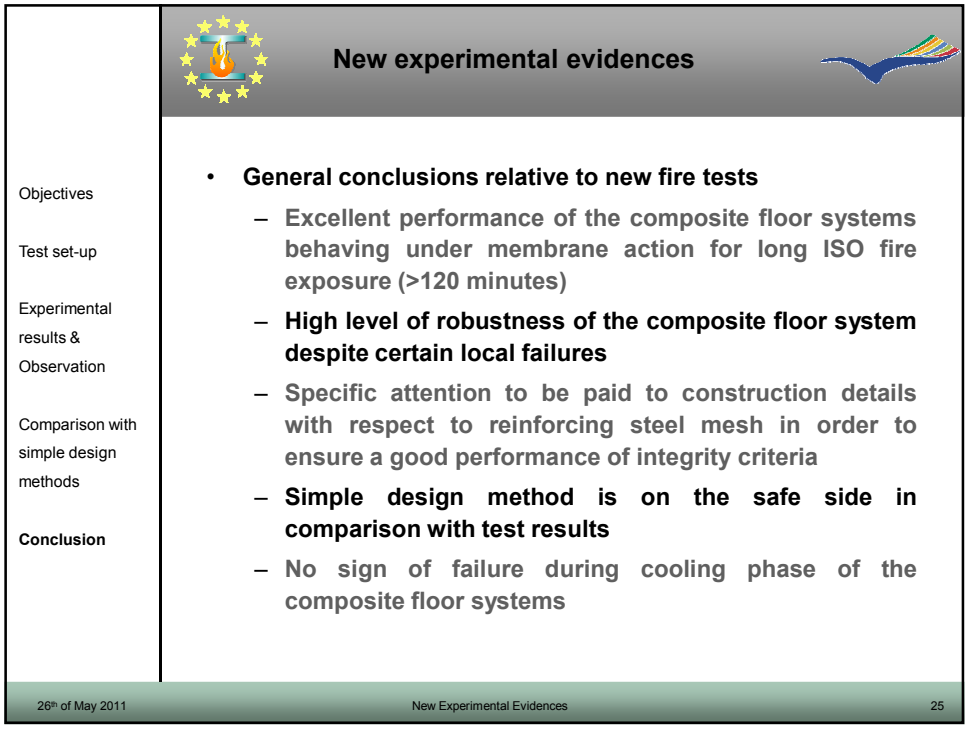
Comparison with simple design methods

Conclusion

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
26th of May 2011
New Experimental Evidences
25