Research Fund for Coal & Steel

MACS+

Fire Behaviour of Steel and Composite Floor Systems

Numerical parametric investigation of simple design method

Content of presentation

- Objectives of parametric study
- Parametric study properties
- Finite Element Analysis
- Validation of the numerical model
- Effect of continuity at the panel boundary
- Parametric study results
- Conclusion

Objectives of parametric study

Objectives

Parametric study properties

Finite Element Analysis

Validation of the numerical model

Effect of boundary conditions

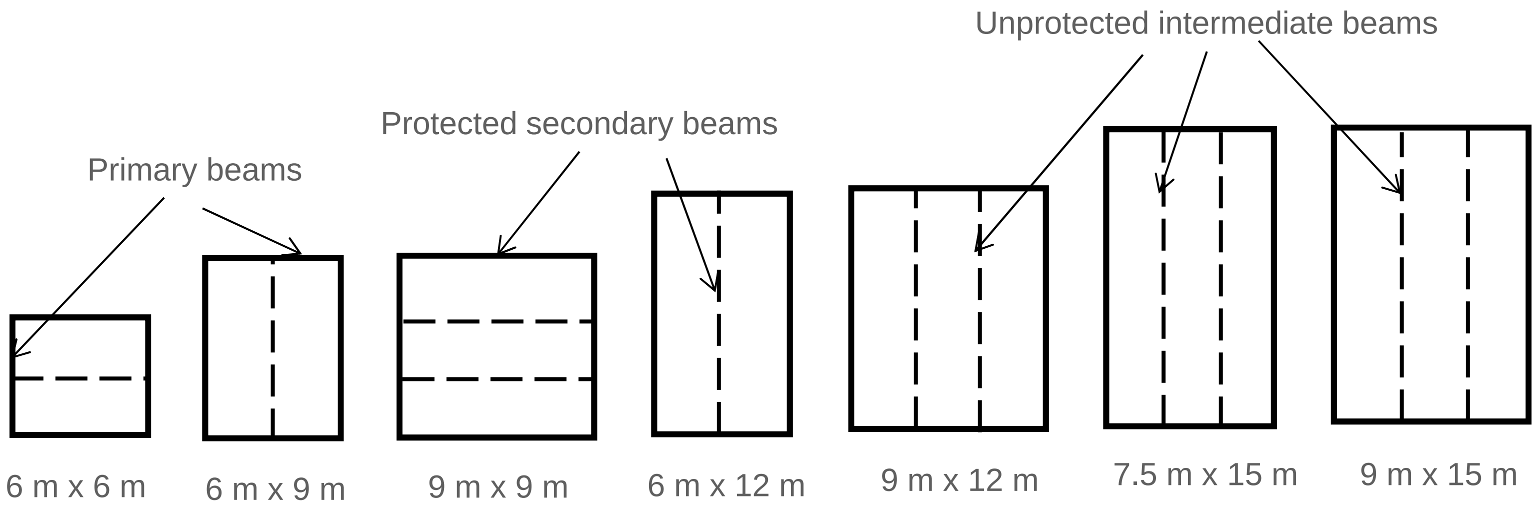
Parametric study results

Conclusion

- **Background**
  - FRACOF (Test 1)- COSSFIRE (Test 2) full scale standard fire tests
    - Excellent fire performance of the composite floor systems (presence of tensile membrane action)
    - Max θ of steel ≈ 1000 °C, fire duration > 120 min
    - French construction details
    - Deflection ≈ 450 mm
  - FICEB (Test 3) full scale natural fire test with Cellular Beams
- **Objective**
  - Verification of the Simple Design Method to its full application domain (using advanced calculation models)
    - Deflection limit of the floor
    - Elongation of reinforcing steel

Parametric study properties (1/3)

- **Grid size of the floor**



- **Load levels**

According to EC0 load combination in fire situation for office buildings:

G (Dead Load) + 0.5 Q (Imposed Load)

G= Self weight + 1.25 kN/m²

Q= 2.5 & 5 kN/m²

Objectives

Parametric study properties

Finite Element Analysis

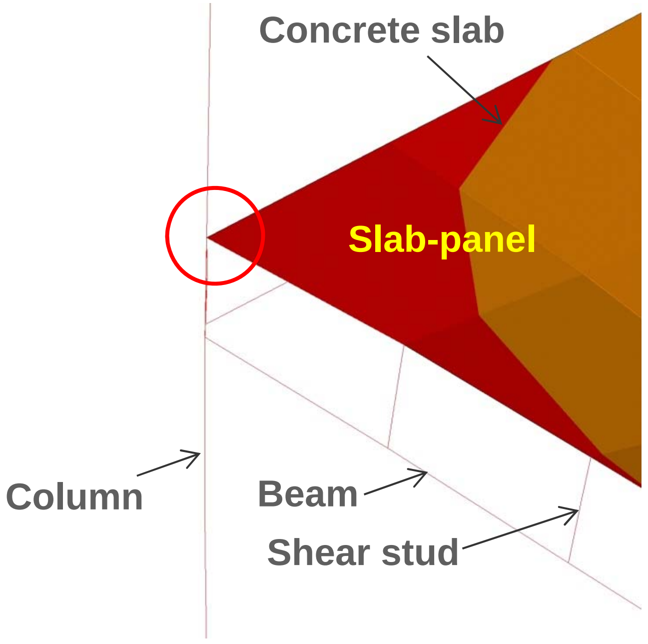
Validation of the numerical model

Effect of boundary conditions

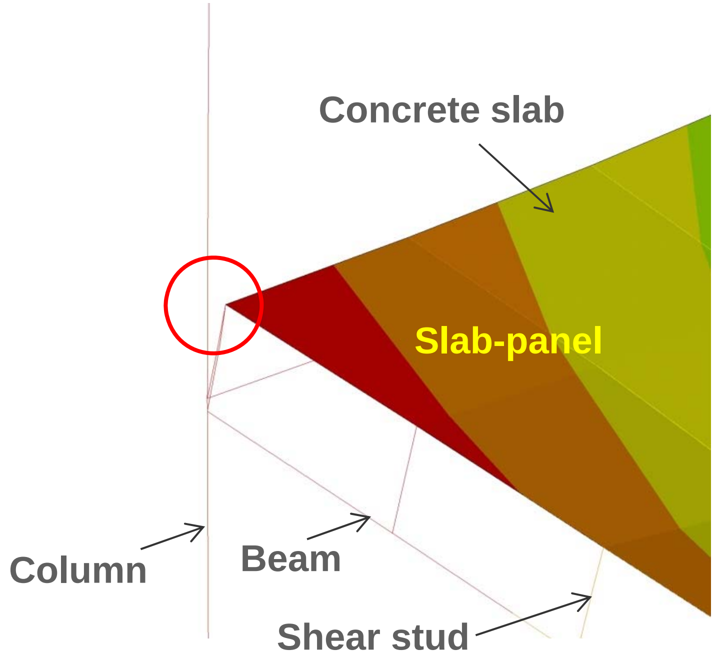
Parametric study results

Conclusion

- **Link condition between floor and steel columns**

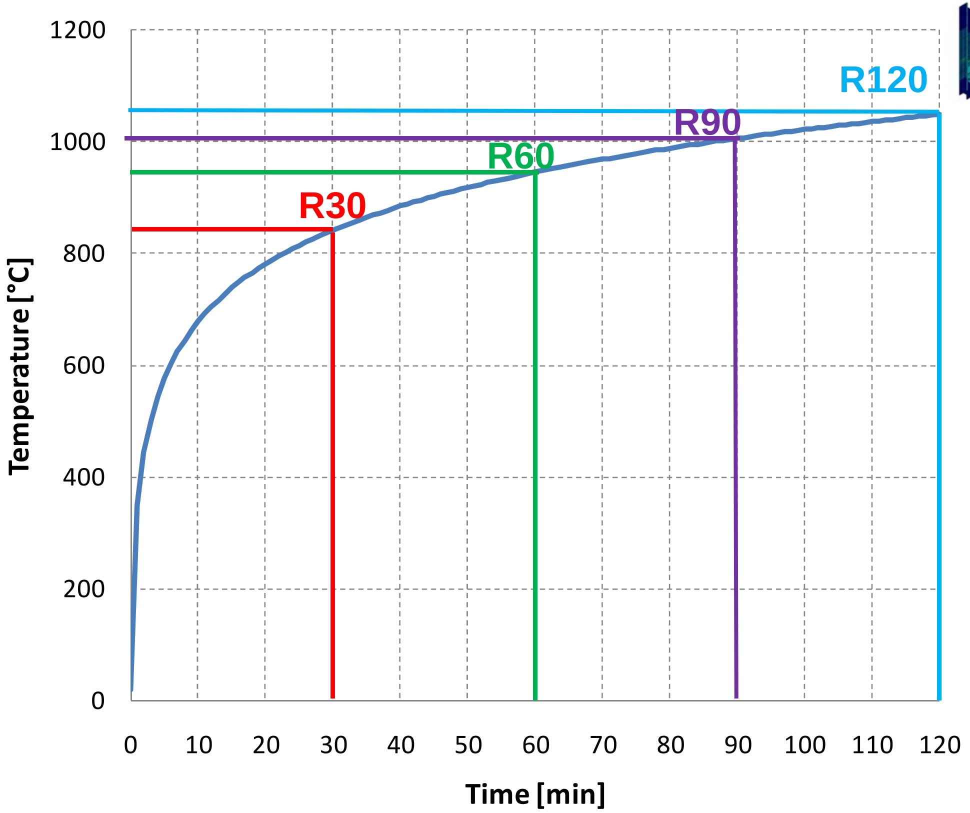


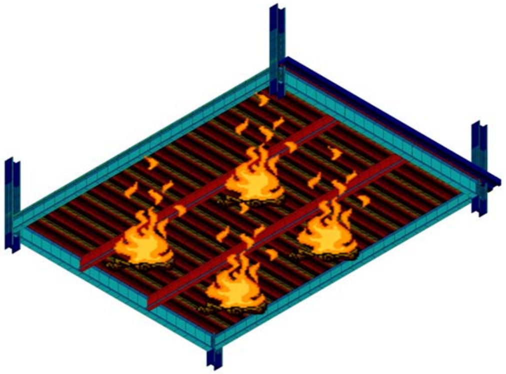
With mechanical link between slab and columns



Without mechanical link between slab and columns

- **Fire rating: R30, R60, R90 and R120**

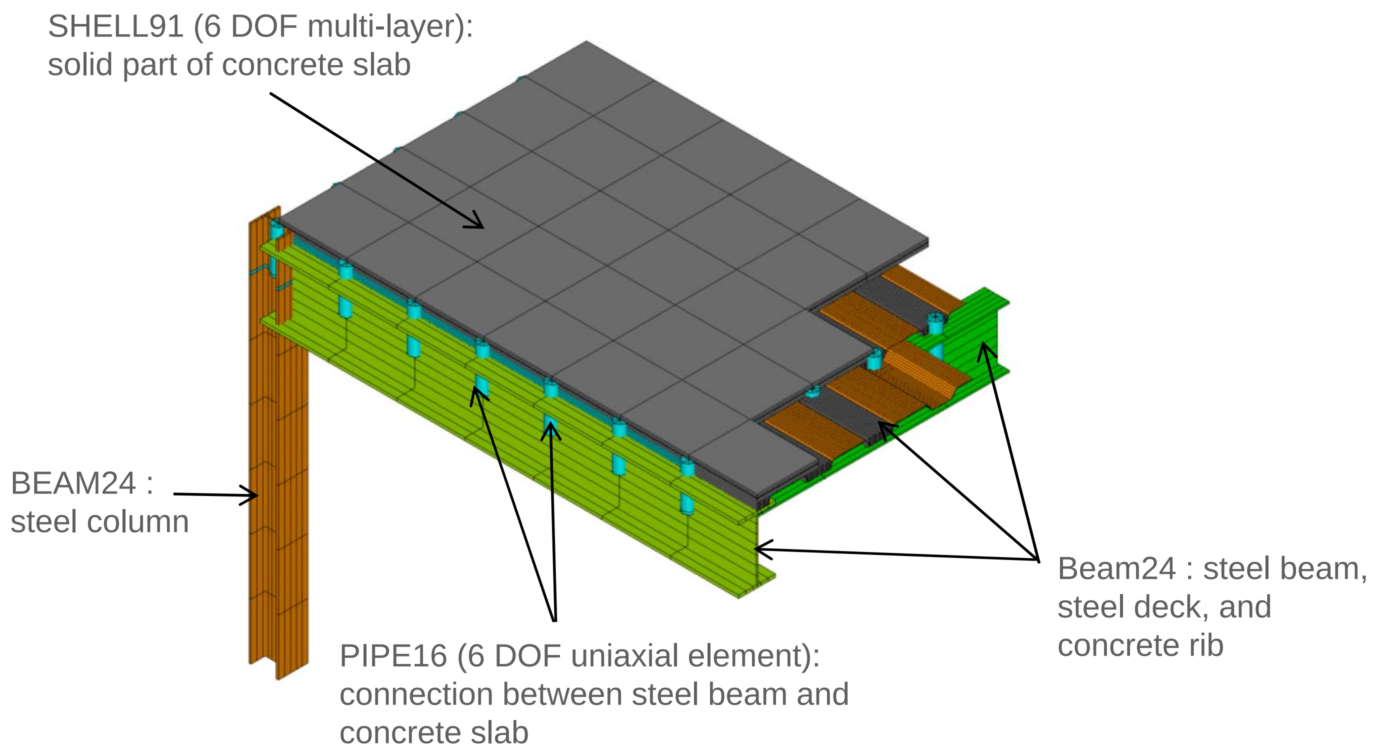




Heating of boundary beams (Max. 550 °C)

Finite Element Model

- **Hybrid model based on several types of Finite Element with computer code ANSYS**



Finite Element Model

Objectives

Parametric study properties

Finite Element Analysis

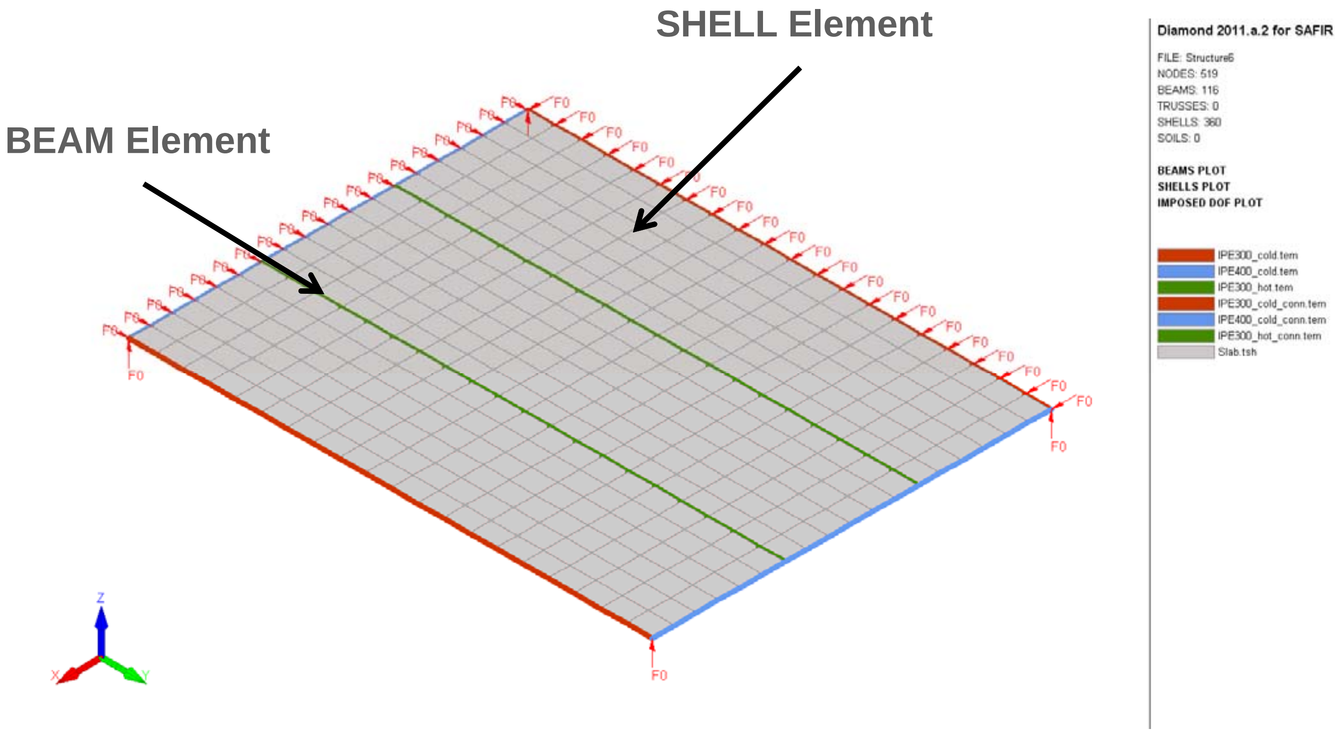
Validation of the numerical model

Effect of boundary conditions

Parametric study results

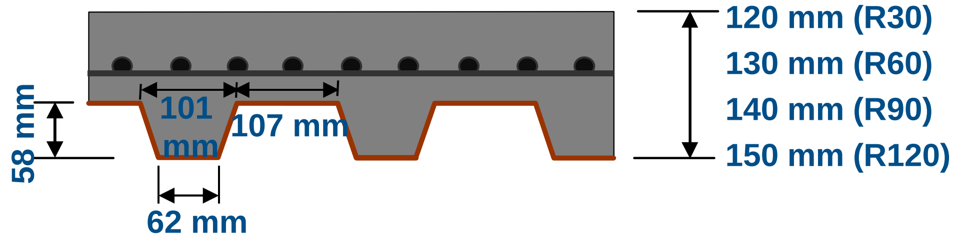
Conclusion

- **Hybrid model based on several types of Finite Element with computer code SAFIR**



Slab panel properties

- **S235 beams**
- **COFRAPLUS60 trapezoidal steel decking (0.75 mm thick)**
- **Normal weight concrete C30/37**
- **S500 reinforcement mesh**
- **Average mesh position (from top surface) = 45 mm**



Thermo-mechanical properties (1/2)

Objectives

Parametric study properties

Finite Element Analysis

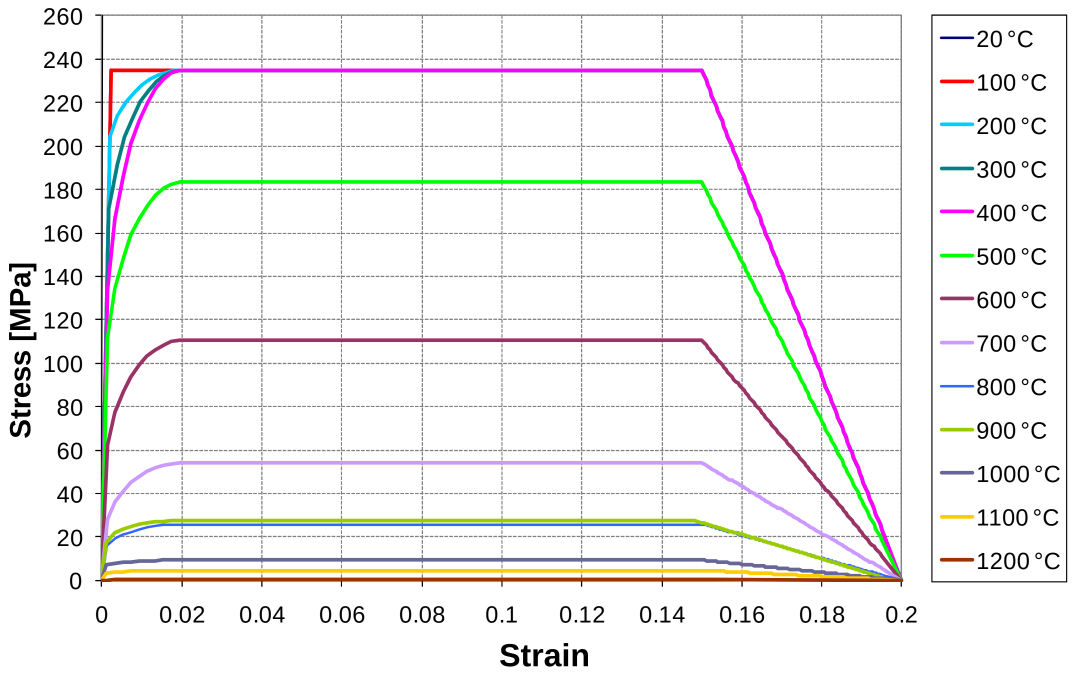
Validation of the numerical model

Effect of boundary conditions

Parametric study results

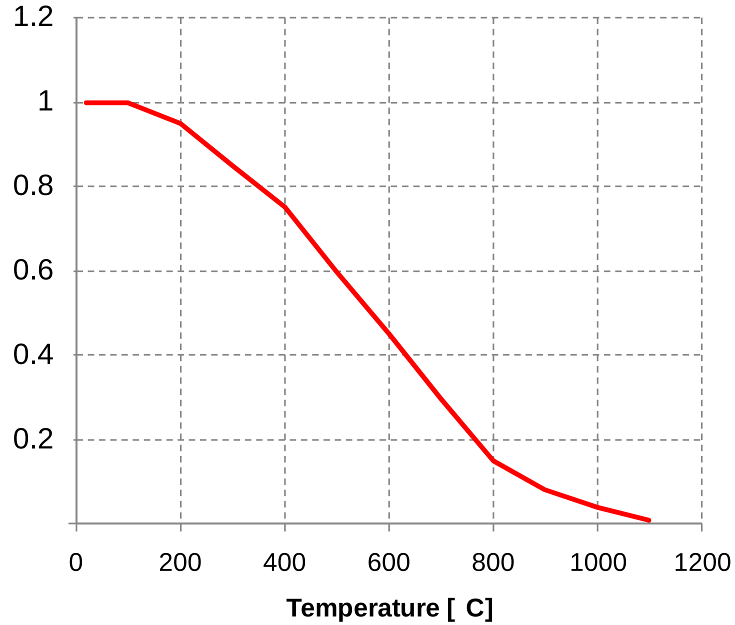
Conclusion

- **Steel thermo-mechanical properties:**
  - Thermal properties from EC4-1.2
  - Unit mass independent of the temperature (ρ_a = 7850 kg/m^3)
  - Stress-strain relationships:



Thermo-mechanical properties (2/2)

- **Concrete thermo-mechanical properties:**
  - **Thermal properties from EC4-1.2**
  - **Unit mass as a function of temperature according to EC4-1.2**
  - **Drucker-Prager yield criterion**
  - **Compressive reduction factors from EC4-1.2:**



Validation of the ANSYS numerical model vs Test 1 (1/2)

Objectives

Parametric study properties

Finite Element Analysis

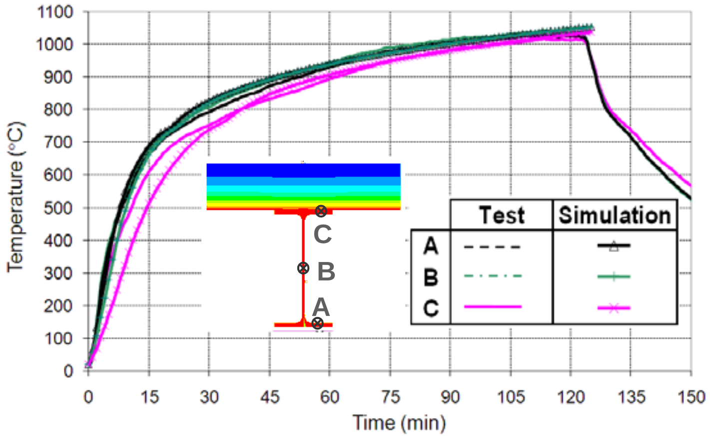
Validation of the numerical model

Effect of boundary conditions

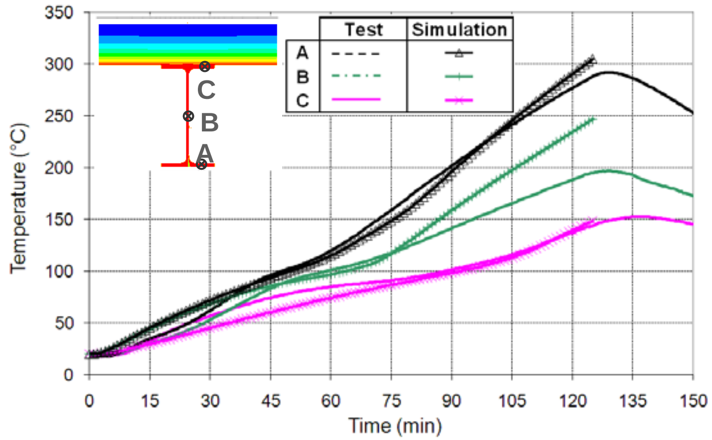
Parametric study results

Conclusion

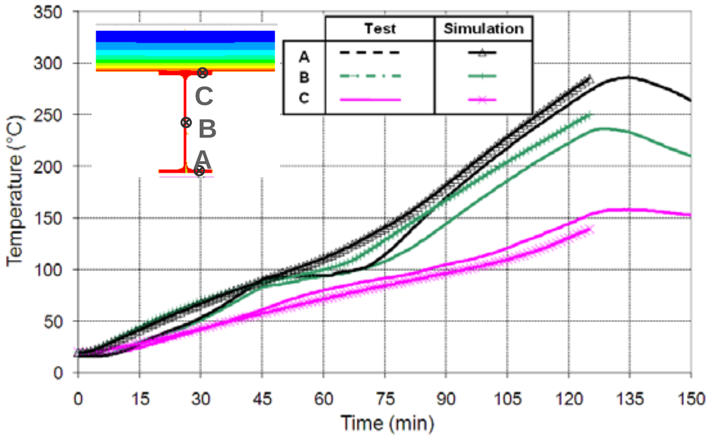
- **Comparison with fire test (heat transfer analysis)**



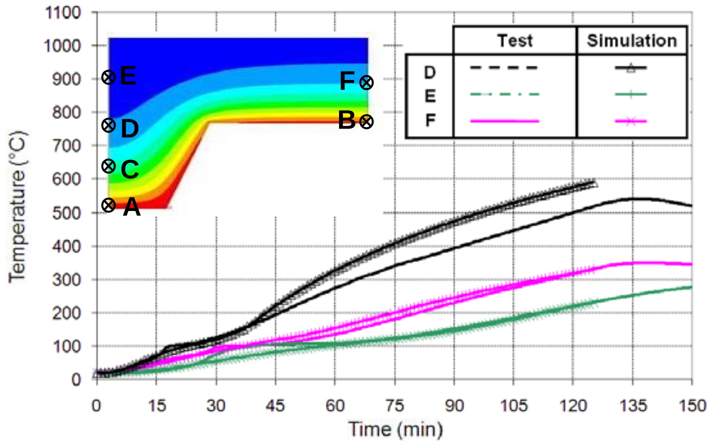
Unprotected steel beams



Protected secondary beams



Protected primary beams



Composite slab

Validation of the ANSYS numerical model vs Test 1 (2/2)

Objectives

Parametric study properties

Finite Element Analysis

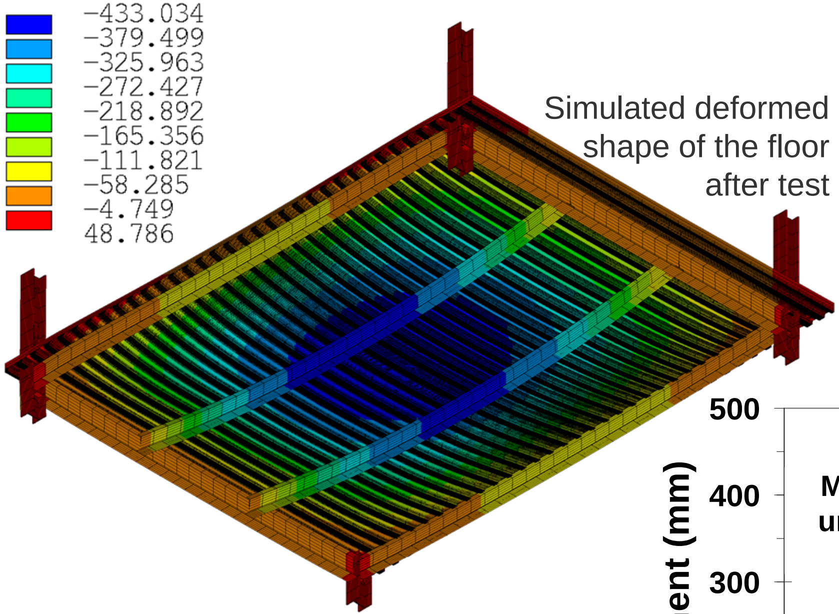
Validation of the numerical model

Effect of boundary conditions

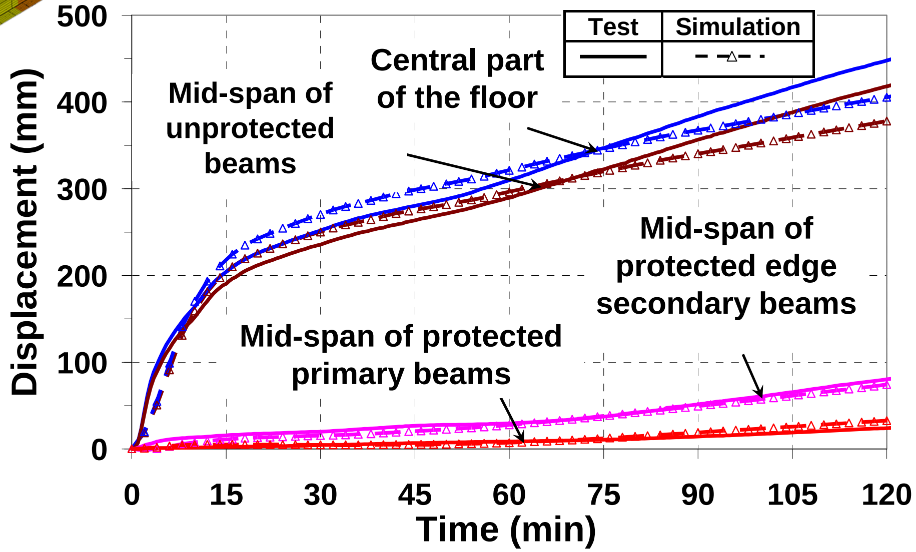
Parametric study results

Conclusion

- **Comparison with fire test (deflection)**



Simulated deformed shape of the floor after test



Comparison of the deflection (slab and beams)

Objectives

Parametric study properties

Finite Element Analysis

Validation of the numerical model

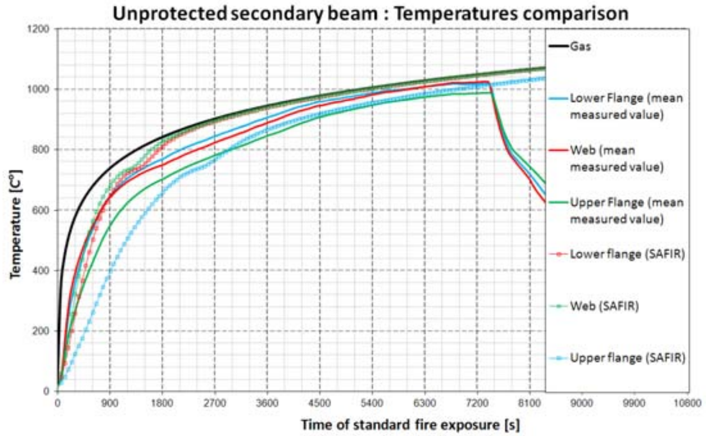
Effect of boundary conditions

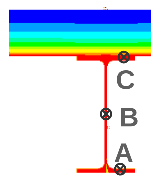
Parametric study results

Conclusion

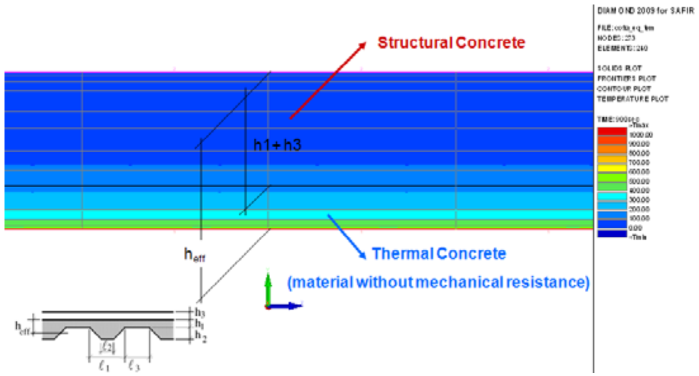
Validation of the SAFIR numerical model vs Test 1 (1/2)

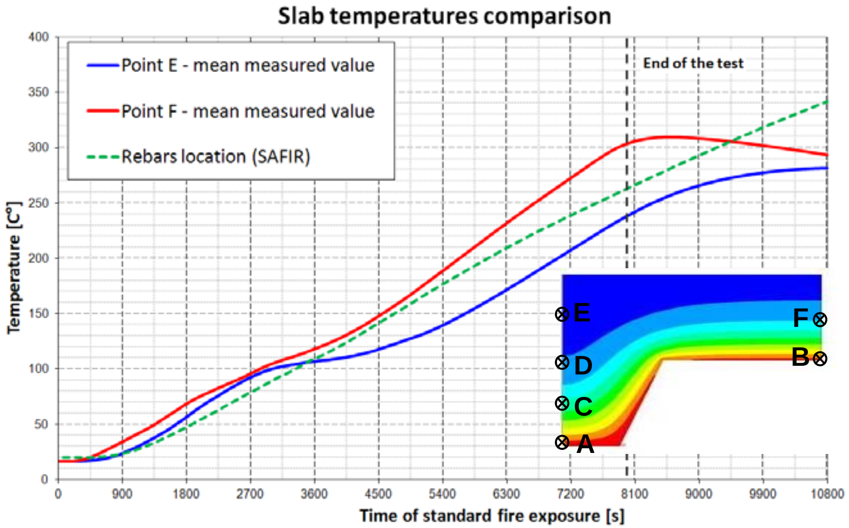
- **Comparison with fire test (heat transfer analysis)**





Unprotected steel beams





Composite slab

Validation of the SAFIR numerical model vs Test 1 (2/2)

Objectives

Parametric study properties

Finite Element Analysis

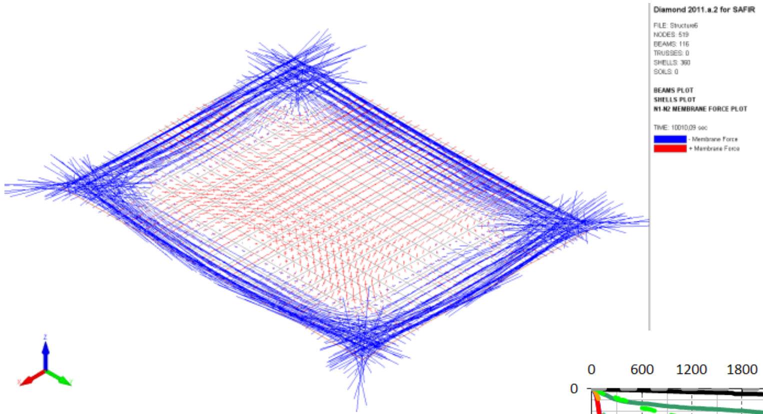
Validation of the numerical model

Effect of boundary conditions

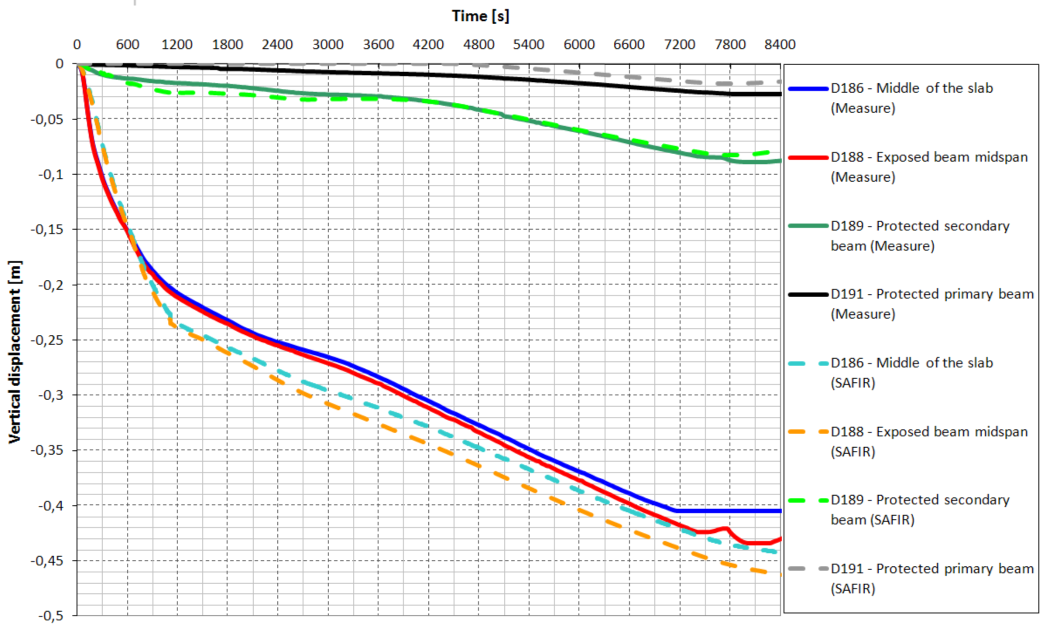
Parametric study results

Conclusion

- **Comparison with fire test (deflection)**



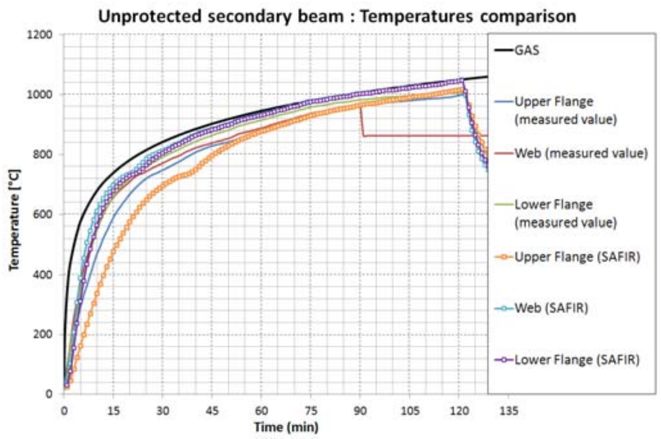
Simulated stresses in the slab end of the test

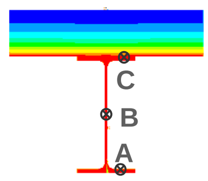


Comparison of the deflection (slab and beams)

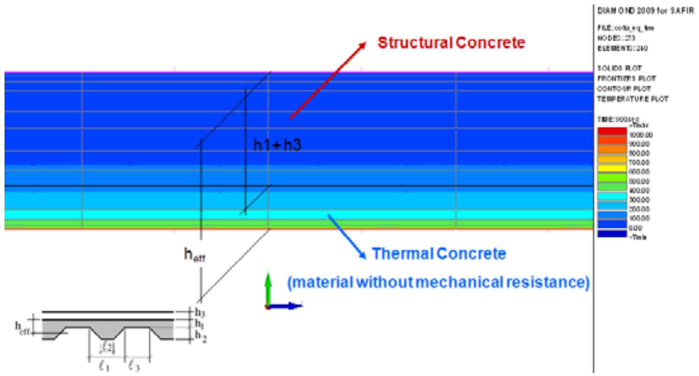
Validation of the SAFIR numerical model vs Test 2 (1/2)

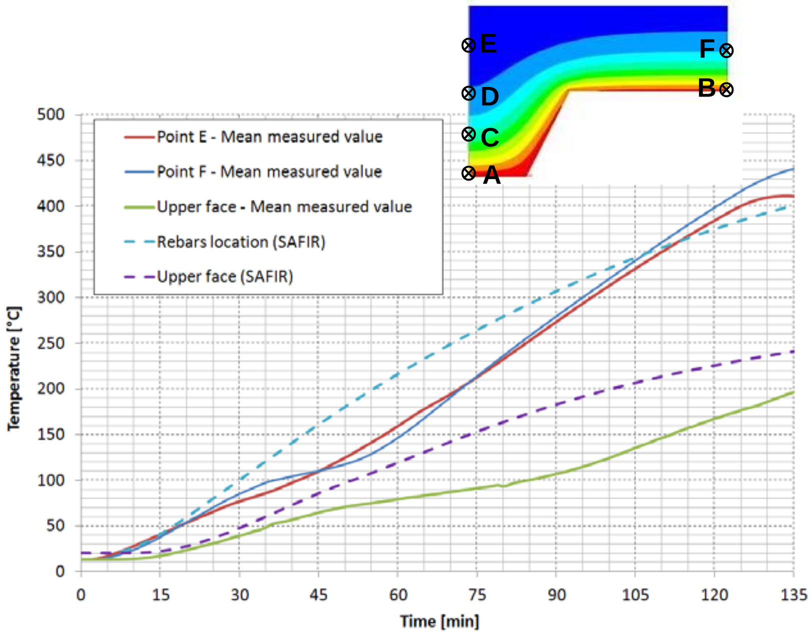
- **Comparison with fire test (heat transfer analysis)**





Unprotected steel beams

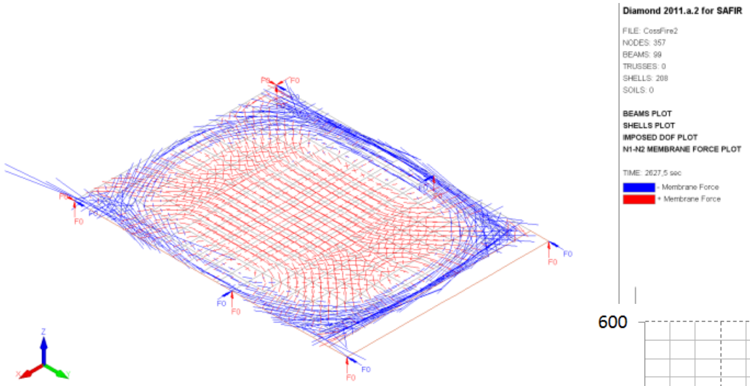




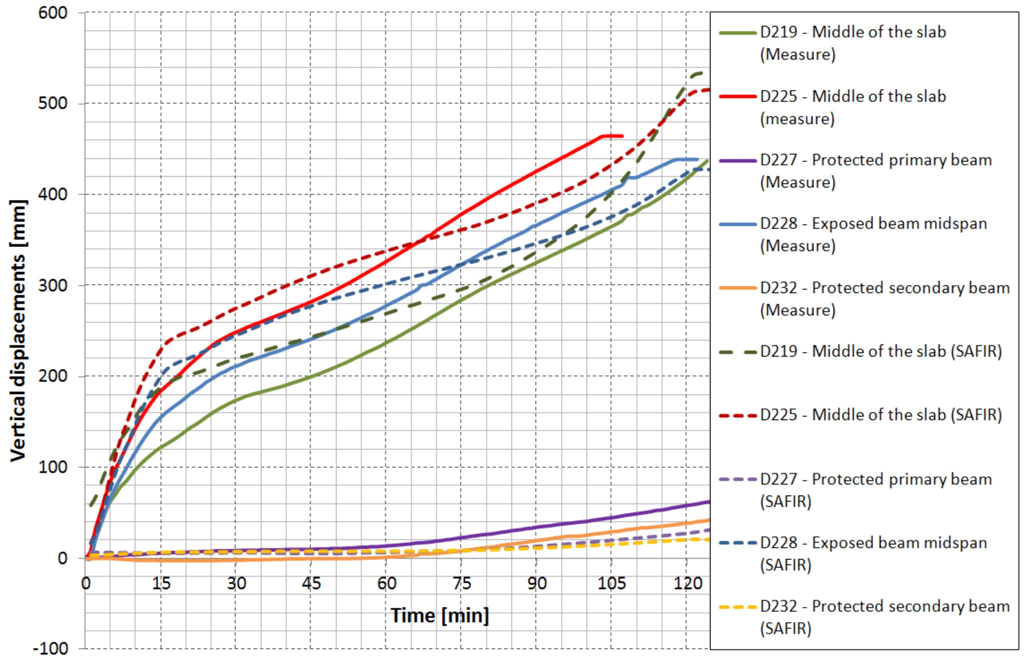
Composite slab

Validation of the SAFIR numerical model vs Test 2 (2/2)

- **Comparison with fire test (deflection)**



Simulated stresses in the slab end of the test



Comparison of the deflection (slab and beams)

Objectives

Parametric study properties

Finite Element Analysis

Validation of the numerical model

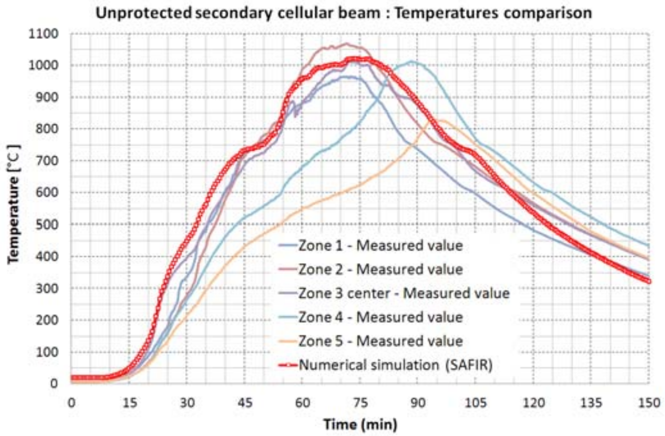
Effect of boundary conditions

Parametric study results

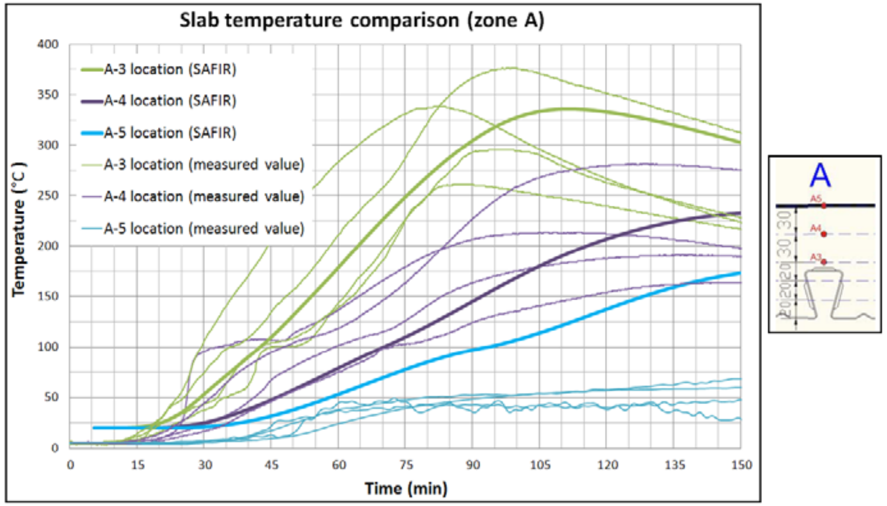
Conclusion

Validation of the SAFIR numerical model vs Test 3 (1/3)

- **Comparison with fire test (heat transfer analysis)**



Unprotected steel beams



Composite slab

Validation of the SAFIR numerical model vs Test 3 (2/3)

Objectives

Parametric study properties

Finite Element Analysis

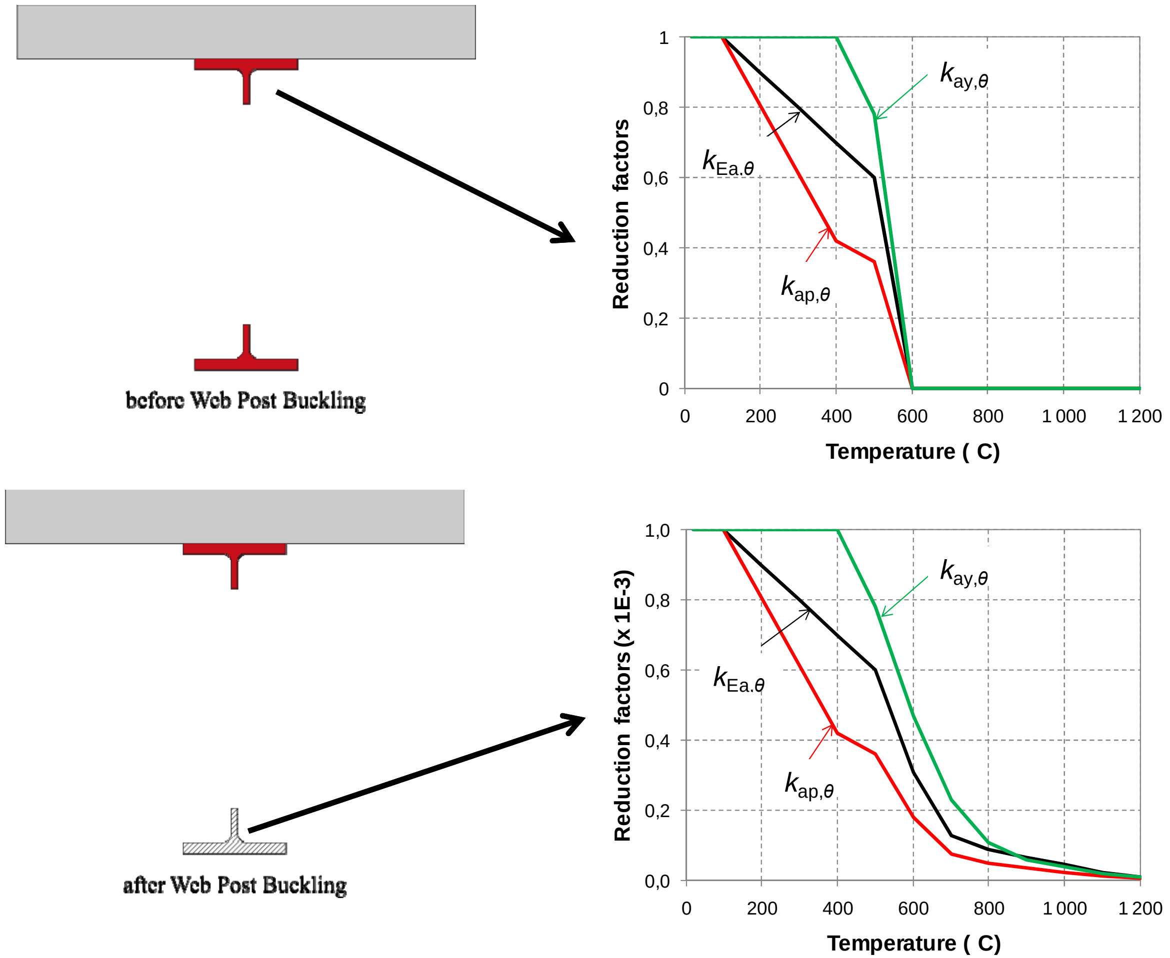
Validation of the numerical model

Effect of boundary conditions

Parametric study results

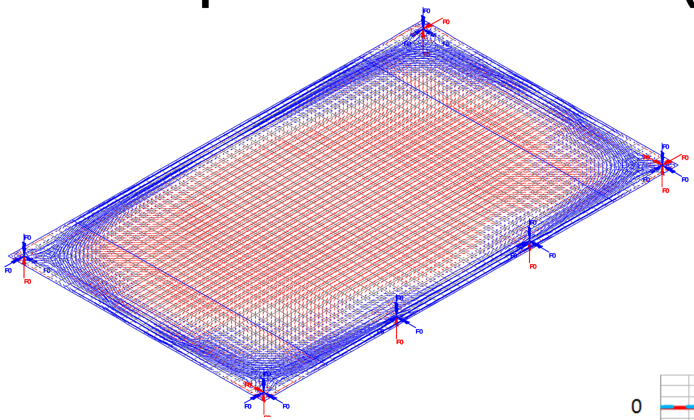
Conclusion

- **Hybrid Model to take into account the WPB with BEAM element**

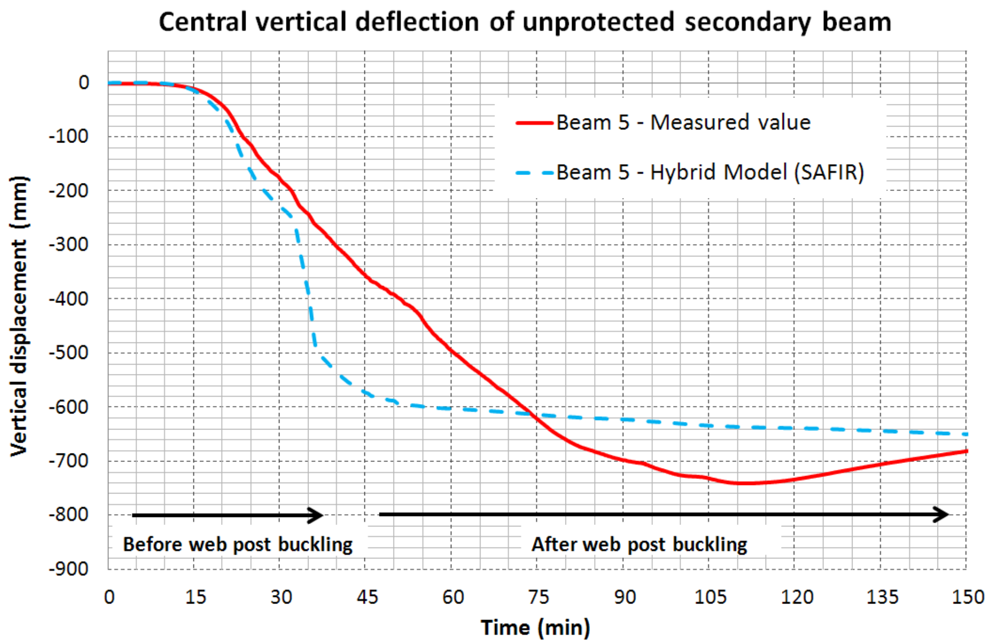


Validation of the SAFIR numerical model vs Test 3 (3/3)

- **Comparison with fire test (deflection)**



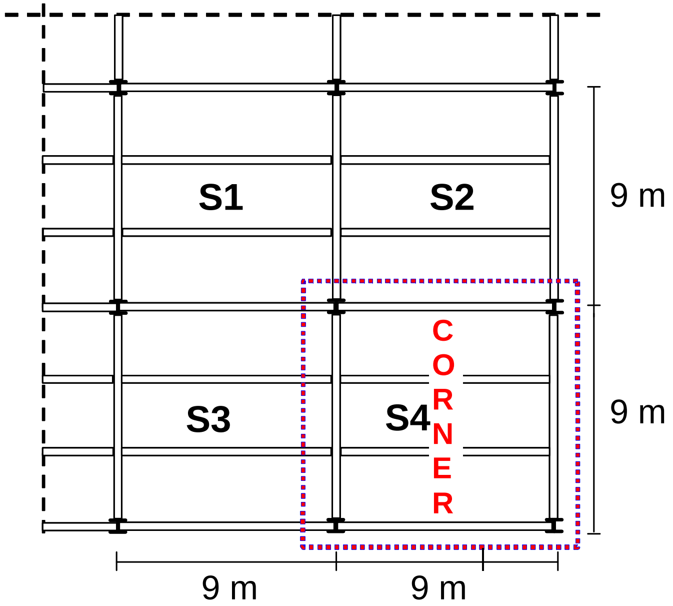
Simulated stresses in the slab end of the test



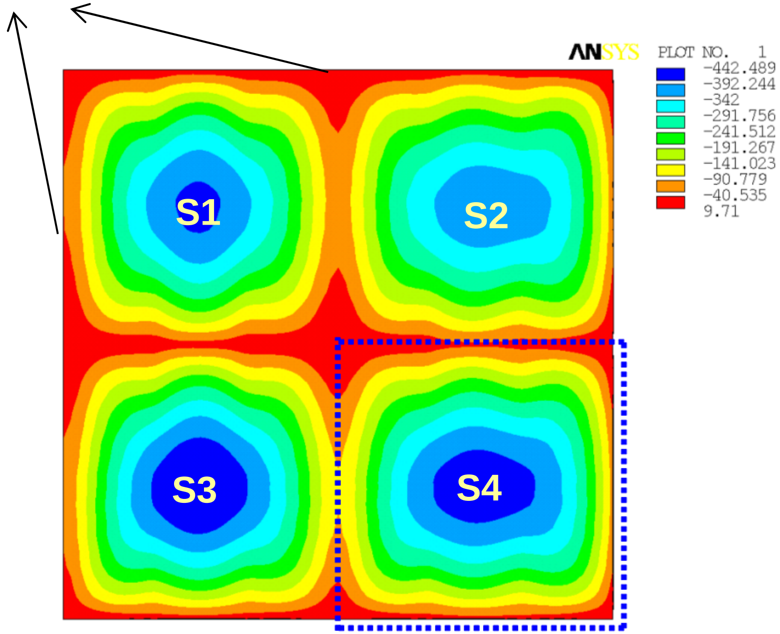
Comparison of the deflection

Effect of boundary conditions

Restraint conditions



Structure grid of a real building



ANSYS model

- **Conclusion**
  - **More important predicted deflection in the corner grid with 2 continuous edges than in other 3 grids with 3 or 4 continuous edges.**

Objectives

Parametric study properties

Finite Element Analysis

Validation of the numerical model

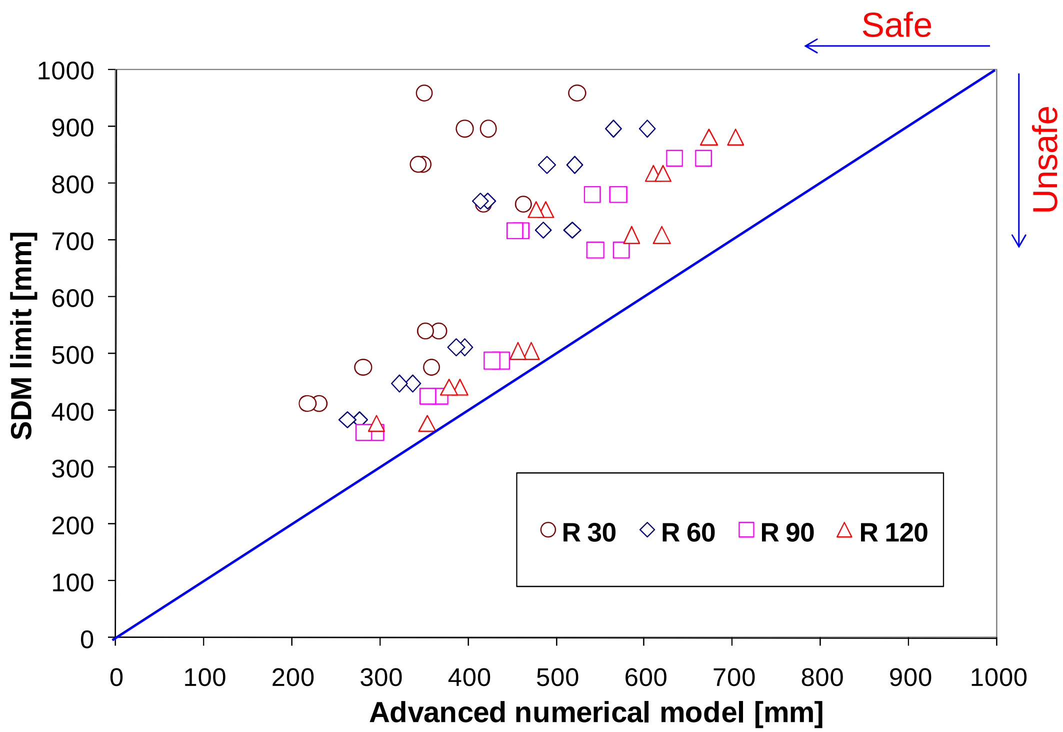
Effect of boundary conditions

Parametric study results

Conclusion

Parametric study results (1/4)

- **Comparison of the FEA deflection with the maximum allowable deflection according to SDM (Simple Design Method)**



With mechanical link between slab and columns in advanced calculations

Objectives

Parametric study properties

Finite Element Analysis

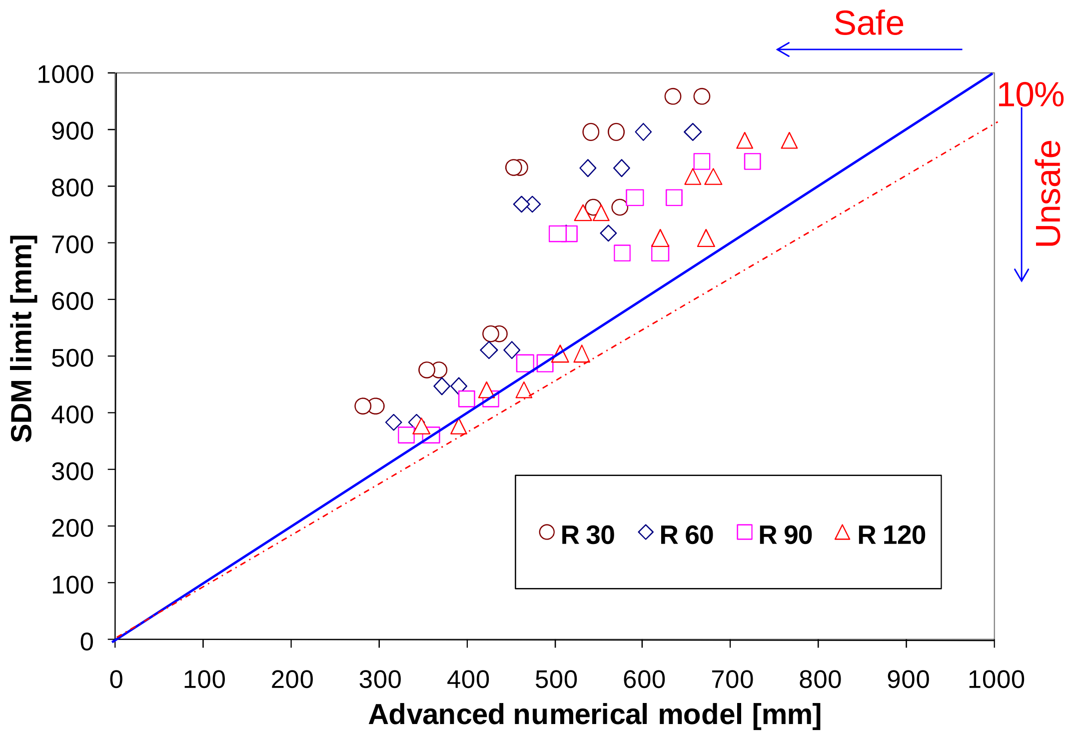
Validation of the numerical model

Effect of boundary conditions

Parametric study results

Conclusion

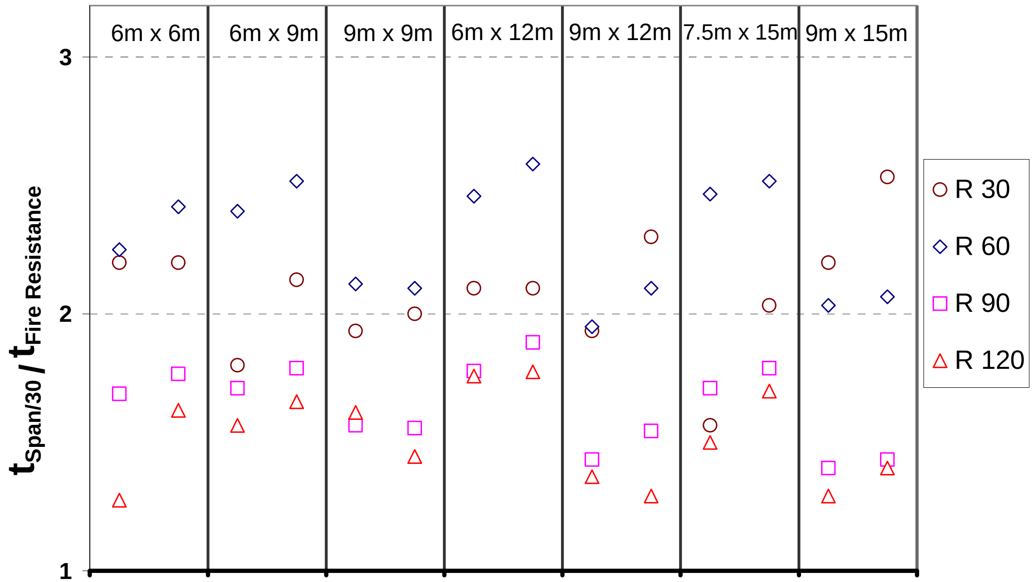
- **Comparison of the FEA deflection with the maximum allowable deflection according to SDM (Simple Design Method)**



Without mechanical link between slab and columns in advanced calculations

Parametric study results (3/4)

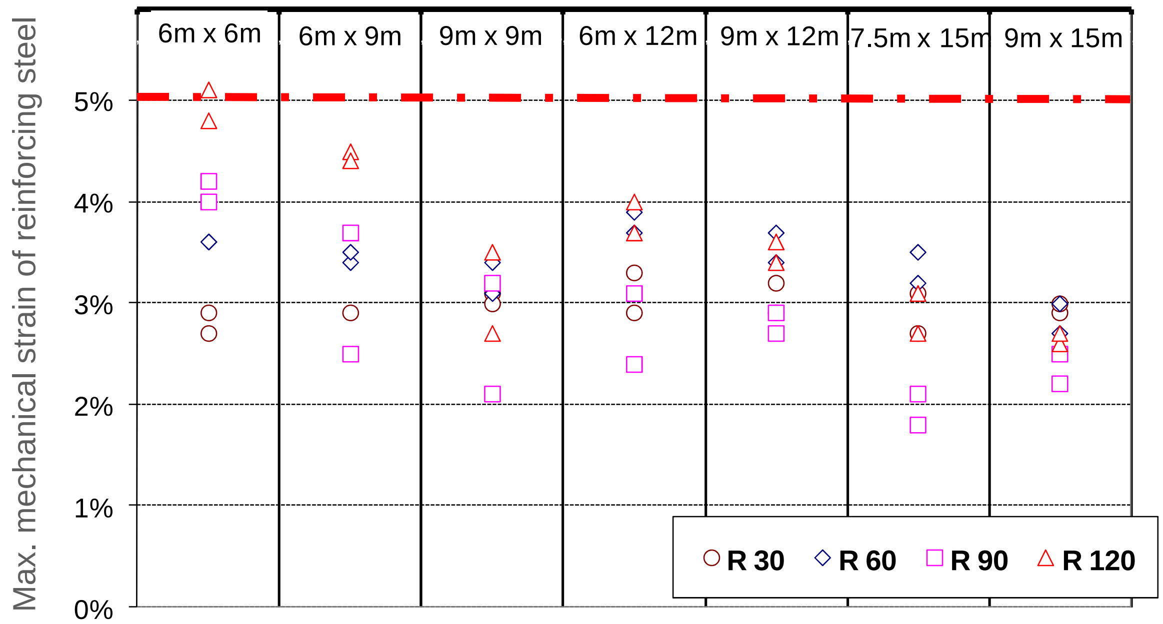
- **Comparison of the time when the FEA deflection reaches span/30 with the fire resistance according to SDM (Simple Design Method)**



- **Conclusion**
  - **Span/30 criterion is not reached in FEA all through the fire resistance duration predicted by SDM**

Parametric study results (4/4)

- **Elongation capacity of reinforcing bars**



- **Conclusion**
  - **Elongation of reinforcing steel < 5 % = Min. allowable elongation capacity according to EC4-1.2.**

Conclusion

- **SDM (Simple Design Method) is on the safe side in comparison with advanced calculation results.**

- **Concerning the elongation of reinforcing steel mesh, it remains generally below 5 %.**

- **Mechanical links between slab and columns can reduce the deflection of a composite flooring system under a fire situation but they are not necessary as a constructional detail.**

- **SDM is capable of predicting in a safe way the structural behaviour of composite steel and concrete floor subjected to standard fire.**