Numerical parametric investigation of simple design method
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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

- Background
  - FRACOF (Test 1)- COSSFIRE (Test 2) full scale standard fire test
    - Excellent fire performance of the composite floor systems (presence of tensile membrane action)
    - Max $\theta$ of steel $\approx$ 1000 °C, fire duration $> 120$ min
    - French construction details
    - Deflection $\approx$ 450 mm
  - FICEB (Test 3) full scale natural fire test with Cellular Beam

- 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
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Grid size of the floor

- **Objectives**
- **Parametric study properties**
- **Finite Element Analysis**
- **Validation of the numerical model**
- **Effect of boundary conditions**
- **Parametric study results**
- **Conclusion**

**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
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- Link condition between floor and steel columns

**Objectives**

- Parametric study properties

**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
Finite Element Model

Objectives

Parametric study properties

Finite Element Analysis

Validation of the numerical model

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Parametric study results

Conclusion

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

- SHELL91 (6 DOF multi-layer): solid part of concrete slab

- BEAM24: steel column

- PIPE16 (6 DOF uniaxial element): connection between steel beam and concrete slab

- Beam24: steel beam, steel deck, and concrete rib
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Objectives

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- Hybrid model based on several types of Finite Element with computer code SAFIR
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**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
Steel thermo-mechanical properties:
- Thermal properties from EC4-1.2
- Unit mass independent of the temperature ($\rho_a = 7850 \text{ kg/m}^3$)
- Stress-strain relationships:
**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)

• Comparison with fire test (heat transfer analysis)

Unprotected steel beams

Protected secondary beams

Protected main beams

Composite slab

Objectives

Parametric study properties

Finite Element Analysis

Validation of the numerical model

Effect of boundary conditions

Parametric study results

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

- Comparison with fire test (deflection)

Simulated deformed shape of the floor after test

Comparison of the deflection (slab and beams)
Validation of the SAFIR numerical model vs Test 1 (1/2)

- Comparison with fire test (heat transfer analysis)

Objectives
- Parametric study properties
- Finite Element Analysis

Validation of the numerical model
- Effect of boundary conditions
- Parametric study results

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

- **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)
Validation of the ANSYS 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)
Comparison with fire test (heat transfer analysis)

Unprotected steel beams

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

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

![Graphs showing reduction factors vs temperature](image)

Objectives

Parametric study properties

Finite Element Analysis

Validation of the numerical model

Effect of boundary conditions

Parametric study results

Conclusion
Validation of the ANSYS numerical model vs Test 3 (3/3)

- Comparison with fire test (deflection)

Simulated stresses in the slab end of the test

Central vertical deflection of unprotected secondary beam

Comparison of the deflection (slab and beams)
Effect of boundary conditions

Objectives

Parametric study properties

Finite Element Analysis

Validation of the numerical model

Effect of boundary conditions

Parametric study results

Conclusion

- More important predicted deflection in the corner grid with 2 continuous edges than in other 3 grids with 3 or 4 continuous edges.
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
• 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
• **Comparison of the time when the FEA deflection reaches span/30 with the fire resistance according to SDM (Simple Design Method)**

![Graph showing comparison of time and fire resistance](image.png)

• **Conclusion**
  - Span/30 criterion is not reached in FEA all through the fire resistance duration predicted by SDM
- Elongation capacity of reinforcing bars

![Graph showing max. mechanical strain of reinforcing steel vs. dimensions and reinforcement ratios](image)

- **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.