Integrated Fire Engineering and Response
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Benchmark problem: Thermo-mechanical behaviour of composite slabs under fire conditions

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The benchmark problem

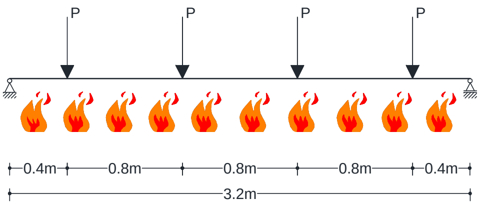
The problem is referred to the evaluation of the thermal and the mechanical behaviour of a simply supported, one way composite slab under fire conditions

- The results are obtained through a finite element model using the non-linear finite element code MSC Marc
- The validity of the numerical results is verified through comparison with experimental results (experimental study by Hamerlinck)
- The comparison of the results is focused on the mid-span deflection and on the temperature distribution of the cross-section of the slab

Description of the problem

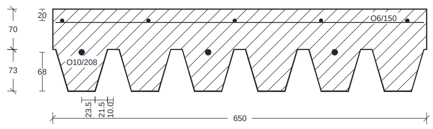
Geometry – Mechanical loading

The structural system



- self-weight of the slabs is 2.7 kN/m^2
- imposed load is equal to 3 kN/m^2
- The loading was applied by four point loads

The cross-section of the slab



- Prins 73 steel sheeting
- t=1mm
- Positive reinforcement: Ø10/208
- Negative reinforcement: Ø6/150
- Concrete depth d=173 mm

Description of the problem

Material properties

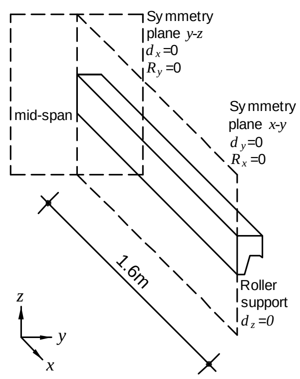
Measured mechanical properties of steel and concrete at room temperature

Steel		
	Yield stress	Ultimate stress
Ø6 (hot-rolled)	552 MPa	598 MPa
Ø10 (cold-worked)	587 MPa	677 MPa
Steel sheeting	306 MPa	384 MPa
Concrete		
	Compressive stress	Tensile stress
C25	33.6 MPa	3.5 MPa

- **In the numerical analysis, all the mechanical and thermal material properties are assumed to be temperature dependent according to EN 19913-1-2 and EN 1994-1-2 for concrete and steel respectively**

The numerical model

Kinematic boundary conditions



- ❖ Due to the fact that the composite slab is formed using continuous profiled sheeting, only a part of the cross-section has to be studied
- ❖ For further simplification only half of the total length of the slab is considered, using the appropriate symmetry boundary conditions

- Fixed displacement $d_y = 0$ and fixed rotation $R_x = 0$ for all the nodes on the $x-z$ symmetry plane.
- Fixed displacement $d_x = 0$ and fixed rotation $R_y = 0$ for all the nodes on the $y-z$ symmetry plane.
- Fixed displacement $d_z = 0$ for the lower edge nodes of the end of the slab corresponding to the roller support.

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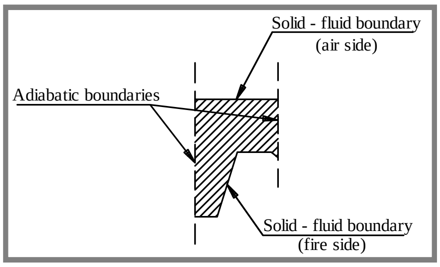
The numerical model

Thermal boundary conditions

- ➢ Along the symmetry boundaries, adiabatic boundary conditions were considered.
- ➢ On the upper side of the composite slab (ambient air side), a solid-fluid boundary condition was considered (convective heat transfer coefficient was assumed to be constant and equal to h_c =4 W/m2K)
- ➢ On the lower side of the composite slab (fire side), solid-fluid boundary conditions were also considered (convective heat transfer coefficient was assumed to be constant and equal to h_c =25 W/m2K)



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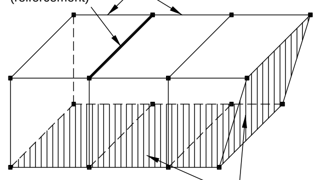
The numerical model

- The steel profile is modeled through four-node shell elements
- Concrete is simulated with three-dimensional solid elements
- Two-node, 3D frame elements are used for modeling the reinforcing bars

Note: The nodes of the shell elements were connected to the corresponding nodes of the 3D-solid elements of concrete



The numerical model

- The numerical model assumes a perfect bond between the steel sheeting and the concrete.

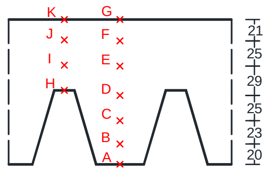
Concerning the possible debonding that has been observed during fire tests it is recalled that the phenomenon is local and it has been observed in composite slabs with steel sheeting of considerable height
Moreover, according to the results that are presented in several experimental studies, the typical failure mode for fire exposed composite slabs is flexural.

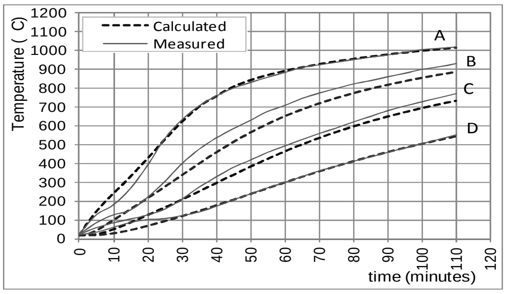
- The longitudinal shear failure that is observed at room temperature does not usually arise in fire tests.

This can be attributed to the fact that the temperature of the steel decking increases rapidly during the fire, its strength is significantly reduced and the tensile forces are undertaken by the reinforcing bars. Therefore, longitudinal shear failure does not seem to be a critical phenomenon during fire exposure and flexural failure is expected.

Validation and Verification of the numerical model

The comparison of the numerical and the experimental results, considering the thermal response shows a good agreement between the measured and calculated values.



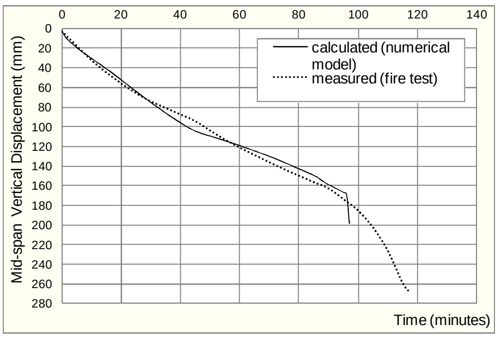


Validation and Verification of the numerical model

Considering the evaluation of the mechanical response of the slab, it is noted a very good agreement between the measured and the calculated deflections until the 97th minute of the fire exposure

After this minute the numerical analysis stops due to numerical problems attributed to the significant cracking of concrete.

In general, it can be concluded that the numerical model represents accurately both the thermal and the mechanical response of the studied composite slab under fire conditions.



Thank you for your attention

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