CERIS Civil Engineering Research and Innovation for Sustainability

Analysis on the continuity effect in composite steel decking concrete slabs in case of fire

Summary

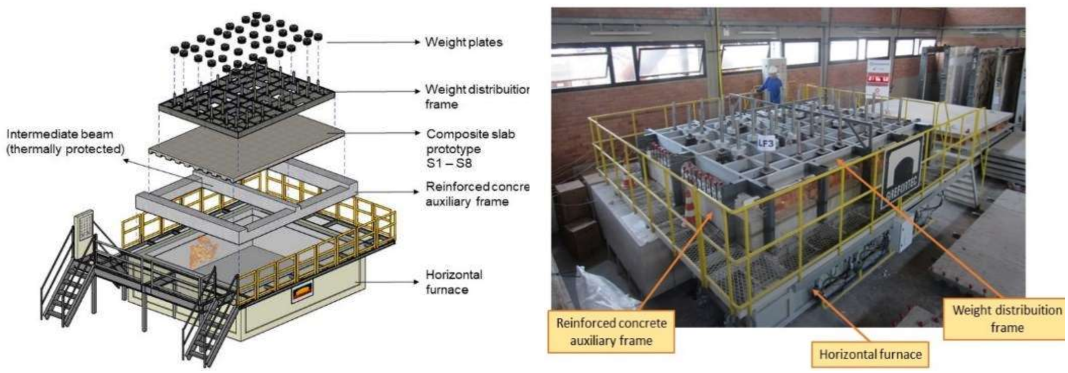
This thesis studied the use of reinforcement on the fire behavior of composite steel decking and concrete slabs. It has been estimated that the replacement of positive (AP) by negative (AN) rebars will optimize their steel consumption, since the steel decking already works as AP and the AN is more thermally protected. The AN also mitigate the sagging moments and the mechanical responsibility of the decking in fire, and also increasing the structural redundancy.

Numerical and experimental analysis of structurally continuous slabs under fire conditions was carried out. The influence of the use of positive (AP) and / or negative (AN) rebars on the fire performance was compared. Numerically, two analysis criteria were used: (C1) constant temperature distribution with increased applied load on the slab over time, and (C2) variable temperature distribution with constant applied load over time. C1 makes it possible to determine the ultimate load capacity of the slab at each temperature and/or time of ISO 834, while C2 its fire resistance rate (FRR). The numerical simulation was solved in Abaqus software.

The experimental research was used in the parametric calibration of the numerical models. 17 full-scale prototypes of composite slabs were built: 9 with dimensions of 886x4600 mm and 8 of 3000x4600 mm, evaluated at normal (five-point bending test) and high temperatures (with horizontal furnace according the ISO 834 curve) with 540 days of age. These prototypes were tested with rigid intermediate support, forming 2 spans of 2300 mm. These tests allowed the calibration of the numerical model with 31 reading points. As a result, the C1 criterion showed thermomechanical responses, while C2 thermo-physical-mechanical. It was clearly noted that the design procedure of EN 1994-1.2 and NBR 14323 is based on C1. However, C1 does not allow to identify the increase in the stress state in the slab due to thermal effects, such as tensile membrane action. C2 showed more realistic results, but it is more complex and time-consuming than C1, as it involves thermo-physical-mechanical parameters and several tests to define the ultimate loading of the slab at each ISO 834 time. From the C1 and C2 perspective, the replacement of AP by AN was not interesting. The slabs with only AP showed the best results. Removing the AP compromised the ultimate moments of resistance for sagging bending, that becoming the weak point of the slab in fire. In this case, the use of AN was unnecessary, becoming underutilized. This is due to the loss of composite behavior in fire conditions, caused by the detachment of the decking before the initial 30 min. C2 also showed that the slabs with AP preserved the tensile membrane action for longer.

Some adjustments are needed in the simplified method of EN 1994-1.2 and NBR 14323, which is based on C1. This motivated the proposal of new formulations, in an attempt to simplify the C2 phenomenons in the fire-resistant moment equations of the standard. A new method has also been proposed for the definition of temperatures in concrete, positive and negative rebars and decking. A new table for the definition of the thermal insulation was presented.

Keywords
Composite steel deck and concrete slabs, fire, numerical analysis, experimental analysis.



(a) Assembly for fire resistance tests *(b) Slab ready for testing*
Figure 1 – Experimental procedure (full-scale tests)

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