Robustness of a typical beam-column concrete structure exposed to fire

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Summary

Concrete structures behave mostly well during a fire, however, in some cases collapse is found before the calculated fire resistance is obtained. This premature collapse during fire can be explained when studying the global structural response, as stresses are induced by restraint actions of the thermal deformations. This paper studies the behaviour of a structure consisting of beam-column connections exposed to the ISO 834 fire by means of the finite element package Diana. It is found that the effects of thermal restraint can be modeled. Internal thermal restraint may cause vertical cracks in the concrete element which do not extend towards the bottom surface of the heated beam. External thermal restraint is found as the gradual development of plastic hinges and the increase of shear forces which first appear well before the fire resistance according to the simplified methods of EN 1992-1-2 is attained. Due to the thermal deformations, cracks may also occur in building elements not directly exposed to the fire.

Keywords: fire; concrete; cracks; collapse; EN1992-1-2; finite element analysis.

1. Introduction

In most cases, concrete structures behave very well during a fire and although they suffer from damage to a certain extent, they mostly show to have a remaining load bearing capacity after fire. Nonetheless, in some cases, concrete structures fail partly or completely due to the event of a fire. The question can then be raised why those structures collapse, as they fail before the fire resistance as found from simplified calculations (e.g. tables, 500°C-isotherm and Zone method) according to EN1992-1-2 is reached.

Recent examples of such premature collapses are found in the underground car park in Gretzenbach (Switzerland) in 2004 [1] due to punching failure and the partial collapse of a hollow core slab in the apartment building Harbour Edge (the Netherlands) in 2007 [2, 3]. Other examples are the total collapse of a warehouse in the port of Ghent (Belgium) in 1974 [4] and the Library in Linköping (Sweden) in 1996 [4], both due to shear failure at the top of the columns.

The mechanism behind these premature collapses is explained at the structural level, namely the influence of restrained thermal deformations at the supports and the interaction with other parts of the structure. The authors have illustrated this concept in [5, 6] with respect to punching shear of underground car parks. From this point of view, the simplified calculation methods of EN1992-1-2 are limited in their capability to assess the fire resistance, as they basically consider the fire resistance of a single element and do neglect indirect thermal actions due to restraints of deformations. On the other hand, the framework and material laws to execute a global structural analysis are stated in the Eurocodes. Nevertheless, due to lack of time and specific knowledge of

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