Numerical and experimental analysis of a novel real-scale test set-up for the analysis of tensile membrane actions in concrete slabs

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Summary

Research with respect to robustness of (concrete) structures gained wide interest due to the partial collapse of some case examples, such as the famous collapse of the apartment building in Ronan Point (UK) in 1968. A very important property of concrete structures with respect to robustness is the rigid connectivity with neighbouring elements. When a hyperstatic concrete slab is excessively loaded or when a certain support is lost due to an accidental event, membrane forces can be activated in order to establish a load transfer to the remaining supports, which can considerably enhance its load-carrying capacity compared to predictions obtained from small deformation theories. Thus, membrane actions can prevent a progressive collapse and increase the robustness of concrete structures.

Finite element methods can simulate the behaviour of concrete plates under these large deformations. Currently, however, different questions remain unsolved in order to properly assess the membrane actions, i.e. the influence of the constitutive laws which are implemented, the modelling of connectivity, fracture mechanical aspects under tensile membrane actions and large displacements, etc. As currently only limited research has been focussing on tensile membrane actions, a novel real-scale test set-up has been developed in order to assess these actions in real-scale concrete plates. The details of this test set-up will be explained and some experimental test results will be discussed. Finally, the results will be compared with numerical FEM analyses and the influence of different model assumptions will be evaluated.

Keywords: concrete, robustness, FEM analysis, membrane actions, real-scale, mechanical testing.

1. Introduction

The reliability of structures is most often associated with the consideration of uncertainties in the structure and load effect. Numerous engineering failures, however, can be assigned to accidental loading effects that are difficult to define and include into the design. Research in the field of robustness of concrete structures emerged as the apartment building at Ronan Point (UK) in 1968 experienced a progressive collapse resulting from a gas explosion (Yi et al. (2008)) [1].

The explicit interest in this research topic slightly decreased in the 1980s and the early 1990s. However, threats of terrorism in several locations and the attacks on the World Trade Centre in New York and the Pentagon in Washington in 2001 triggered a renewed interest.

It has long been acknowledged that membrane forces in reinforced concrete slabs can significantly favour its load carrying capacity (Bailey, 2001) [2]. Previous experimental and theoretical research can be traced back to the early 1920s. Westergaard and Slater (1921) [3] examined membrane behaviour in numerous full-scale tests on floor panels tested until structural collapse.

The design of reinforced concrete slabs is usually based on small deformation theories. Regardless of which design method is used, the deflections and crack width should remain within acceptable limits under service load level. The risk of a structural failure increases in accidental situations, typically accompanied with large deformations. Thus, the investigation of tensile membrane action is of great importance with respect to the robustness of a structure.

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