Catenary behaviour in concrete slabs: Experimental and numerical investigation of the structural behaviour

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Summary

A very important property of concrete structures with regard 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 situation, membrane forces can be activated in order to establish a load transfer to the remaining supports. This favourable effect can considerably enhance the slab's load-carrying capacity compared to predictions obtained from small deformation theories. Thus, membrane actions can prevent or delay a progressive collapse and increase the robustness of concrete structures.

A novel real-scale test set-up has been developed in order to assess the structural behaviour under catenary action in real-scale concrete slabs and the influence of reinforcement curtailment, since in current design practice the main flexural reinforcement is calculated for the slab's critical sections and consequently the reinforcement is curtailed based on the envelope of the acting internal actions. The investigations include the testing of a reinforced concrete slab strip with continuous flexural reinforcement over the entire length and a second test differing only from the reinforcement arrangement, considering current design codes for reinforcement curtailment. The slab specimens were exposed to an artificial failure of the central support and subsequent vertical loading until collapse.

Furthermore, finite element methods allow to simulate the behaviour of concrete slabs under these large deformations. Numerical FEM analysis of the executed real-scale tests will be explained and compared with the experimental results. Finally, the influence of reinforcement curtailment on the overall performance under catenary action will be discussed.

Keywords: concrete, robustness, FEM analysis, membrane action, mechanical testing.

1. Introduction

Calamities such as the collapse of the apartment building at Ronan Point (UK) in 1968 or more recent catastrophes such as the failure of the Alfred P. Murrah Federal Building in Oklahoma City in 1995 or the collapse of the World Trade Centre in New York in 2001 indicated the need to carefully design reinforced concrete structures in order to avoid progressive collapses.

It has long been recognized that the development of membrane action can considerably increase the load-displacement behaviour of concrete structures [1, 2]. Fig. 1 illustrates the response curve of a fully restrained slab under membrane action.

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