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Experimental and Numerical Dynamic Analyses of Hollow Core Concrete Floors

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ABSTRACT

Due to their low self-weight and high strength, precast and prestressed hollow core concrete slabs are widely used in construction. However, the combination of low self-weight and long span implies that the slabs are sensitive to vibrations induced by human activities. In this work, experimental tests and numerical analyses are performed in order to understand the dynamic behaviour of hollow core concrete floors. For the experiments, a test floor of dimension 10 m × 7.2 m and consisting of 6 hollow core elements was built. Very good agreements between experimental and numerical results have been obtained. Comprehensive numerical parametric analyses have been performed in order to determine the optimal value of the material parameters.

1. Introduction

Precast and prestressed hollow core slabs, see Fig. 1, are often used in the construction of floors for high-rise apartments, multi-story buildings, shopping malls, offices or parking garages, in particular in Sweden. In the past years, some research concerning shear behaviour, structural behaviour, thermal performance and fire performance of hollow core concrete slabs has been addressed [1–28]. However, the combination of prestressing and low self-weight due to the voids in the cross-section makes it possible to build long-span floor elements. This implies that the floor is more sensitive to vibrations induced by human activities. These vibrations are usually not a safety problem for the construction but they can induce important comfort problem for people staying in the building. In fact, in many cases, the length of the span is not limited by static strength criteria but by dynamic comfort considerations.

For these reasons it is important to understand in depth the dynamic behaviour of hollow core concrete slabs. Despite this fact, there are no guidelines or recommendations that structural engineers can use to model and study the dynamic behaviour of these structures. Besides, only a few works about this topic can be found in the literature. And most of these works are only numerical studies. In fact, to the authors' knowledge, dynamic experimental tests of hollow core concrete floors in which natural frequencies and associate mode shapes are identified have not been presented in the literature. Natural frequencies of a solid slab and a hollow core slab have been compared by Jendzelovsky and Vrablova [29]. Marcos et al. [30] presented a parametric study on the vibration sensitivity of hollow core slabs. They found that the most important parameter for the first natural frequency is the span. But these two studies were only numerical and the results were not confirmed by experimental investigations. Laboratory tests with three simply supported elements were conducted at Lund Technical University in Sweden and were presented in the Master thesis of Johansson [31]. However, the mode shapes associated to the natural frequencies were not measured and consequently, the dynamic behaviour of the slab cannot be really understood. Field measurements on existing buildings were carried out by Granberg and Häggstam and were presented in their Master thesis [32]. But here also, the mode shapes were not identified. Besides, due to the influence of the surrounding building on the measured accelerations, it is difficult to understand the behaviour of the concrete slab itself.

The purpose of the present work was to perform experimental tests and to use the results to develop a finite element model that can represent the real dynamic behaviour of hollow core concrete floors. For that, an experimental structure consisting on six hollow core elements supported by steel beams were built. The objective was to determine the natural frequencies and corresponding damping coefficients and mode shapes. In that context, it was important to identify not only the lowest natural frequency but also the higher ones. As a matter of fact, the higher modes may have an influence on human induced vibrations and their experimental determination makes it possible to better verify and calibrate the numerical model. In order to achieve that, two kind of

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Fig. 1. Hollow core concrete slabs.

tests were conducted, by exciting the experimental structure with a hammer and with a vibration exciter.

The outline of the paper is as follows: The experimental tests are described in Section 2. The finite element model is presented in Section 3. In Section 4, both experimental and numerical results are presented. Finally conclusions are derived in Section 5.

2. Experimental tests

The experimental structure was built at the production plant of the company Contiga, a leading supplier of precast concrete structures in Sweden. The slab consisted of 6 hollow core elements of dimension 10 m × 1.2 m × 0.27 m each, see Figs. 2 and 3. The connections (joints) between the slabs were poured with grouted concrete. A 50 mm height concrete topping was added on the slab thirty days after the casting of the joints. The strength class of the concrete was C45/55 for the hollow core elements and the joints and C30/37 for the topping.

Fig. 2. Experimental structure.

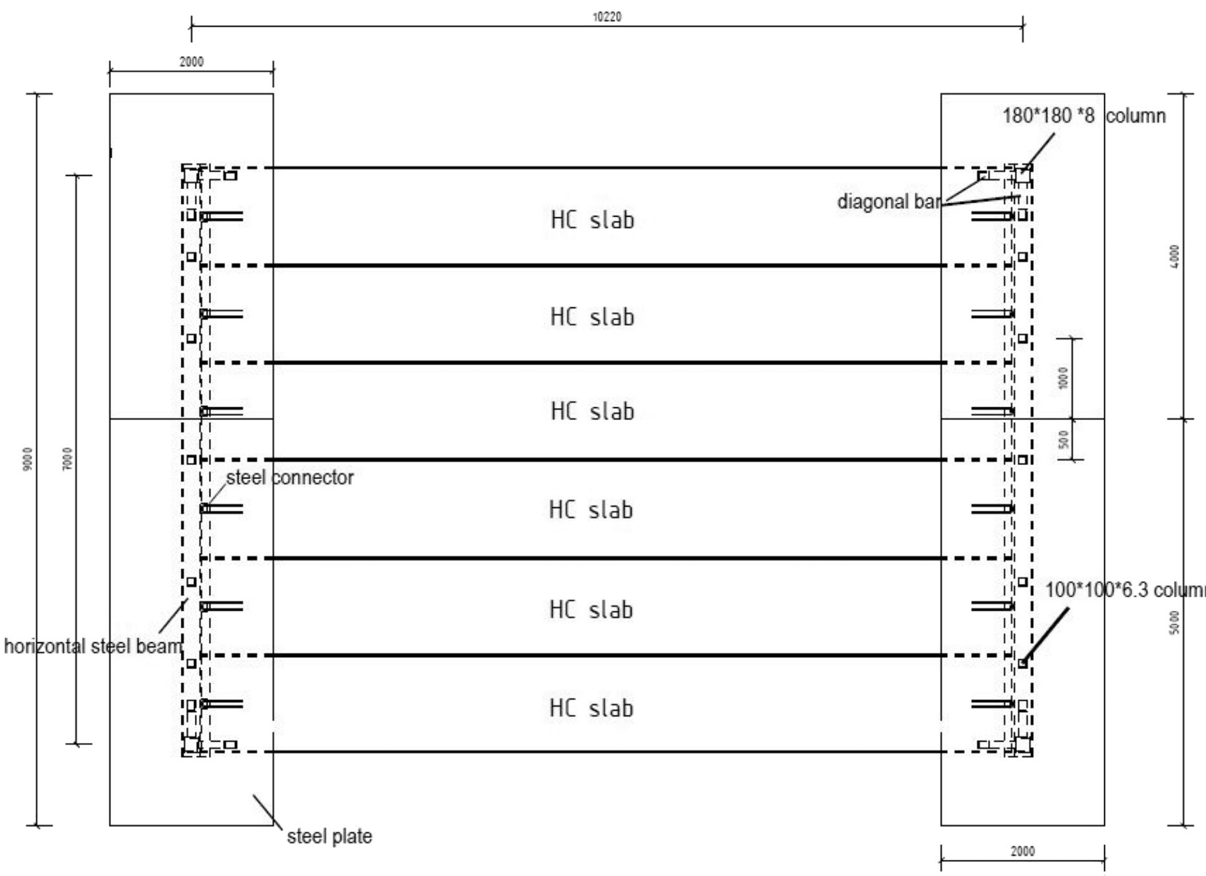

Fig. 3. Experimental structure plan.