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Optimisation of Composite Waffle Slab Structure Design

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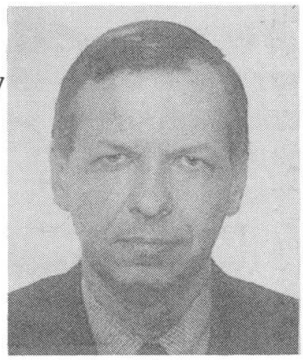

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Summary

The quality of structural design and the resulting quality of the structure's performance depends on the level of knowledge of structural behaviour. The structural behaviour of RC waffle floor slabs and composite waffle slabs has been theoretically analysed and verified in a wide range of experiments. The results of the tests, supported by theoretical conclusions, have confirmed significantly better structural properties of the composite waffle slabs than the assumptions commonly considered in analysis models. Primary theoretical assumptions of high torsional rigidity of waffle slabs have been proven. The ribs of the tested specimens were however not reinforced with shear and torsional reinforcement.

Keywords: reinforced concrete, waffle slab, ceramic fillers, hollow bricks, experiments, torsion, flexure, optimisation, quality design

1. Introduction

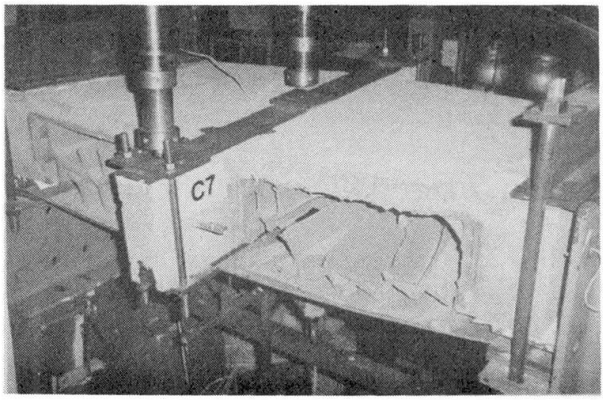
The development of construction technologies should be influenced by the effort to decrease consumption of material and energy sources while increasing the structure's serviceability, durability and reliability throughout its entire expected life. This general need for quality design and the resulting quality of the structure's performance is determined by the level of knowledge of the structural behaviour of the corresponding structure. A complex optimisation of material and energy flows within the whole life of the structure should therefore become a necessary part of the quality design approach.

A better understanding of the structural behaviour of composite waffle structures is the necessary basis for the development of more realistic and precise structural analysis models and for the improvement of code requirements with the general aim to decrease the cost and to increase the serviceability and reliability of the structure i.e. to increase the quality of the design as well as the quality of the final waffle structure performance.

2. Experimental Investigation

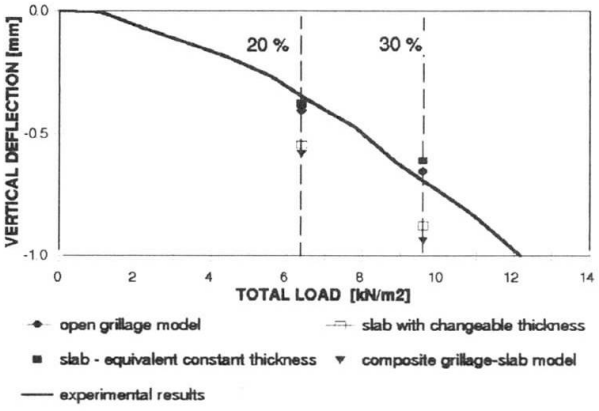
To investigate the structural behaviour of composite waffle slabs exposed to flexural and torsional loads, three types of specimens were tested. Test specimens were subjected to different combinations of flexural and torsional loads. A full scale test on a composite waffle slab with ceramic fillers (size 3.15m x 3.15m) was carried out in 1996. The results of all these tests supported the theoretical assumptions and verified the proposed analysis models.

3. Composite Action of Ceramic and Concrete in the Composite Section



The interaction of fillers with the concrete part of the section is determined by the mechanical properties of the fillers. In the case of brick fillers the ceramic material has a relatively high compression strength while the tensile strength is very low. Moreover, brick ceramic material is brittle. Thus, the interaction of ceramic fillers with concrete can only be considered if any part of the filler is in the pressure zone of the section. The quality of interaction depends on the bond strength between ceramics and concrete. Experiments showed, that the part of the ceramic filler which was in direct contact with the concrete, was in an effective composite action until structural failure of the whole composite structure occurred. The internal parts of hollow brick fillers failed just before the structural failure, usually in the stage when deflections were over the corresponding serviceability limits.

4. Comparison of Analysis Models with Experiments



A composite waffle slab structure can be considered in structural analysis models as an open grid with appropriately substituted properties for the corresponding beam elements or as a slab structure with an equivalent thickness. Four proposed analysis models have been compared with the experiments. The comparison is presented in the graph. Deflections in the centre of the slab are shown for the load steps representing 20% and 30% of the total load when structural collapse occurred during the loading test.

5. Conclusions

1. The results of testing have confirmed high torsional as well as flexural rigidity and ultimate bearing capacity of composite waffle slab structures, even when the ribs were without shear and torsional reinforcement. The composite waffle slab behaves very similarly to the full RC slab with reduced thickness.

2. The significant coupled action of hollow brick elements with concrete has been proven. The ultimate bearing capacity in flexure of a composite waffle slab was approx. 15 to 30% higher than that of an RC waffle slab without fillers. The ultimate bearing capacity in torsion of a composite waffle slab was even approx. 60 to 90% higher.

3. New analysis equivalent models for structural analysis of composite waffle structures have been described and compared with the experimental results. This comparison confirmed the possibility of using the simpler slab model with constant thickness or the grillage model.

4. Optimisation of reinforcement of composite waffle slab structures is possible by using the same principles and corresponding code conditions which are generally used for full RC slabs.

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