Shear capacity of hollow core slabs in Slim-Floor-Constructions

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Summary

A common type of Slim-Floor-Constructions consists of prestressed hollow core slabs supported on the lower flange of transverse shallow steel beams. This construction method enables slender ceilings without girders. However, the shear capacity of the hollow core slabs is considerably reduced due to transverse stresses when the supporting beams with a limited bending stiffness deflect. At the Institute of Structural Concrete at RWTH Aachen University, four full-scale tests on two-span floor systems were performed to investigate the load bearing behavior of hollow core slabs on flexible supports. The effects of several test parameters, such as cross section of the slabs, bending stiffness of the steel beam, bearing details, horizontal constraints of the slabs and filling of selected cores on the shear capacity were determined. International design provisions are briefly described and recommendations regarding the construction and the design are given.

Keywords: shear capacity; hollow core slabs; prestressing; flexible supports; precast concrete.

1. Introduction

Slim-Floor-Constructions consisting of prestressed hollow core slabs supported on the lower flange of transverse shallow steel beams are frequently used in Scandinavia and the Netherlands. After the slabs are set in place, the joints between the slabs and the beam are reinforced and grouted with in-situ concrete to obtain diaphragm action. This construction form features numerous advantages, however, deflections of the supporting beams lead to transverse stresses considerably reducing the shear capacity of the hollow core slabs. A composite action between the beams and the slabs occurs. There are different approaches considering the decrease in shear capacity in the design. At the Institute of Structural Concrete at RWTH Aachen University, the load bearing behavior of four full-scale, two-span floor systems (6 x 10 m²) with shallow steel beams at the middle support was investigated.

2. Load bearing behavior and experimental investigations

Investigations of the hollow core slabs load bearing behavior under different support conditions in Finland revealed that a decrease in shear capacity up to 60 % may occur. Furthermore, longitudinal cracks at the soffit of the slabs due to transverse bending, which can increase the transfer length of the prestressing strands, were observed. Web shear failure of the edge slabs occurred in all tests from literature with single span beams. Since shear deformations are the main impact on the edge slabs (fig. 1) it is indicated that they control the design. However, they cannot solely be explained by the deflection and curvature of the beam because even small deflections of $l/1000$–$l/300$ (with l: beam span) led to a decreased shear capacity. The slabs at midspan of the beam are exposed to transverse bending moments and tension at the soffit and hence there is a risk of longitudinal cracks. Some countries use the Finnish design model to consider the support conditions. Another approach is a general decrease of the utilized shear capacity in combination with structural measures.

https://doi.org/10.2749/222137908796292399

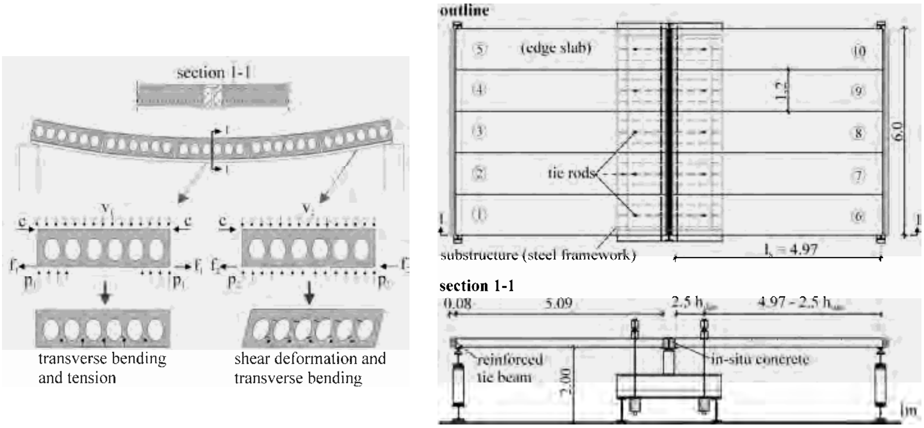
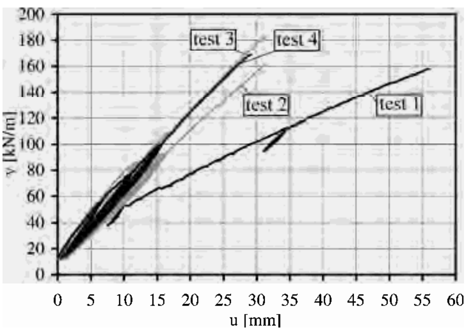


Fig. 1: Stresses of hollow core slabs on a flexible steel beam (left) and test setup to determine the shear strength on flexible supports (right)

Four full-scale tests on floor systems consisting of 10 slabs as well as reference tests of single slabs on rigid supports were performed. The outline and a sectional view of the test setup to investigate web shear failure on flexible supports are illustrated in fig. 1. The slabs were supported on a shallow, so-called Integrated Floor Beam (IFB) in the middle of the two spans. Main test parameters were cross section of the hollow core slabs, bending stiffness of the steel beam, bearing details, horizontal constraints of the slabs and filling of selected hollow cores. A steel frame was arranged over the slabs where failure occurred at first in order to determine the failure load of the remaining slabs in the opposite span under symmetric loading of the IFB in a second test run.



A main parameter of the tests was the influence of the beam deflections on the shear capacity. Fig. 2 illustrates the load-displacement behaviors of the floors until failure of the first slabs. Despite varying maximum deflections at failure from appr. *l*/100–*l*/200 web shear cracking of the edge slabs occurred at comparable shear loads from 158–182 kN/m corresponding to 60–68 % of the shear capacities on rigid supports in all tests. It is indicated that the decrease in shear capacity is not solely attributable to the deflection of the supports. However, great deflections increase the risk of longitudinal cracking of the slabs.

Fig. 2: Load-displacement behavior at midspan of the IFB

Summarizing, for deflections from *l*/100–*l*/200 no effect of the support stiffness on the shear capacity was observed. It is implicated that besides a limitation of the beam deflections further measures are necessary to increase the shear capacity significantly. However, when the deflections are limited appropriately only marginal longitudinal cracking of the inner slabs occurs and the controlling edge slabs are not affected by longitudinal cracks. An in-situ concrete filling of selected hollow cores did not increase the shear capacity, but the resistance against shear deformations may be enhanced. Due to poor bond of the slabs and in-situ concrete no considerable shear transfer of the infill was observed. The slabs shear capacity has to be decreased to ensure a sufficient safety level. Test results indicate that 60–70 % of the capacity on rigid supports can be utilized under appropriate conditions. Composite action of the slabs and the IFB causes transverse stresses and shear deformations of the edge slabs. However, it can be assumed that in addition considerable shear forces are transferred from the inner to the outer slabs over the grouted joints increasing the shear load of the edge slabs.