

Discussion: FE analysis of shear-loaded hollow-core slabs on different supports

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Contribution by J. Sagaseta

In beams supporting hollow-core units on their bottom flange, the initial situation of composite interaction is based on the concrete bond in the grout between the ends of the decking units and the bond perimeter of the beam section. Also the friction on the bearing layer of the bottom flange will take part in picking the connection shears, but the interaction cannot be explained by the friction alone. The system of connections between the decking and the beams is variable in the course of loading and the initial situation of the flexural member may be analysed by employing the general flexural theory of composite members considering full interaction and rigid connections. However, this is valid only to a load level which causes vertical cracks in the grout interface, starting from the supports of the beam and extending towards the section of maximum bending. Above this level, redistribution of longitudinal shear forces will take place and for transferring the compressive force activated by the interaction in the upper hull of the decking units, the webs have to act as 'shear connectors'. The system may still be analysed as a composite beam, but with considerably less efficient interaction: the compressive stress resultant of the concrete flange (i.e. the upper hull of the hollow core unit) in the section of the maximum bending of the beam (section 1–1 in Figure 1 of the paper discussed) has to be balanced by the horizontal shears through the webs of the hollow core units in the length from the maximum bending to the zero bending. This is exactly similar to behaviour in any normal composite beam, but now the webs of the decking units have also to serve as shear connectors.

The paper (Hegger *et al.*, 2010) includes an incorrect idea of the horizontal equilibrium between the compressive stress resultant in the upper hull of the hollow-core units and the connection shear forces in the interface with the beam: the local horizontal connection shear flow (denoted as f in Figure 1 of the paper discussed) is not directly related to the compressive stress resultant (denoted as c), but to its change Δc within length Δx of the beam, that is $f\Delta x = \Delta c$ or $f = \Delta c/\Delta x \rightarrow dc/dx$. The relationship is general and appears in any composite flexural members, independent of the nature of the shear interfaces. The main

importance of this is that for balancing Δc the same shear flow has to first pass through the webs of the hollow core units. Furthermore, the span length of the beam plays an important role in the distribution of the shear flow $f(x)$ along the beam and the horizontal equilibrium between the sections of maximum bending moment and zero bending always requires that

$$c_{\max} = \int f(x)dx$$

Furthermore, from the general behaviour of composite flexural members it is known that the interaction efficiency will increase when the span length of the member increases. This is equally true in members with ductile and non-ductile shear connections.

Authors' reply

The authors agree with the comments on the general interaction behaviour in a composite beam and also on the non-linear (load-dependent) interaction between hollow cores slabs and the supporting beam. However, they consider that their main conclusions in the paper discussed may have been misunderstood.

The friction model applied in the numerical investigations does not represent the friction between the soffit of the slabs and the beam flange alone, but rather accounts for the remaining interaction mechanisms at the ultimate limit state. Since these mechanisms concentrate at the slabs soffit and in the lower part of the slabs face side owing to the cracking of the grout between the beam and the slabs, the finite-element modelling as described in the paper was considered to be an acceptable simplification.

The comments on the shear flow in a composite beam and the horizontal equilibrium between the sections of maximum bending moment and zero bending are true for elastic composite beams and those with ductile shear connections. However, the authors observed extensive cracking of the grouted joints along the beam and between the single slabs in own full-scale tests at the ultimate limit state. Considering that the neighbouring slabs are equally

loaded and no shear stresses but only horizontal compressive stresses are transferred between the upper slab flanges over the longitudinal joints between them, the comments on the composite behaviour do not apply fully any more.

In recent works the authors derived a design model to determine the shear resistance of hollow core slabs on flexible supports. This model is based on the general approach, which is described in the paper discussed. The model and its approach will be further described in a following publication in the near future. It

reproduces the shear resistance of 21 tests appropriately, whereas among other influence parameters also the effect of the beam span is represented appropriately.

REFERENCE

Hegger J, Roggendorf T and Teworte F (2010) FE analyses of shear-loaded hollow-core slabs on different supports. *Magazine of Concrete Research* **62(8)**: 531–541, <http://dx.doi.org/10.1680/macr.2010.62.8.531>.