German Committee for Steel Construction Reports from Steel

Forschungsvereinigung Stahlanwendung e. V.

Issue 2020/4

Engineering model for calculating the shear capacity of steel composite steel floor panels in building construction with practice-relevant reinforcement AiF No.: 19801N

Summary of the research project AiF No.: 19801N

The design of composite floors is regulated in DIN EN 1994-1-1. However, for the shear force design of composite steel floor panels, reference is made to the model for non-shear reinforced concrete cross-sections in DIN EN 1992-1-1, since no independent model for composite steel floor panels was available until recently. The model from DIN EN 1992-1-1 is a semi-empirical design model based on the comb and tooth models and was developed through the evaluation of an extensive database. However, the specific load-bearing and bonding behavior of composite floors is not taken into account in this model. Furthermore, there is no reference to the special geometry of the composite sheets and no consideration of the sheets' own shear capacity. A safety deficit has also already been identified for composite steel floor panels made of lightweight concrete. Based on the previous statements, Hartmeyer developed a mechanical design model for the shear capacity of composite steel floor panels that are longitudinally reinforced exclusively by the composite sheet. The model is equally valid for composite steel floor panels made of light-weight concrete and normal concrete, but the focus of the investigations was on lightweight composite steel floor panels. In practice, composite floors are always constructed with additional concrete steel reinforcement. However, the loadincreasing effect of the concrete steel reinforcement cannot be taken into account in the current model for composite steel floor panels. Therefore, there was still a need for research to describe the shear capacity of composite steel floor panels with combined longitudinal reinforcement and to develop a safe and cost-efficient design method. The shear failure of composite steel floor panels with additional concrete steel reinforcement is coupled with the flexural capacity of the slabs and is often not decisive in reality, which makes the design of shear tests considerably more difficult. Therefore, tests were developed on composite steel floor panels with high-strength concrete steel reinforcement, in which shear failure could be observed. In the tests, flexural cracking was initially observed. One of the flexural cracks developed into a flexural shear crack, which propagated into the compression zone. In contrast to the known failure process in shear failure of concrete components, however, this was a stable crack growth. As soon as the shear crack reached

Editor: German Committee for Steel Construction DASt e.V. | Managing Director: Gregor Machura
Sohnstraße 65, D-40237 Düsseldorf | Tel. (0211) 54012-094 or (0211) 54012-080
For further inquiries, please contact: forschungsmanagement@dast.deutscherstahlbau.de

the compression zone, a system change occurred and two compression struts appeared. One compression strut rested on the composite sheet in the shear crack and the second compression strut ran directly into the support. In the further course of the test, the load could be increased considerably after the formation of the shear crack. Longitudinal cracking in the direction of the support was observed. Continuous strain measurement using a sensor fiber later demonstrated that the shear force transmitted across the shear crack is transferred back into the concrete via tensile stresses. For the shear force behavior of composite steel floor panels with additional concrete steel reinforcement, the classical bending theory is not valid assuming that the cross-sections remain flat. Rather, it is a load transfer in the sense of the archtension band model or the truss structure. Figure 1 shows the crack pattern when the ultimate load is reached, both on the surface and inside a test specimen. Based on the experimental observations described above, a mechanically based design model for composite steel floor panels made of normal weight concrete was developed, which additively considers four load-bearing components: the shear capacity of the uncracked compression zone, the load-bearing component of the cracking process zone and the mixed dowel action of sheet and reinforcing steel establishes equilibrium in the crack. In addition, the vertical portion of the direct compression strut in the support is taken into account in terms of system load-bearing capacity. In the developed model, the shear force capacity is directly related to the bending stress of the component. When performing a verification method in a given design section next to the support, the shear force capacity of the plate can also be taken into account. In many models, the shear capacity is determined as a pure cross-sectional load-bearing capacity, which, however, should be viewed critically. On the one hand, shear and normal stresses cannot be considered independently of each other and, on the other hand, the acting bending moment directly determines the input variables for determining the shear force capacity. These include, for example, the height of the compression zone or the utilization of the reinforcing steel. A separate consideration of bending and shear load-bearing capacity is therefore not realistic. The model developed in this work to describe the shear force behavior can also take into account the different bond behavior of profiled sheet and reinforcing steel. The different bond properties resulting from the sheet geometries are also taken into account, meaning that the model provides very good agreement with the test results for both undercut and open profiled sheet geometries. In summary, it can be said that the result of this work makes it possible for the first time to mechanically describe the shear capacity of composite steel floor panels using a combination of composite sheet and reinforcing steel reinforcement. Compared to previous Eurocode design models, this allows for a significant increase in load-bearing capacity, which brings an economic advantage for composite steel floor panels. In the course of the current revision of the Eurocodes, the

Editor: German Committee for Steel Construction DASt e.V. | Managing Director: Gregor Machura
Sohnstraße 65, D-40237 Düsseldorf | Tel. (0211) 54012-094 or (0211) 54012-080
For further inquiries, please contact: forschungsmanagement@dast.deutscherstahlbau.de

developed model has already been included in the draft of DIN EN 1994-1-1. For this purpose, the engineering model was simplified to provide a design method that is applicable in practice, sufficiently safe and economical. Due to the difficulty of generating shear failure in tests on composite steel floor panels, the test specimens were designed with a high degree of longitudinal reinforcement and high slab heights. In this work, these effects of component height and reinforcement ratio were recorded and taken into account in the design model.

The research project was financially supported by the German Federation of Industrial Research Associations „Otto von Guericke“ e. V. (AiF), Cologne, within the framework of the Program for the Promotion of Collective Industrial Research (ICR) by the Federal Ministry for Economic Affairs and Energy based on a resolution of the German Bundestag. We thank them for this support. We would also like to thank our project partners ArcelorMittal Construction Deutschland GmbH, Montana AG, Reppel BV and Tata Steel UK Limited for supplying the composite sheets free of charge. Special thanks also go to the Composite Construction Working Committee of bauforumstahl as the project support committee.

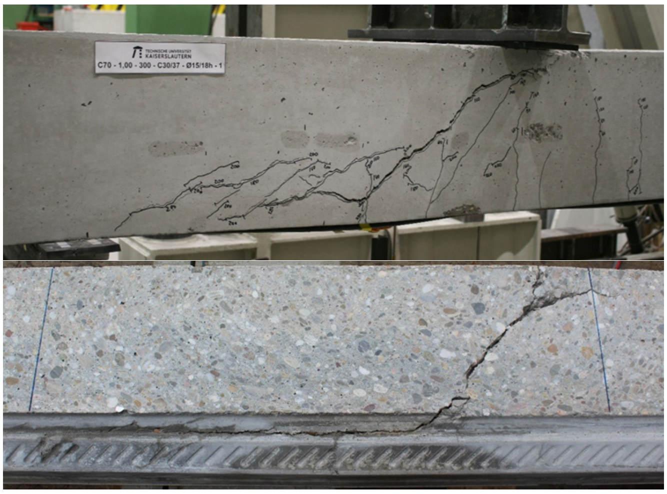

Image 1: Decisive shear crack formation on the component surface and inside a test specimen.

INDUSTRIELLE GEMEINSCHAFTSFORSCHUNG

Forschungsnetzwerk Mittelstand

Gefördert durch:

Bundesministerium für Wirtschaft und Energie

aufgrund eines Beschlusses des Deutschen Bundestages

Editor: German Committee for Steel Construction DASt e.V. | Managing Director: Gregor Machura
Sohnstraße 65, D-40237 Düsseldorf | Tel. (0211) 54012-094 or (0211) 54012-080
For further inquiries, please contact: forschungsmanagement@dast.deutscherstahlbau.de