Zukunft Bau

Abstract

Titel

Investigations of the load bearing behavior und load bearing capacity of filigree composite beams with large web openings

Introduction

Composite beams made of a slender steel web and a high strength concrete slab, which are connected with a puzzle bar, are well suited to build hybrid roof structures or ceilings.

Openings weaken the web and they are changing the local structural behaviour significantly. The influence of these openings on the load bearing behaviour and the deformation behaviour has not yet been examined sufficiently.

Aim of the research project

The research project includes both, experimental tests and numerical studies. The experimental tests were divided into small- and large scale tests (Fig. 1). The small scale test bodies were performed to determine the load bearing of the puzzle bars. The aim of the research project is to provide a reliable design concept for structural engineers.

The project was divided into several work steps.

First, the composite beams were preliminarily designed with the FEA package Ansys Workbench (V.14). The steel web and the concrete slab were modelled with solid elements.

The first four large scale test bodies W00 to W03 should fail by pulling out the puzzle bar at ÖR2, the area where the shear force has to be transmitted from the steel web into the concrete slab (Fig. 2).

With a concrete slab width of 70 cm a common rafter spacing was chosen. For the preliminary design, the push-pull-interaction (“anchor characteristic”) for the puzzle bar was derived of another research project which was accomplished at the TU Kaiserslautern.

To test the FEA model, known large scale tests without web openings were calculated. The calculations showed a good accordance to the experimental tests. Afterward the model was used to carry out a parameter study.

A square web opening was chosen for the first tests, W00 and W01. The opening was arranged in the middle of the web. The load was raised till the axial force at ÖR2 was large enough to pull the puzzle bar out of the concrete. The axial force was calculated by integrating the axial force in the area of ÖR2. Subsequently the calculated and the experimental pull out force were compared. After completion of W00 and W01 the next test bodies, W02 and W03 were designed.

To determine the bearable axial and shear force of the puzzle bars and to derive an interaction between both, five push-out tests (Fig. 3), three pull-out tests and nine combined push-pull test (Fig. 4) were performed. At the innovative push-pull test, shear and axial force in three different ratios were loaded. The result is, that there is no huge influence of the load bearing.

In a next step, four composite beams were designed and the tests accomplished. After evaluation the results (Fig. 5), the last two composite beams were designed and tested.

The design concept envisages that the total shear force is first divided in the opening area into the top and the bottom of the composite beam, based on the stiffness ratio. Then the shear force is split at the top part to the concrete slab and the rest of the web, again based on the stiffness ratio. The result is the force which has to be transmitted from the web to the concrete slab.

The experiments and the Finite Element Analysis showed that the transition took place over a very short length. In this range, there are only about two puzzles. Consequently, the force has to be limited to the bearable load of two puzzles. The transferable force can be calculated backwards from the small scale tests.

A punching at the other opening edge did not occur under the test condition. For the here tested geometry of the puzzle and the location in the concrete the limit state will not be reached. However, the crack width on the upper side of the concrete slab at the ÖR1 had the largest size. This can reduce the bearable shear force with respect to the service limit state. The calculation presented here is only valid for the used geometry and material.

Finally, an economic analysis was performed.

Conclusion

The task which was accomplished in the course of the project was to develop a calculation for the opening area. The calculations were attempted with the large scale tests. An extension to other parameter constellations will be done in further work at the institute.

The load bearing capacity of the puzzle bars was determined for the tested parameters (Fig. 6). Because the bearing capacity is depending on the various parameters it is recommended to test it for other conditions with small scale tests again.

Overall an economic analysis proved that the here presented system is competitive enough compared to conventional systems e.g. glue wooden truss.

Figures:

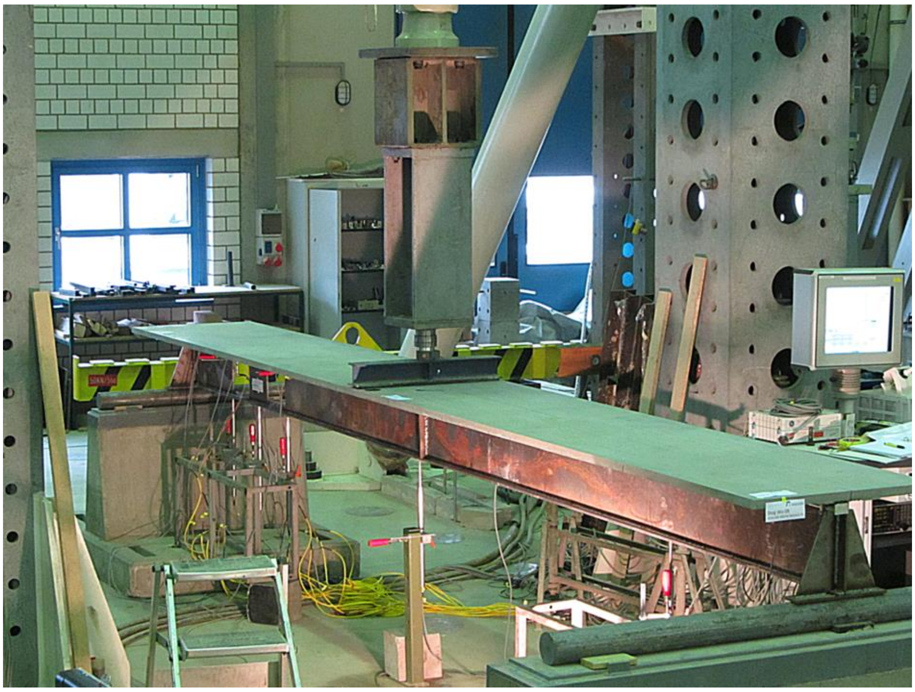

Figure 1: Bild1.jpg

Experimental setup of specimen W08

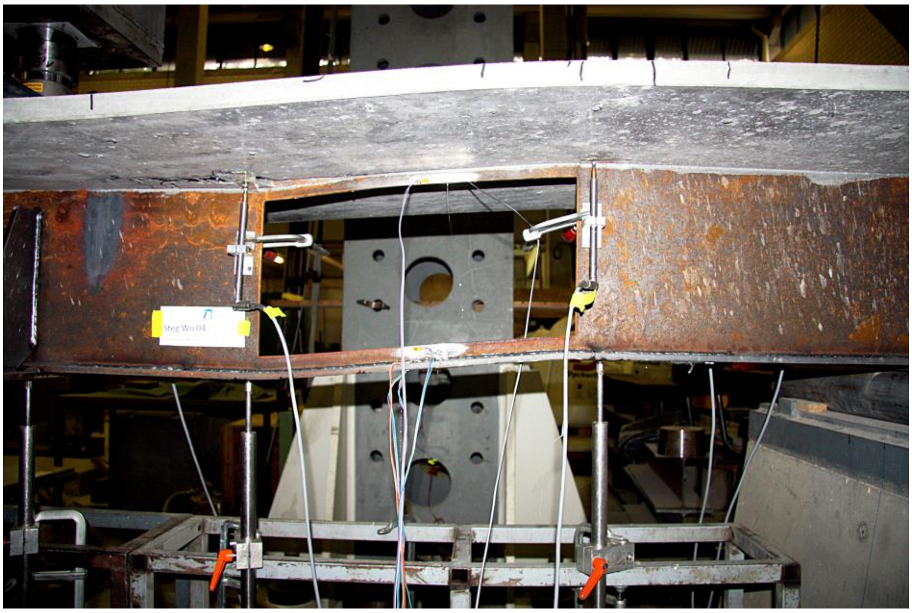

Figure 2: Bild2.jpg

Seriously deformed web opening of specimen W04 just before reaching the ultimate load.

The Puzzle bar has been pulled out of the concrete together with a concrete cone at the left side of the opening.

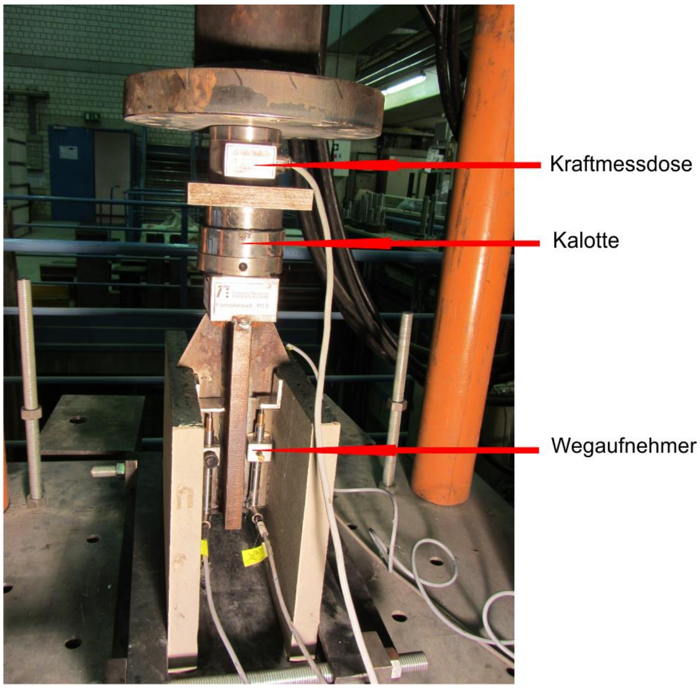

Figure 3: Bild3.jpg

Experimental setup of the Push-Out tests (small scale test)

Figure 4: Bild4.jpg

Experimental setup of the Push-Pull tests (small scale test)

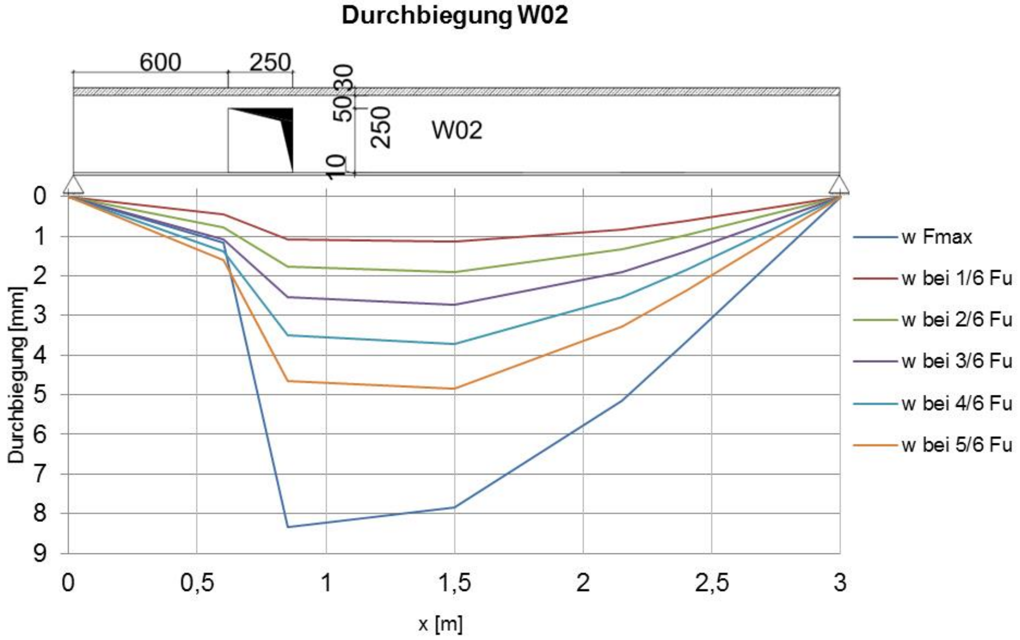

Figure 5: Bild5.jpg

Deflexion curve of specimen W02 under various load steps.

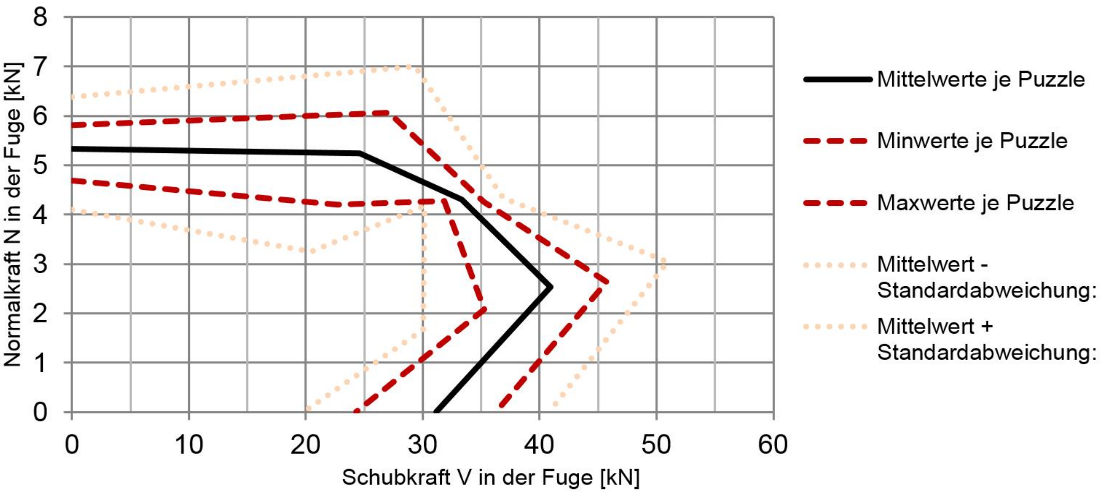

Figure 6: Bild6.jpg

Tension-longitudinal shear-interaction curve derived from the he push-pull tests (per each puzzle)