# Load capacity and deformation behaviour of headed studs used in trapezoidal steel sheetings

**Ulrike Kuhlmann**
Professor Dr.-Ing.
Universität Stuttgart
Stuttgart,Germany

*u.kuhlmann@ke.uni-stuttgart.de*

**Matthias Konrad**
Dipl.-Ing.
Universität Stuttgart
Stuttgart,Germany

*matthias.konrad @ke.uni-stuttgart.de*

## Summary

So far design rules for headed studs in trapezoidal sheetings are purely based on experiments and do not take into account any specific failure mode. Recent research results point out the necessity to consider in more depth not only load capacity but also deformation behaviour. Within a currently ongoing project funded by DIBt, these questions are checked with a special view at the position of the stud in the rib and in case of two studs in the rib at the position to each other. The aim of the project is to clarify, if the safety level is sufficient with regard to the ductile behaviour and the load capacity. This paper summarises recent research results and presents the current status of this project.

**Keywords:** Headed studs, composite beams, trapezoidal steel sheeting,

## 1. Introduction

According to most of the codes the design load capacity of headed studs in composite beams with profiled steel sheeting transversely to the supporting beam is determined by multiplying the shear resistance of headed studs in solid slabs of composite beams with a reduction factor k. This does not consider the observed different failure modes in comparison to studs in solid slabs and the real deformation behaviour. So the question arises whether headed studs in trapezoidal steel sheeting might possibly fail brittle and at a lower resistance as predicted by the design rules. Further, the observed influence of the position of the headed stud in the trough is not taken into account. This paper presents the current status of design rules concerning headed studs in composite slabs with steel sheetings and summarises recent research results. Further, first results of a currently ongoing research project at the Institute of Structural Design, Universität Stuttgart funded by Deutsches Institut für Bautechnik (DIBt) are given.

## 2. Assessment of the presented models and Eurocode 4

The comparison of nearly 80 test results (load capacity $P_t$) mainly found in Hintergrundbericht EC4[6] with the presented models shows that the approach of Lungershausen gives mostly lower load capacities in the cases of one stud in mid-position (cf. Fig. 1). The same behaviour can be determined for two studs in the trough in mid position parallel to each other (cf. Fig. 2). In contrast to Lungershausen, the load capacity $P_e$ determined by the model of Johnson and DIN EN 1994-1-1[4], respectively the reduction factor k of [4] and of the model of Johnson multiplied with the mean load capacity for studs in solid slabs given in Hintergrundbericht EC4[6], overestimates the capacity of the connection in some cases. However, it should be considered that the boundary conditions/ application boundaries of the model of Johnson and of the design equation in DIN EN 1994-1-1[4] have not been checked in this consideration such as the shank diameter or the anchored

https://doi.org/10.2749/222137908796292443

depth in the concrete topping.

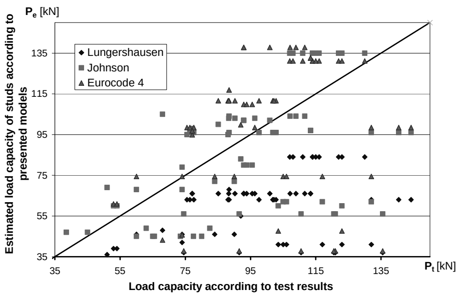


*Fig. 4: Assessment of the presented models in case of one stud in the trough in mid-position*

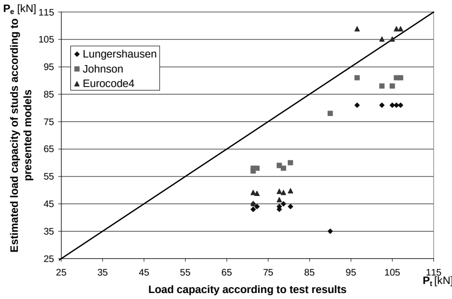


*Fig. 5: Assessment of the presented models in case of two studs parallel in the trough in mid-position*

The comparison of the presented models and design approaches with test results for studs in favourable and unfavourable shows similar behaviour.

## 3. Own test programme and first results

The analysis of the existing test results and models showed that there is obviously an influence of the position of the stud in the trough which is not reflected by the models or by the approach in DIN EN 1994-1-1[4]. Preliminary own FE calculations have confirmed this observed behaviour. Further, it may be noted that the load capacity of a stud in case of two studs in the trough in favourable position is nearly 50% higher than in unfavourable position and the deformation behaviour is more rigid in comparison to studs in unfavourable position in the considered case. Also, it has to be noted that the tests given in literature are mainly focused on the load capacity and not on the possible brittle concrete failure due to the position of the stud and the geometry of the used profiled sheeting. As a result of this fact, the 17 new push-outs tests have been planned with a main focus on the influence of the stud position considering steel sheetings which are applicable according to DIN EN 1994-1-1[4] and the anchoring depth of the stud in the concrete topping. The aim of these tests is to develop and evaluate a FE model considering the different failure modes of studs in a trough. So, the calculated plastic strain may be a good indicator for the occurring concrete failure as rib-punch failure. This approach is possible due to the used plasticity-based damage model for concrete with a smeared cracking approach. Furthermore, there is a tendency to use sheetings with higher ribs in composite beams which are not within the application range of DIN EN 1994-1-1[4]. So, a new analytic model considering the real load deformation behaviour and the real failure modes is crucial for this process

## 4. Summary and Outlook

On one hand, it has been shown that the existing models overestimate the load capacity in some cases. On the other hand, existing models that refer to the failure load estimate the load capacity very low which is unsatisfying in view of cost-effectiveness. Within the frame of the ongoing research project 17 new push-out tests have been planned with the focus on the load capacity and possible brittle concrete failure. The tests will be realised in spring 2008 so that first results may be presented during the conference.