Carrying capacity of a headed stud using trapezoidal profile sheeting

Origin: Previous examinations have shown that the rules in DIN 18800-5 to determine the carrying capacity of a headed stud give insufficient results when trapezoidal metal sheeting are used spanning transversally to the beam. So, the equation in order to determine the reduction factor considers neither different failure mechanisms of the headed studs with trapezoidal sheeting compared with the solid slab nore sufficiently the main influence parameters: Anchorage depth, profile sheeting geometry, position of the headed stud in the trough. Furthermore, it was shown that the assumption of a ductile behaviour of the connection device may be incorrect despite of compliance with the geometric condition given in the code. Former investigations have already pointed out on this fact and proposed models or reduction factors considering the different failure mechanisms and thus should enable a more precise and secure prognosis on the carrying capacity and the deformation behaviour of the headed studs. However, these models have not been expanded into the current standards until today. Based on own push-out test, the quality of existing models and the rule according to DIN 18800-5 should be assessed.

Investigations: The main focus for the 17 push-out test was set on the determination of the influence of the headed stud's position in the trough on the one hand, and on the influence of the headed stud's anchoring depth in the concrete topping. The profile sheeting used were spanned transversely to the load direction and all lay in the standard's range of application. The profiles used were ThyssenKrupp T85.1, Cofrastra 70/183 and Holorib 51/150 profiles, respectively. In the first test group (6 specimens, T85.1) the main focus was put on the influence of the position of 2 headed studs in the trough as well as on the influence of the lower reinforcement on the carrying capacity and ductility of the connection. In the second test group (6 test specimen Cofrastra 70/183) the influence of the anchoring depth of a headed stud into the concrete topping considering the headed stud's position in the trough. In the last test group (5 specimens, HR51/150) the main focus was on the influence of the re-entrant profile sheeting on the carrying capacity of the headed stud. For this, the anchoring depth of the headed stud as well as its position in the trough and the number of headed studs was varied. Subsequently, the test results were compared with the rules according to the standard, including the construction rules to insure the ductile behaviour as well as with existing models from literature.

Results: In summary, it may be recorded as a result that only 3 out of 17 tests achieved the carrying capacity expected according to DIN 18800-5 or exceeded it, respectively. Interestingly, these 3 tests were not within the application range allowed for the determination of the reduction ratio k. Mainly tests with headed studs in an unfavourable position did not reach the carrying capacity calculated according to the standard. At the same time specimen with headed studs in a favourable position also scarcely fell below the calculated carrying capacity. Thus, the normative claim on a alternating positioning of the headed studs in case a central positioning is not possible, has to be discussed. Furthermore, it was shown for 10 test specimen that the headed stud connection according to DIN 18800-5, Element 924 could be classified as ductile, in spite of falling below the calculated carrying capacity, even though the geometric conditions according to element 926 were only partially observed.

In addition, none of the presented existing verification models showed a significantly improved conformance with the test results. So all models showed at average the best correlation for headed studs in favourable position or mid-position, respectively, while for headed studs in unfavourable position the carrying capacity was either strongly overestimated, see the model according to Johnson and Yuan, or resulted at average in to small calculated carrying capacities (see model according to Jenisch). Likewise, it is remarkable that all models reached the best correlation for the open profiles of the ThyssenKrupp range, although this profile is close to the upper margin of the application range according to DIN 18800-5 ($h_p < 85$mm). Furthermore, it was observed that the models using for a reduction ratio for the application of headed studs in a solid slab have the largest differences with headed studs in an unfavourable position. Considering security aspects, i.e. no overestimation of the carrying capacity, the models according to Roik/ Lungershausen, Jenisch and Ernst would be definitively applicable, however, partially high reserve carrying capacities would be unused in this case.