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Loadbearing behavior of headed stud anchors in profile sheets with high ribs under fire exposure. | ICR No.: 01IF21403N

Summary of the research project ICR No.: 01IF21403N

Composite steel floor panels, consisting of profiled steel sheets and a concrete belt, represent a modern and efficient method of composite construction. The use of profiled sheets, which are preferably stretched between the secondary girders of the composite structure, is characteristic of this construction method. If composite action is to be achieved using headed stud anchors, the geometry of the composite steel floor panel has a decisive influence on the loadbearing behavior of the headed stud anchors. The loadbearing behavior of headed studs in profiled sheets at room temperature has been extensively investigated in numerous research projects in recent years, leading to the development of new design approaches in EN 199411:2024 E. However, it is still unclear how these new design approaches can be applied in the context of a fire resistance design according to EN 199412:2024 E. Furthermore, the question arises whether the existing design approaches in EN 199412 are also applicable to modern profiled sheet geometries or whether they require fundamental adaptation due to possibly changed heating behavior. EN 199411 offers the possibility of designing steel composite girders in partial composite construction, which significantly increases the economic potential of composite construction. However, the requirement formulated in EN 199412 to take into account the change in longitudinal shear forces due to heating of the composite crosssection effectively limits the application of this method for fire resistance design. The ICR research project N19105 has already shown that the fire resistance design of steel composite girders in partial composite with solid concrete slabs is generally unproblematic if the minimum degree of doweling according to EN 199411 is observed. However, it has not yet been clarified whether this finding can also be applied to steel composite girders with profiled sheets. The aim of this research project was to assess the loadbearing behavior of headed stud anchors under fire exposure in modern profiled sheet geometries that fall within the scope of the new design approaches of EN 199411:2024 E. On the basis of the investigations carried out, proposals should be developed to extend the new design approaches to fire resistance design according to EN 199412. In addition, the loadbearing behavior of steel composite girders with profiled sheets in case of fire should be investigated in order to be able to

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derive wellfounded statements on the applicability of the partial composite theory in case of fire. The findings are summarized below.

The loadbearing capacity of shear studs in vertically arranged profiled sheets was investigated at both room temperature and elevated temperatures, varying the type of profiled sheet and the positioning of the shear studs. A total of 21 pushout tests were carried out both at room temperature and under fire exposure according to the standard temperaturetime curve. The results show that the failure mode in the pushout tests changes with increasing temperature. While concretedominated failure occurs at low temperatures, shearing of the headed studs occurs as the component temperature increases (see Figure 1). The transition zone between these failure modes is characterized by a combined failure, in which both concrete breakouts at the bolt base and the formation of plastic hinges occur. It was found that concrete damage at the bolt base increases with increasing load level. The temperature measurements have shown that the geometry of the profiled sheet has no direct influence on the heating behavior of the headed studs, since the heat input occurs mainly via the welded connection to the steel girder. However, in the case of profiled sheets with deep corrugations, the reduced coverage of the steel girder top flange by the concrete flange leads to a heating behavior that resembles a foursided flame exposure. This leads to accelerated heating of the headed stud, whose temperature can still be estimated at 80% of the flange temperature. The position of the headed stud within the profiled sheet bead also has only a negligible influence on its heating behavior. The results of our own experimental investigations confirmed a good agreement between the design approaches developed in the project and the loadbearing capacities achieved in the fire tests. In particular, the more accurate prediction of the failure mode compared to EN 199412:2010 underlines the suitability of the presented method.

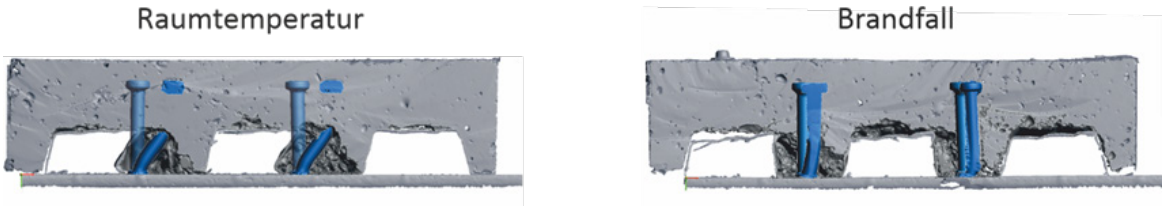

Image 1: 3D scans of pushout specimens before and after testing

The second research question addressed the nonlinear loadbearing and deformation behavior of steel composite girders under fire exposure. For this purpose, fire tests were carried out and evaluated on steel composite girders with a low degree of doweling (see Figure 2). These experimental results were complemented by numerical calcula-

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tions, followed by a comprehensive parameter study. The resulting database enabled a detailed analysis of the influences of all relevant configuration parameters. The results confirmed findings from N19105 that, in case of fire, slip effects develop in different directions due to the inhomogeneous temperature distribution in the composite crosssection. These effects lead to a temporal change in the longitudinal shear forces and deformations of the composite joint compared to the situation at room temperature. The findings from the investigations carried out indicate that the partial composite theory can also be consistently applied in the event of fire for conventional steel composite girders in building construction with profiled sheets arranged perpendicular to the girder axis, provided that the minimum degree of doweling is observed.

EN 199412:2024 E permits the application of partial anchoring for steel composite girders designed according to the simplified design method of Level 2 of Annexes B and C. The findings obtained during fire tests on steel composite girders show that this verification method is also suitable for very low levels of dowelling. It enables a good estimation of the fire resistance duration and thus expands the possibilities for the design of steel composite girders in the event of fire.

Image 2: Conducting fire tests on steel composite girders at the iBMB (Institute for Building Materials, Solid Construction, and Fire Protection) in Braunschweig

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