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Issue 2 2023
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Advantages with careful planning – Shear connector welding through galvanized profiled sheet

Shear connector welding through galvanized profiled sheet has been practised in composite reinforced concrete construction for decades and offers a number of advantages. This article presents the various construction methods and welding techniques, examines the different influencing variables and describes an application example at Keflavik airport in Iceland.

Stud welding is admittedly a marginal sector among joining processes by welding. However, stud welding connections can be found in many products. In virtually all cases, welded studs serve to provide force transmission to considerably larger components. Studs are not only fastening devices, but also welding additives. "Small" studs are welded onto "large" vehicles, ships, industrial furnaces, bridges, parking garages, machines and appliances, etc. Studs come in numerous different shapes, round studs from about 3 to about 25 mm in diameter, as well as rectangular studs and wire formed parts. The choice of stud shapes outside the welding cross-section is (almost) unlimited, but rotationally symmetric cross-sections are easiest to process.

The model most frequently used in building construction is the "shear connector", a round pin with an upset head. It serves to provide positive-locking force transmission between the steel component, a girder or a mounting part, and the concrete into which the stud is embedded. The type of structural design, in which shear connectors are primarily subjected to shear load, for example on a bending girder, is known as composite reinforced concrete construction. Here the steel girder and concrete slab function together as a single unit, because the shear connector prevents the relative movements between steel and concrete under load. One advantage of this construction method are slender, wide-span girders with few support pillars.

Various construction methods

An elegant method to provide the formwork required for concreting is the use of profiled metal sheets. In a composite ceiling, they can replace the lower reinforcement layer, may be applied statically and simultaneously serve as a working platform (Fig. 1). The profiled sheet and the shear connectors are on one level, and the question is in which order the studs and the sheets are mounted. The two methods in common use are the following:

- The shear connectors are welded onto the girders in a production plant, the profiled sheets are laid only between two girders according to the span width, so that the row of shear connectors remains free. Each sheet functions only as a single-span load carrier without any direct connection to the shear connectors. This is the traditional construction method in Germany.

Fig. 1 • Steel structure with laid-on profiled sheets.

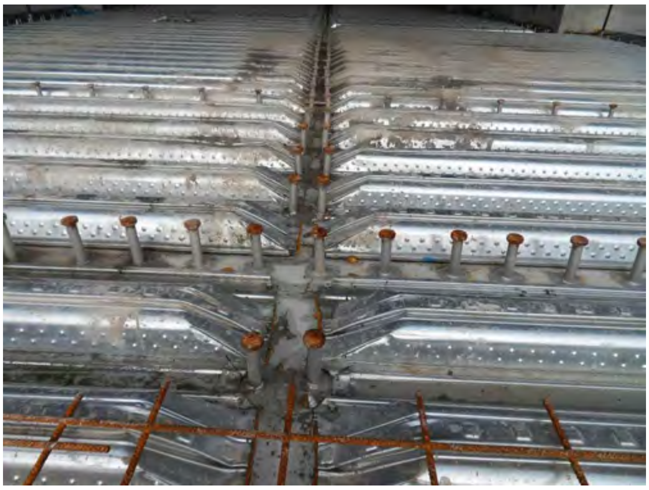

Fig. 2 • The openings of the profiled sheets have been closed by pressing them down.

Fig. 3 • The entire cover area is without openings if laid with care.

- The profiled sheets are laid over several spans (continuity effect), the shear connectors are welded on the building site. The weld connects the girder, profiled sheet and shear connector with each other by an inextricable bond. The longer the sheet, the fewer openings need to be closed prior to concreting. This method is preferred by Anglo-Saxon bureaus of architecture; it can be found in the United Kingdom as well as on many building sites in the Near and Middle East.

With both methods, the openings of the profiled sheets must be closed prior to concreting, either by pressing down the opening (Fig. 2) or by plugging it with a foam fitting. Here of course, method number 2 has the edge, since there are fewer openings to be closed. With well-fitting joints, openings are limited to the ends of the concrete slab. (Fig. 3).

Adapted welding technology

Especially when looking at welding technology, some advantages and drawbacks of both methods become obvious. Profiled sheets come with a zinc coating of about 20 µm on both sides. Zinc always presents some problems in welding, because it already evaporates at 906°C, that is, well below the melting point of steel. The stud welding process is completed after less than 2 s, so that excessive formation of pores cannot be excluded. The executing company must counteract this with appropriately adapted welding technology.

According to EN ISO 14555 [1], the qualification of the welding procedure specification (WPS) also includes welding through galvanized profiled sheets ("through deck stud welding technology"). When this standard was established under German leadership on the basis of a national predecessor standard (DIN 8563 T. 10), as a European standard to begin with, the aim was for it to replace conflicting national standards. In Germany, there were no specific regulations for through deck stud welding technology, so that possibly the new European standard EN ISO 14555 would not have been accepted in Britain, because it would have been inadequate to replace the national regulations in force there. In fact, the British qualification differed significantly from those in Germany and in France (where a national standard for stud welding also existed). While on the continent it was common practice to qualify a welding process just once at the executing company, which included visual examination, bend tests, macro section and radiographic testing, and in France surface crack testing (PT) after cutting off the stud as well, the main focus in the UK lay on building site conditions. According to the information supplied by the British members of the working group to establish the standard, the qualification there was invariably granted for only one specific project, because the profiled sheet, its zinc coating, the welding power source, the cable lengths, etc., were expected to be different in each case. Ten studs are welded, and these are subjected to a visual examination and a bend test (bending angle 30°) – but no macro section, no radiographic testing. Taking the necessary test samples for this purpose would actually be almost impossible. However, the production monitoring authority then stipulates a ring test on all studs in addition to the visual examination. This ring test, also regulated under the EN ISO 14555 standard, has occasionally triggered head shaking, but sometimes it is also prescribed for direct welds,

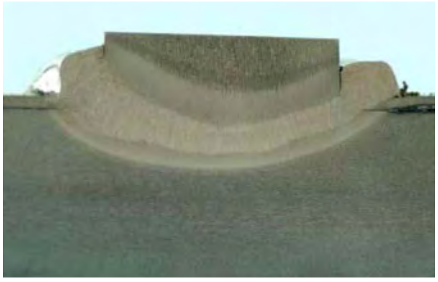

Fig. 4 • Faultless stud weld through galvanized sheet.

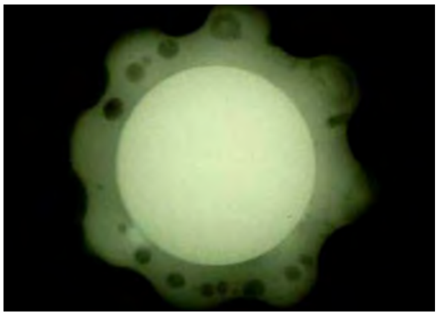

Fig. 5 • Weld zone of a through-welded stud without irregularities; according to the valid standard without consideration of the weld collar area.

Fig. 6 • Attempted weld through a profiled sheet on a coated upper flange.

Fig. 7 • The taped area remains without coating.

Fig. 8 • The coating on the upper flange must be removed, a thin layer of rust is harmless.

Fig. 9 • Faulty welds near a gap between sheet and girder.

Fig. 10 • Drilling out the sheet for direct welding on the girder.

Fig. 11 • Ceramic ferrule for direct welding on the left and for through-deck stud welding on the right.

not "through deck stud welds", which, however, is not intended according to the standard. In ring tests, the welded studs are tapped with a hammer (please refer to the standard for details) with the effect of being slightly deformed. If the weld zone contains too many irregularities, the energy of the hammer blow is partly absorbed by internal cracking, thus producing a dull sound. If the sound is bright and clear, the weld zone is considered to be faultless. An important point: when the stud is tapped with too little energy, it will produce a clear sound with faulty welds, too. For this reason, the standard requires adequate experience on the part of the testing staff. This test method is also expressly designed for use only on buildings under predominantly static load.

In a study conducted by SLV Munich [2], it has been proved that it is basically possible to weld successfully through galvanized profiled sheets. Fig. 4 shows an example of a macro section and Fig. 5 a radiographic picture of a through-welded stud.

Fig. 12 • Favourable design of the node area for seismic stress absorption.

Which influencing variables must be taken into account?

Why are there two variants, and why is each of them concentrated on certain countries? Well, apart from a certain amount of inertia among planners (people do what they have learnt to do), established trade practices and technical regulations also play a part.

Coatings

The author remembers a convention, where one of the speakers reported that his major steel construction company had successfully welded studs through profiled sheets in Germany until about 1975. But then a very large number of faulty welds had suddenly been detected in a project. The cause was soon found: in combination with the zinc coating, the coating on the upper flange of the girder prevented good results. In Germany, every steel component is usually given at least a primer coating before it arrives on the building site. Unfortunately, this is why through welding technology is hardly practised in Germany to this day. Here we can recognize a basic prerequisite for successful through welding technology, namely an uncoated upper flange. Only a few types of shop primer coatings can be regarded as weldable. In Britain, girders are delivered to building sites with a rolling skin or slightly rusted: here the fire protection layer required in buildings is sprayed concrete, which adheres even more effectively to a layer of rust.

We can safely conclude that the decision “for or against through welding” must be made at the planning stage. On the building site, hardly any changes are possible except and only with high extra costs. In Fig. 6 we can see the result of an attempt to weld through a profiled sheet plus coating.

What can we do when coating of steel construction components is mandatory? There are two alternatives:

- Tape the centre part of the upper flange prior to coating: if possible, apply the coating only to the edge of the upper flange, as we can never know how accurately the centre of the beam will be hit during welding (Fig. 7).
- Grind the upper flange prior to laying the sheet; a thin layer of rust is harmless (Fig. 8).

Direct contact between profiled sheet and upper flange

Perhaps this sounds trivial, for why should the sheet not lie directly on the girder? With small sheets, this presents no problem, but when sheets have been laid under tension and fastened with set nails, bulges may have formed which cannot be smoothed out even by the weight of an adult person. Height tolerances when spanning several beams may also cause hollow spaces under the sheet, especially on pillars. What are the consequences?

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The arc would penetrate the sheet extremely fast, the weld pool would drop onto the beam and no longer be protected by the ceramic ferrule still lying on top of the sheet (Fig. 9). The only remedy here is to drill out the sheet to the diameter of the ceramic ferrule (Fig. 10).

Moisture

Welding and moisture are incompatible with each other, yet through deck stud welding almost always takes place on building sites and on the top layer of the sheets just laid. This dependence on the weather is probably the main reason why shop welding is given preference. Rainwater can only slowly run off from flat surfaces; where necessary, a leaf blower is used to remove it. The presence of water at a welding point invariably causes ignition failure, the pilot arc breaks up. Moisture on the upper flange after the sheets were laid while it was raining is extremely inconvenient since it can run off only very slowly.

Overlapping

Two layers of sheet can never be penetrated reliably. It is therefore absolutely necessary for the laying team to lay the sheets on butt.

Welding equipment and welding parameters

In most cases, size 19 shear connectors are used in through welding. Such welds are carried out with about 1,400 A, 1,500 ms and a lift of about 5.5 mm – that is, with considerably less welding current, but instead a much longer welding time and a longer arc than in direct welding. It is well known that the requirements for expertise on the part of staff members become more and more stringent with increasing stud diameters, which is why size 22 shear connectors are seldom used in through welding, simply in order to minimize possible sources of error, yet in Germany, size 22 shear connectors are given preference in composite construction., in Anglo-Saxon areas, people are often satisfied with size 19, but the span widths are also kept lower there.

At any rate, it is necessary to use larger ceramic ferrules with larger degassing vents and more clearance, simply in order to let zinc vapor escape as quickly as possible. On the left in Fig. 11, a ceramic ferrule for direct welding is shown, on the right a ferrule for through deck stud welding. Both ceramic ferrules are standardized under EN ISO 13918 [3]. Further details can be found in the DVS manual “Stud welding”, chapter 15.1.3 [4].

Fig. 13 • Faultlessly through-deck welded studs (Pictures: SLV Munich (4, 5), Trillmich)

A practical example: Keflavik airport

From the end of August to mid-December in 2022, about 25,000 shear connectors measuring 19 mm × 125 mm were welded through 1.25 mm thick Superholorib SHR 51/600 galvanized profiled sheets for an extension building at Keflavik airport in Iceland. Iceland is a seismically active area, therefore the supporting steel structure including the profiled sheets was designed for maximum possible deformability. Particularly noteworthy are the extremely rigid nodes on the support beams and the inserted upper and lower flanges (Fig. 12). Another advantage is the continuity effect of the profiled sheets spanning more than 12 m.

The welding equipment consisted of a Bolte Pro-I 2800 power source with a GD 25 welding gun. The following welding parameters were selected: welding current 1,390 A, welding time 1,425 ms, lift 5.5 to 6 mm, protrusion about 6 mm. With tight-fitting sheet, the welds were faultless (Fig. 13), as soon as this was not the case, the sheet had to be either hammered down or drilled out. The time schedule was fully met.

Advantages with careful planning

Welding through profiled sheets has been practised for decades and with careful planning offers a number of advantages. The trade operations of steel structure assembly, metal sheet laying, shear connector welding, laying of the reinforcement and concreting must be reliably coordinated within the time schedule. Welding on a building site may be impossible in adverse weather conditions, and thus affects subsequent operations.

Shop welding of shear connectors is less complicated in terms of execution and monitoring. No attention needs to be paid to bad weather, nor to coatings, which are then applied only after shear connector welding. The single-span profiled sheets, however, make more work during laying and preparation for concreting. Moreover, the continuity effect offered by long sheets must be dispensed with.

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