

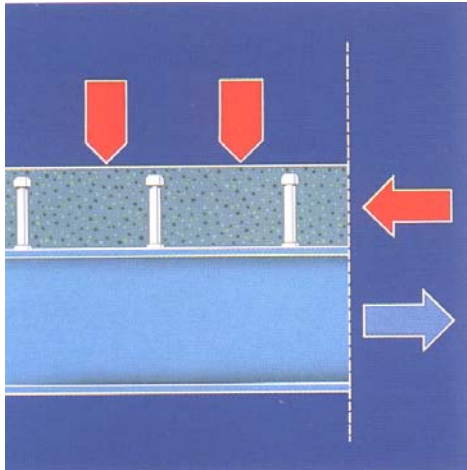


Composite Construction with KÖCO- Stud Welding Technology

IMPRESSIVE TECHNOLOGY

Composite Construction with KÖCO Stud Welding Technology

What is composite construction?



An outstanding feature of efficient, innovative structures is very often an ideal combination of various different building materials. The favourable combination of steel, with its high tensile strength and ductility, and concrete, with its high compressive strength and good resistance to corrosion, has long been recognized in structural concrete construction. With the method of composite construction it is now possible to combine the positive features of steel construction and structural concrete, without having to accept the drawbacks. This means that a steel skeleton structure is combined with concrete parts so that a joint bearing effect is created. The steel beams bear the tensile forces, while the concrete bears the compressive forces and provides fire protection.

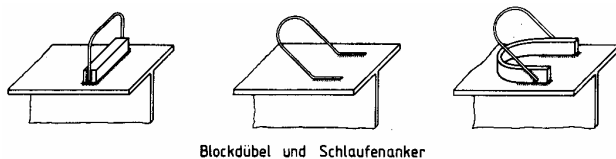
Figure 1: Principle of composite beam (schematic diagram)

Obvious advantages of composite construction with steel and concrete:

| |
|---|
| High loading capacity at low construction heights (important for building construction) |
| For bridges with spans ranging from abt. 40 to 80 m often the most cost-effective solution |
| Wide spans possible, thus allowing large areas free of columns (important e.g. for multi-storey car parks) |
| High ductility of the structure, favourable in case of seismic stress |
| Simplicity of alteration to installations through clamping connections fitted to the steel beams |
| Good fire protection through encased steel beams or beams with concrete cores |
| Quick assembly similar to 100 % steel construction; the steel skeleton serves as a working platform |
| Easy to dismantle, steel and concrete are easy to separate |
| Secure connection between steel and concrete with the help of tested and certified welded-on shear connectors |

Means of connection

In composite structures, the connection between steel and concrete must be resistant to shearing stress, so that a composite effect is achieved, resulting in composite action. At the beginning of composite construction, block dowels and loop anchors were used. Additional anchorage was always required to absorb the lifting-off forces. The main drawback of these means of connection is the insufficient ductility, which can lead to a brittle failure in the composite joint. The production and welding-on of these parts is also very costly. The use of cold-forged shear connectors in the sixties led to the introduction of composite construction on a large scale.



Blockdübel und Schlaufenanker

Figure 2: Obsolete means of connection (Block anchor and loop anchors)

Some important advantages of shear connectors in construction

| |
|---|
| cost-effective production in large quantities and many different sizes |
| reliable and safe under static and dynamic stress |
| Mechanical interlock of steel and concrete, lifting-off of concrete slabs is prevented |
| high ductility, considerable increase in bearing capacity through plastic design |
| anchorage of steel parts in concrete for various load directions, no cracking forces because of mechanical interlock |
| individual design of reinforcement by pre-planned positioning of steel members in concrete |
| firm welds produced by stud welding, with negligible steel deformation |
| processing by trained operators, no highly qualified welders required |
| electronically controlled and monitored stud welding equipment ensures repeatability and verifiable quality of the weld |
| internationally recognized regulations create a high degree of safety |

Typical applications for shear connectors in construction

In building construction the composite construction method has firmly established itself in the market. The advantage of quick assembly independent of the weather cuts costs because the building becomes available for use at an earlier date. The large column-free areas permit more flexible use and increased floor space.



Figure 3: Wide spans with composite beams in building construction



Figure 4: Stud welding in the mass production of composite beams



Figure 5: Joint between two ceiling slabs in a multi-storey car park, before pouring the mortar

Beams for multi-storey car parks are already bent to the required shape and fitted with shear connectors in the factory (figure 4), so that, following assembly, only the joint must be filled with special mortar. Steel loops encased in concrete fit smoothly around the shear connectors.

Flexible use

When erected in composite construction, industrial and administrative buildings are also very flexible in use, because non-bearing walls can be shifted quickly. Cables and conduits can be attached to the steel beams with clamp connections, on trapezoid zinc-coated sheets serving as permanent shuttering the dove-tailed grooves offer an ideal hanging facility.

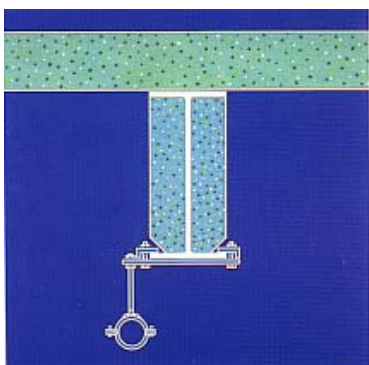


Figure 6: Suspension on the bottom flange



Figure 7: Attachments to the grooves of trapezoid sheets

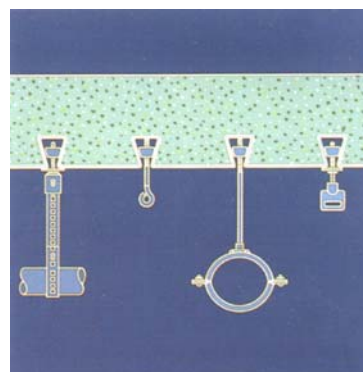


Figure 8: Various examples of installations

Fire Protection

Beams and columns encased in concrete or with concrete cores are advantageous for buildings with a high fire risk. The concrete permits only slow heat transfer to the stem, which thus maintains almost full bearing capacity for a long time.

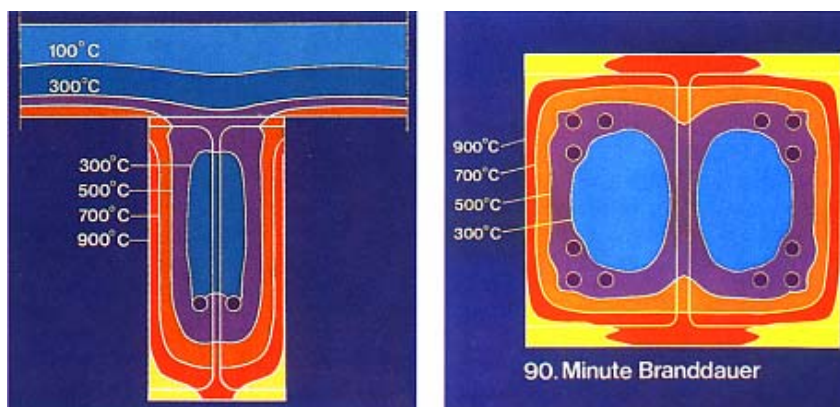


Figure 9: The effect of heat generated by fire on a composite beam

Slender and rigid columns

Rigidity and fire safety of columns in multi-storey buildings are enhanced by the insertion of steel or concrete cores, for example where shear connectors anchor a steel profile in a concrete casing. A steel pipe surrounding a concrete core holds the concrete in place and has the same effect as strong reinforcement of the concrete with steel bars.

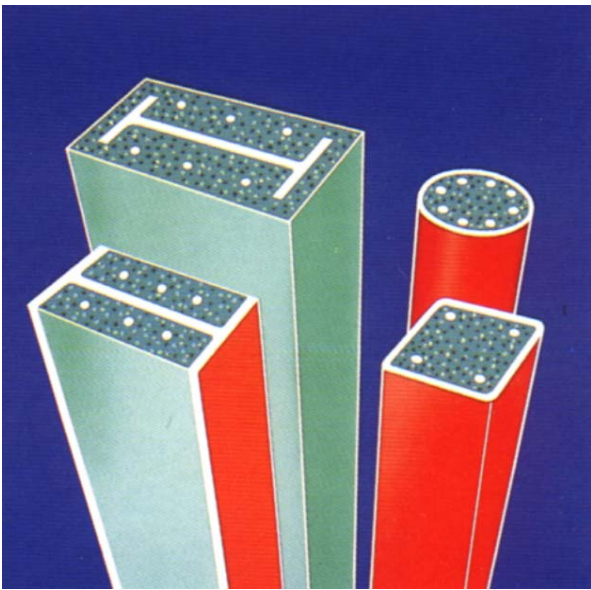


Figure 10: Various types of composite columns



Figure 12: Composite bridge "Wilde Gera" (bottom flange as steel trough)

Composite bridges

Composite bridges are over-hanging structures which would be unthinkable without shear connectors. On long bridges there are often several tens of thousands of studs, affording a lasting connection between the supporting steel structure and concrete slabs.

In so-called double-composite structures the lower flange also has a composite cross-section.



Figure 11: End of a composite bridge



Figure 13: Composite bridge made of I-beams during assembly

KÖCO shear connectors in structural concrete (CE-conform)

Anchor plates set in concrete with welded-on KÖCO shear connectors are ideally suited for joining steel or wooden structures to reinforced concrete elements. The great advantage of anchor plates with shear connectors set in concrete is their ability to keep extremely high loads safely anchored in the concrete, even in areas subjected to tensile stress.

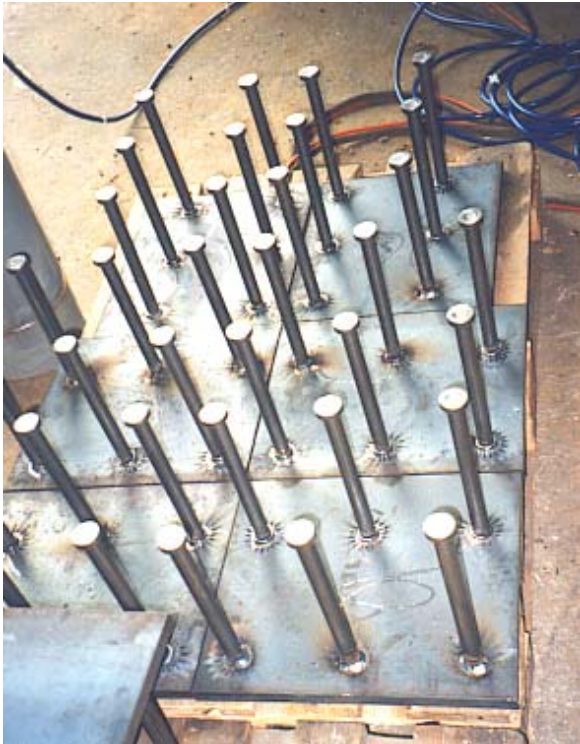
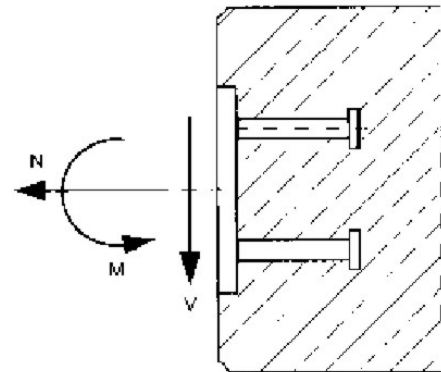
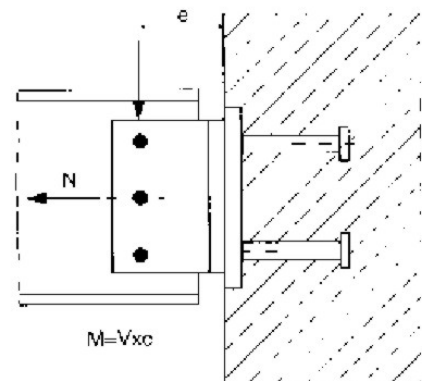


Figure 14: Anchor plates with welded-on KÖCO shear connectors in production



Load on an anchor plate



Steel beam joined to an anchor plate set in concrete

Figure 15: Schematic diagram showing the load transferred by an anchor plate

KÖCO shear connectors are approved according to European Technical Approval ETA-03/0039 for use on anchor plates. Their CE-conformity has been demonstrated.

To prove the load-bearing capacity of steel elements connected to concrete we offer the calculating software StudCalc, free of charge (www.koeco.net → Download → Software-Download). This programme enables the user to quickly and accurately measure the bearing capacity of various anchor plates, concrete elements and loads.

As a means of rough orientation, the load-bearing capacities of commonly-used anchor plates with welded-on KÖCO shear connectors are listed in the chart below.

The permissible loads have been calculated without consideration of any lateral influences or possible transverse or longitudinal reinforcement. In rectangular plates (not squares) the lateral force has been calculated for the longer side. The maximum permissible tensile and lateral stresses shall not be applied simultaneously for the same element. The chart is intended as a rough guide for a first assessment; a precise calculation should be carried out with StudCalc.

All values are given without warranty. The responsibility for compliance with technical regulations always rests with the constructing engineer.

| Load bearing capacity of steel plates with KÖCO shear connectors set in concrete (in KN) | | | | | | | | | | |
|---|----------------------------|------------------------|--------|--------|--------|--------|--------|--------|--------|--------|
| Anchor plate type/ dimensions | Plate thickness (mm) | Shear Conne- tor | C20/25 | | C30/37 | | C40/50 | | C50/60 | |
| | | | Nzul | Vzul | Nzul | Vzul | Nzul | Vzul | Nzul | Vzul |
| 1/100x100 | 10 | 10/75 | 14,8 | 10,9* | 19,5* | 10,9* | 19,5* | 10,9* | 19,5* | 10,9* |
| | | 13/100 | 24,6 | 18,2* | 30,2* | 18,2* | 32,8* | 18,2* | 32,8* | 18,2* |
| 2/200x100 | 10 | 10/75 | 27,1 | 21,7* | 33,0 | 21,7* | 38,3 | 21,7* | 39,1 | 21,7* |
| | | 13/100 | 35,9 | 36,5* | 43,7 | 36,5* | 50,8 | 36,5* | 55,7 | 36,5* |
| 3/300x150 | 10 | 10/75 | 33,6 | 32,5* | 40,9 | 32,5* | 47,6 | 32,5* | 52,1 | 32,5* |
| | | 13/100 | 43,3 | 54,8* | 52,7 | 54,8* | 61,3 | 54,8* | 67,2 | 54,8* |
| | 15 | 16/150 | 65,5 | 84,4* | 79,7 | 84,4* | 92,6 | 84,4* | 101,5 | 84,4* |
| 4/200x200 | 15 | 13/100 | 52,0 | 73,0* | 63,3 | 73,0* | 73,6 | 73,0* | 80,6 | 73,0* |
| 4/250x250 | 20 | 16/150 | 86,2 | 112,5* | 104,8 | 112,5* | 121,9 | 112,5* | 133,5 | 112,5* |
| 5/300x200 | 20 | 13/100 | 69,2 | 109,6* | 84,1 | 109,6* | 97,8 | 109,6* | 107,2 | 109,6* |
| | | 16/150 | 92,5 | 168,8* | 112,5 | 168,8* | 130,8 | 168,8* | 143,3 | 168,8* |
| 6/300x300 | 20 | 13/100 | 75,6 | 151,3 | 92,0 | 164,4* | 107,0 | 164,4* | 117,2 | 164,4* |
| | | 16/150 | 99,2 | 198,4 | 120,7 | 241,4 | 140,3 | 253,3* | 153,7 | 253,3* |
| | | 22/175 | 111,1 | 222,2 | 135,1 | 270,3 | 157,1 | 314,2 | 172,1 | 344,2 |

Nzul (tensile and compression stress) and Vzyl (Shear stress) are the permissible loads according to official approval, calculated with StudCalc (Beta). The centre distance for groups of studs has been chosen so that the minimum edge distance is 25 mm from the edge of the steel plate. Dimensioning of the plate thickness must be carried out separately, e. g. by using StudCalc and taking into account the connexion profile.*

* Steel failure is decisive, higher utilization is possible with increased stud diameter.

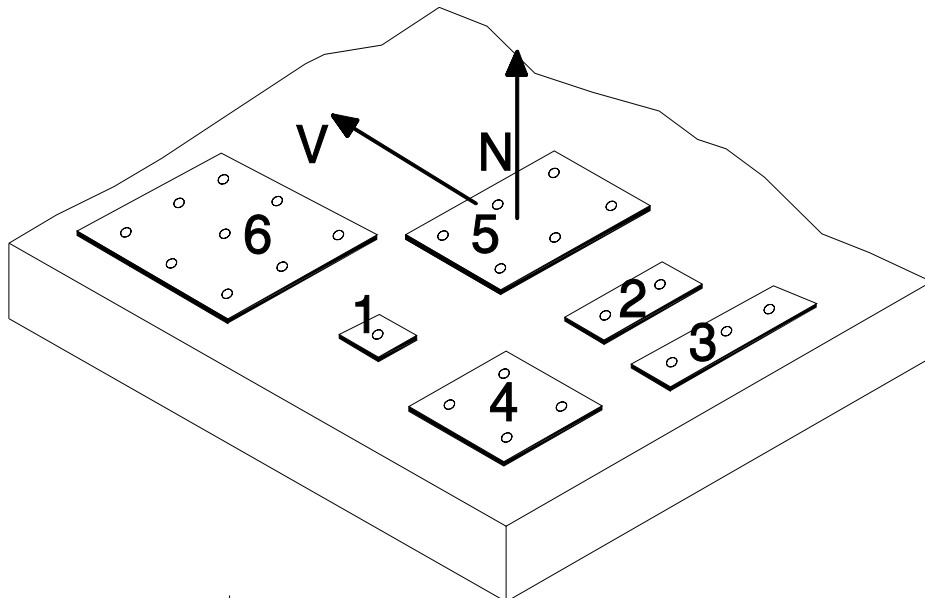
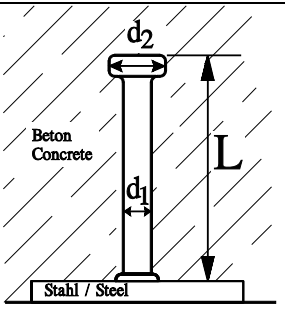


Figure 16: Types of anchor plates approved by the building authorities

KÖCO as a supplier in composite construction

KÖCO has taken an active part in the development of composite construction from the very beginning. As early as in the mid-sixties, KÖCO was already producing millions of shear connectors and also welding them on. Shear connectors are manufactured on multistage presses, forging the head and end face in several cold-forging steps. In comparison with hot-forging, this increases the strength and the yield point; however, the doubly killed steel with a low carbon content, which is specially suited for this purpose, still has sufficient ultimate elongation of at least 15%. Cold forging provides high precision in dimensions as well as a clean surface, which in turn ensures the good contact required for stud welding.

Dimensions of shear connectors (All measurements are given in mm.)

| Stud diameter d_1 | Head diameter d_2 | Min. length L_{\min} | Max. length L_{\max} |  |
|---------------------|---------------------|------------------------|------------------------|---|
| 10 | 19 | 50 | 200 | |
| 13 | 25 | 50 | 400 | |
| 16 | 32 | 50 | 525 | |
| 19 | 32 | 75 | 525 | |
| 22 | 35 | 75 | 525 | |
| 25 | 40 | 75 | 525 | |

Shear connectors are almost exclusively welded on by drawn arc stud welding (No. 783 according to ISO 4063). By this process, a drawn arc with high current melts the end of the stud and the work-piece surface below it within a very short time. The strength of the current applied – up to 2500 A – must be calculated in relation to the stud diameter. At the end of welding time, the stud is driven by a spring to plunge into the melt, and the current is cut off. The resulting connection over the whole surface has a strength exceeding that of the materials in both the stud and the work-piece.

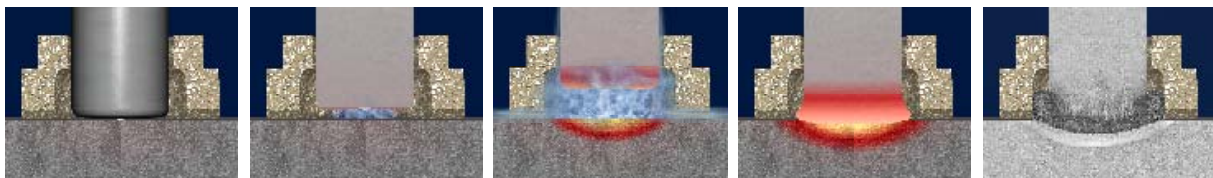


Figure 17: Drawn arc stud welding with a ceramic ferrule shielding the welding pool

Cost-effective welding of shear connectors in large quantities within a short period of time places high demands on welding equipment. The following features make KÖCO equipment first choice for any stud welding tasks:

1. Electronic control of current during welding, which means that the most important parameter is kept stable regardless of mains voltage fluctuations or heating up of the power source;
2. Ignition of the arc via a pilot current with simultaneous testing for sufficient electric conductivity;
3. Hot plunging of the stud into the welding pool, to prevent lack of fusion in the weld;
4. Welding cable diameters of up to 120 mm² allow greater distances between power source and operator, with a low level of heat generation;
5. Digital settings for electric and mechanical parameters provide security for the operator;
6. Settings for different conditions can be stored permanently and recalled at the push of a button.
7. In case of any malfunctions, KÖCO power sources can diagnose the cause and thus contribute to having the malfunction quickly remedied;
8. Manufacturing in accordance with all relevant standards (CE)



Figure 18: KÖCO „ELOTOP“ series stud welding power sources

Ensuring the quality of stud welding connections in construction

Besides modern stud welding equipment, secure welding connections also require skillful construction, the right choice of materials and manufacturing according to up-to-date techniques. The rules for stud welding are found, above all, in EN ISO 14555. Here, among other things, the inspection and testing procedures for stud welds are laid down. These include:

1. Visual test to check the completeness of the weld collar and the correct length of the welded stud;
2. Bend test prior to mass production, and further random bend tests during mass production;
3. Macro-polishing to check the burnt-in joint and investigations to discover any flaws in the connection, cracks or pores which may have arisen from unsuitable materials or welding with incorrect settings.
4. Transmission and tensile tests are designed to detect any flaws over the whole of the welding surface. As a rule they are only carried out during a company's initial application for certification as a qualified manufacturer.



Figure 19: „CLASSIC“ series KÖCO welding guns

Studs which have been proved suitable for welding are listed under the standard EN ISO 13918. With any studs included in that list, there is no need for the user to be concerned about unsuitable materials or stud shapes. In addition to the stud shapes and materials listed in the standard, KÖCO can also supply some special studs, for instance extra long shear connectors and threaded studs from high-tensile steel, which are still suitable for welding.

| Comparison of some important characteristics of structural concrete versus steel construction | |
|--|---|
| Steel construction | Structural concrete |
| pre-fabrication to a high degree in the factory, independent of the weather, then quick assembly of prefabricated elements | production mostly on the building site, dependent on the weather, costly due to elaborate formwork (except when using concrete prefab elements) |
| costly fire protection measures required in buildings with a high fire risk | built-in fire protection |
| realisation of large spans possible with relatively little material, light-weight construction | large spans necessitate solid beams and heavy-weight structures |
| sensitive to vibration | insensitive to vibration |
| maintenance (prevention of corrosion) necessary for the structure's entire lifetime | if correctly planned very little necessity for anti-corrosion measures |
| structural changes and adjustment to alternative uses relatively easy | structural changes and adjustment to alternative uses difficult |
| low costs for disposal after demolition – the debris can be scrapped and recycled | high disposal costs after demolition – the debris is not reusable |

Composite construction utilizes the benefits of both construction methods, while avoiding many of their drawbacks.

Sources of illustrations:

Figures 1, 3, 6, 7, 8, 9, 10: Stahl-Informationszentrum (Steel Information Centre), Düsseldorf

Figure 2: Beton-Kalender 1993, Verlag Ernst & Sohn (Roik, Bergmann, Haensel, Hanswille „Verbundkonstruktionen, Bemessung auf der Grundlage des Eurocode 4 Teil 1 / „Composite structures, Design on the base of Eurocode 4 part 1“)

Figures 4, 5: Goldbeckbau, Bielefeld

Figure 12: Ingenieurbüro HRA, Bochum (engineering design bureau)

Figure 13: Köster Italia

Figures 11, 14 to 19: Köster & Co. Bolzenschweißtechnik, Ennepetal