Torsion BSF, BCC

General information about torsion of beams.

If a beam is subjected to torsion the most sensible solution will in most cases be to prevent the torsional moment to be transferred to the column. In principle this is the same problem if the beam is eccentrically supported on the column. There are several reasons for this to be an unfortunate solution:

1. In many cases the moment capacity of the column will not be sufficient, and the vertical load bearing capacity will be reduced.
2. The eccentricity or torsion will deform the column to the extent that it may lead to problems with the erection. Besides it may make the whole building unstable. (See figure 3.0.) Eccentric loading over several floors without stabilization leads to second order deflections larger than the first order ones.
3. Variations in the loads (torsional moment) may in the long run lead to irreversible movement at the support points.
4. Due to the erection clearance between the steel parts the torsion will lead to a tilting of the beam that will be esthetically unacceptable.

If one tries to avoid this by grouting the joint in advance, one has to keep in mind that the quality of such filling is highly dependent upon workmanship, and is very difficult to control.

If one still chooses a solution with grouted joint and introduction of the torsional moment in the column, the following capacity limitations will apply, based on a relatively high concrete grade in the grout:

Unit	Maximum torsional moment (kNm)
BSF 150/20	1
BSF 200/20 and 200/30	12
BSF 200/40 and 200/50	15
BSF 250/50	30
BCC 250	4
BCC 450	6
BCC 800	10

To avoid unnecessary torsional challenges we strongly recommended instead using the principles in the rest of this Memo.

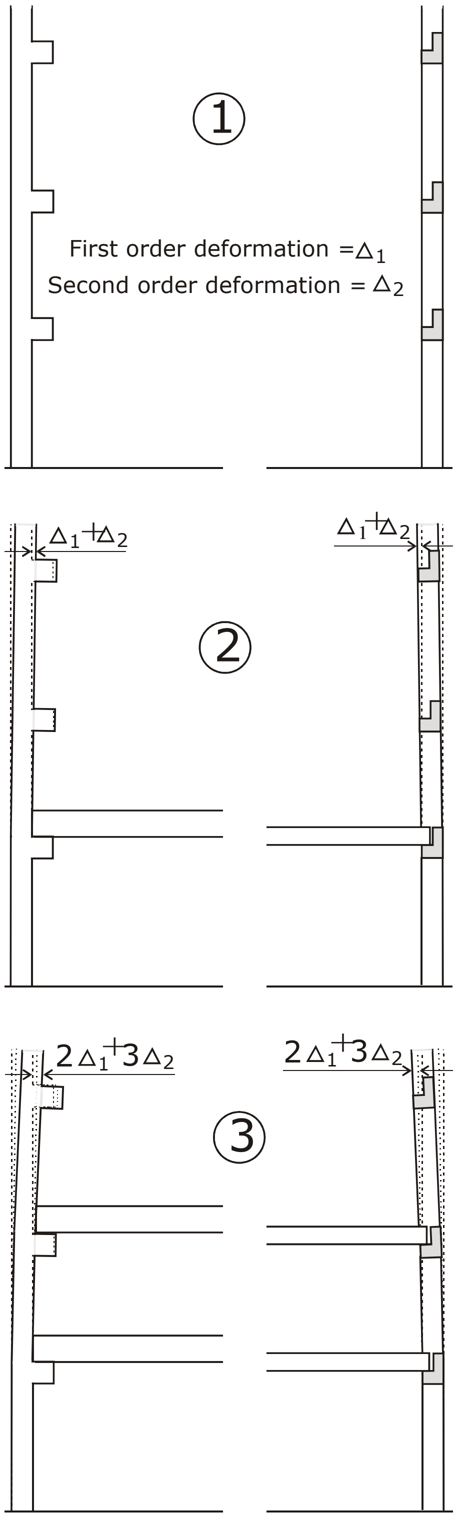

Figure 3.0 Deformation of columns due to eccentricity or torsion.

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Full scale testing of the BSF-units for torsion has not been carried out. However, calculation shows that the knife has a substantial capacity for torsion, probably in most cases considerably larger than the moment that can be resisted by the column.

Due to the clearance for the knife in the beam and column boxes, any torsion will cause a visible inclination of the beam. Consequently torsional moments should be taken care of by other means

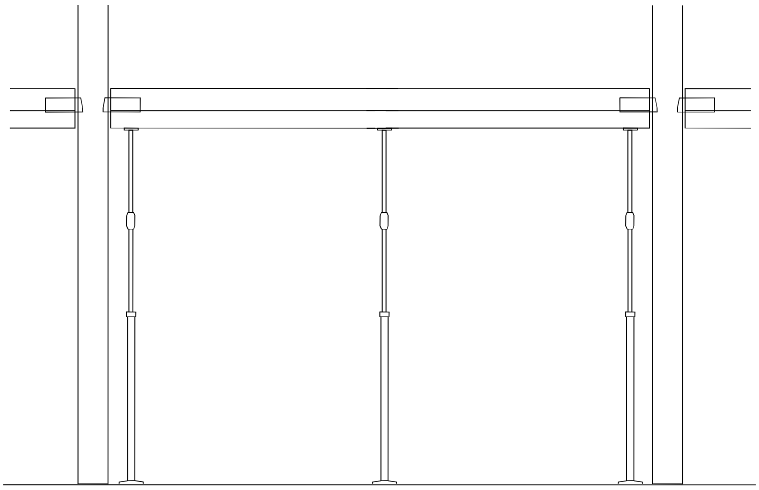

Figure 3.1. Temporary propping.

Example, hollow core slabs or double T's on ledge beams:
Provide temporary supports for the beams during erection. Provide a tensile connection between the beam and the slab as far down in the slab as possible. When the void between the hollow core slab and the beam has been grouted, or the welding has been completed in the case of the double T, the monolithic structure will prevent the beam from tilting, while any rotation of the slabs will introduce negligible torsional moments in the beam.

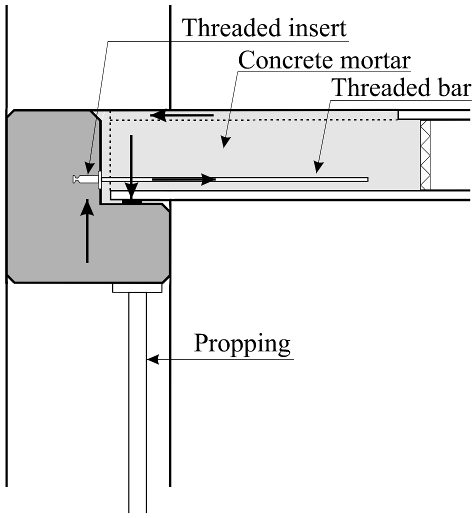

Figure 3.2. Torsional moment connection

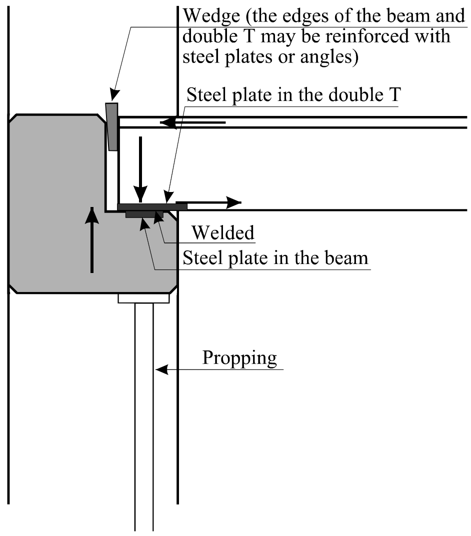

Figure 3.3. Torsional moment connection between double T's and ledge beams.

If the transfer of torsional moments from the beam to the column is required for both live loads and dead loads, it can be done as follows:

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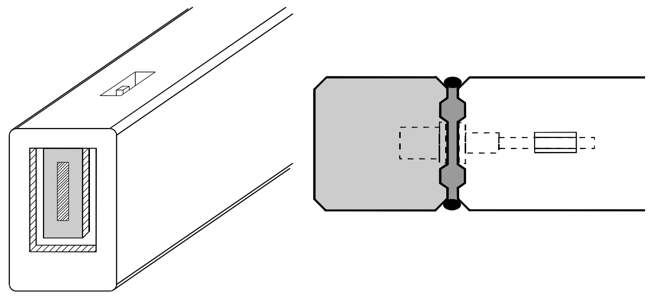
Method A:

Provide a recess on both sides and under the front plate of both the beam- and column units. Fill the joint between the end of the beam and the side of the column with high strength grout before the slabs are erected. The torsional moments can then be transferred without any visible tilting of the beam.
This solution is not recommended if the beam is simply supported and is expected to have large rotations at the supports.



Figur 3.4. Recess in beams and column.

The forces in the joint grout and recess must be calculated in each individual case. However, the torsional moment capacity in the ultimate limit stage can be calculated as:

$$T_r = 0{,}24 \times (f_{cn} / \gamma_c) \times (2 \times h^2 + b^2) \times a \times \cos\alpha \times \cos\beta \times \cos(\alpha - \beta)$$

T_r = torsional moment capacity in the ultimate limit stage

f_{cn} = ultimate compressive strength of the joint grout or the concrete in the elements, whichever is the smallest

γ_c = material factor for concrete

α = inclination of the compressive strut in the joint grout

β = slope of the side face of the recess

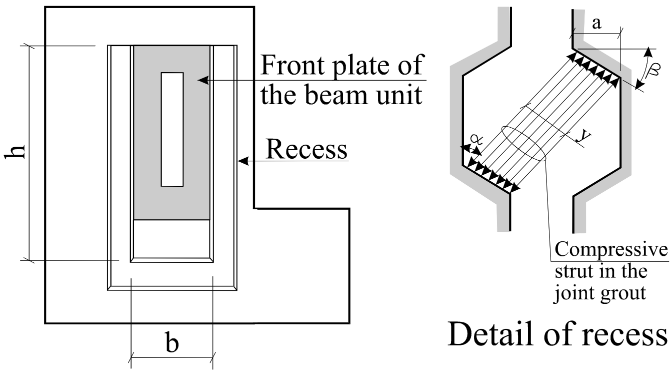


Figure 3.5. Design model for force transfer in the joint grout.

a, b and h = geometrical dimensions shown in figure 3.5.

In the formula above the stress block in the joint grout is assumed to be 40% of the length of the recesses. The distance between the center of the stress blocks will then be 60% of the length. Hence the factor 0,24, which is the product of 0,4 and 0,6.

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Method B:
If it is important to avoid propping, but still transfer the torsional moment to the columns, there are several possibilities. This is a solution that permits a hinged support for the beam. The steel plate welded to the column must slide in a "tray" in order to prevent negative moments from developing. The horizontal forces caused by the torsional moment are resisted by edge pressure between the plate welded to the column and the "tray" in the top of the beam in the beam, and to the columns through the weld. Depending upon the magnitude of the torsional moment, the knife can resist the counteracting horizontal force, or a similar solution must be provided in the bottom of the beam. Instead of a steel plate and a "tray", the connection can be made by using steel channels, where the one welded to the columns fits tightly into the one embedded in the beam.
The beam and column does not have to be of the same width.

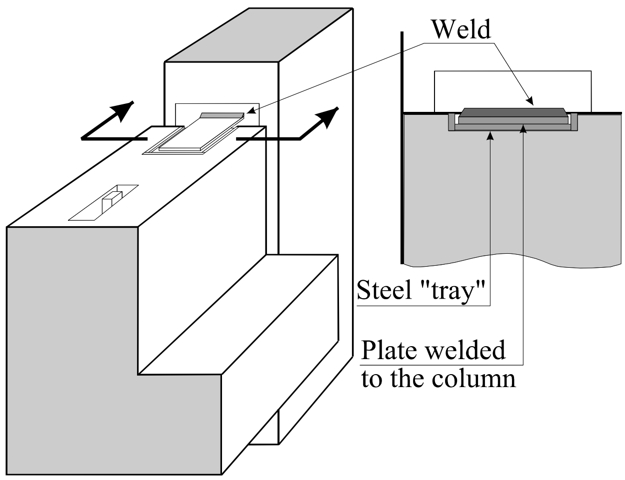

Figure 3.6. Sliding connection.

If the transfer of the torsion from the beam to the columns is done for dead loads only,

temporary propping can also be avoided. The principle is that temporary connections transferring torsion between the beam and columns are provided during erection of the slabs. After the slabs have been erected the connection between the slabs and the beams are established, for example as shown in figures 3.2 and 3.3. Then the temporary connections are removed. Now the torsional moments from the live loads will be absorbed in the connection between the slabs and the beams. For the sake of safety, however, the connection between the slabs and the beams should be designed for the torsional moment caused by the sum of live loads and dead loads. There are several alternative methods that can be used for <u>temporary</u> connections between the beam and the columns:

<u>Alternative 1:</u>

Erection clamps in the top and bottom of the beam, in the joint between the beam and the column. The disadvantage with this solution is that the BSF unit must have a location that does not come in conflict with the bolts passing through the joint. Furthermore, the bolts may complicate the casting of the joints between the beam and the columns, which may be required for fire protection purposes. The beam and column have to be of the same width.

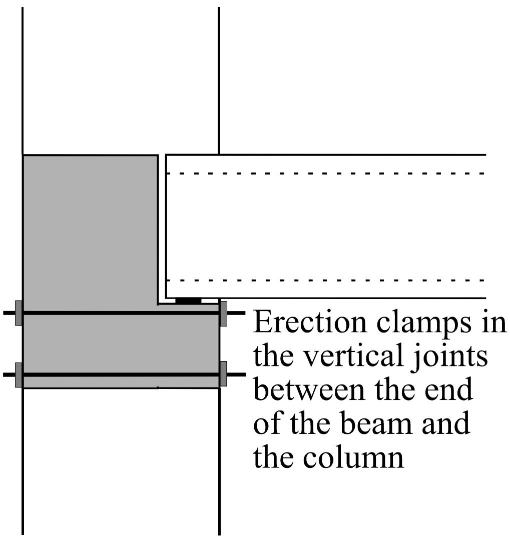

Figure 3.7. Erection clamps in the joints.

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Alternative 2:
Clamps can also be made of steel plates or angles attached to the columns. The disadvantage is that the columns must have threaded inserts or holes, which complicates the production. The connection to the columns will then be with short bolts in the inserts, or longer bolts going through holes in the columns. This solution only requires one plate or angle at the top and one at the bottom of the beam, on opposite sides. The beam and columns have to be of the same width.

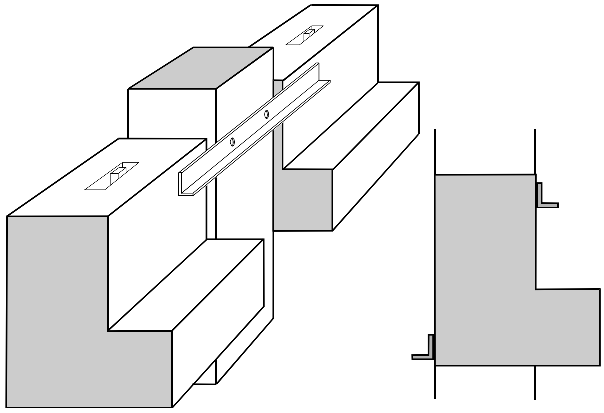

Figure 3.8. Clamps connected to the columns.

Alternative 3:
This solution can be used for beams with ledges forked around the column. There is a clamp at the top, and shims between the elongated ledge and the columns. The shims may be spot welded to a steel plate in the columns. The disadvantage is that this will require some extra reinforcement in the protruding part of the ledge to take care of the horizontal force caused by the torsional moment. The beam and columns have to be of the same width.

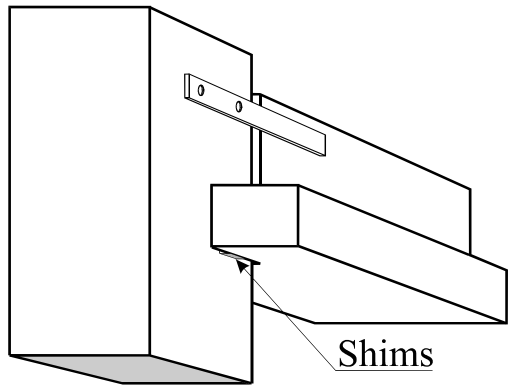

Figure 3.9. Beam with forked end.

Alternative 4:
This is a method that allows for easy adjustment as the erection progresses. The clamps consist of steel plates welded together, with a threaded hole in one of the plates. This hole has a bolt with a handle for easy adjustment. A supporting plate for the bolt is required against the column. The clamps may be costly, and quite a number may be required at each building site. However, once the investment in the clamps has been made, they can be used for years. The beam and columns does not have to be of the same width. A disadvantage is that the connection is not quite stable, and readjustments will normally be necessary during erection.

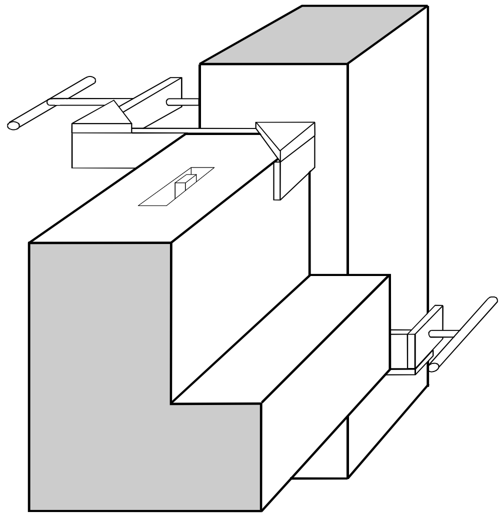

Figure 3.10. Adjustable clamps.

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Alternative 5:
This solution can be combined with any continuity reinforcement required for the beams. Steel plates are welded to the beam units, and are protruding about 25 mm (1 inch) above the top surface of the beam. Either the bar passing through the column can have a tight fit between the plates, or a small transverse steel plate can be welded to the bar and the protruding plates. The counteracting horizontal force can be taken by the knife. The beam and column does not have to be of the same width. The solution will only work for small torsional moments.

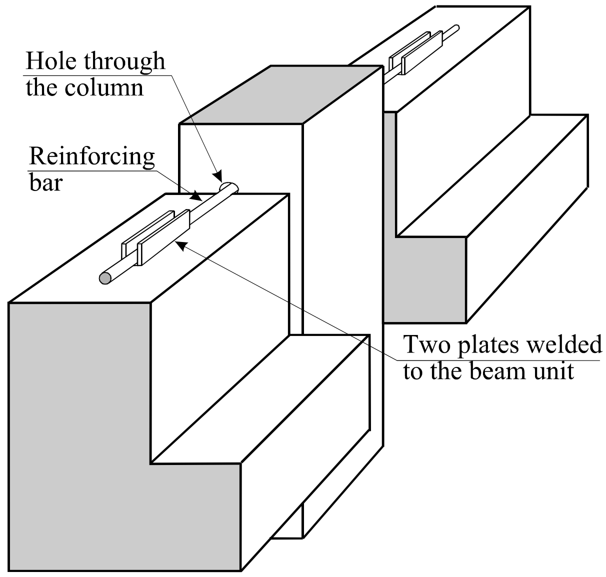

Figure 3.11. Simple solution for small torsional moments.

Alternative 6:
This is a solution similar to alternative 2, only that now the beam and column does not have to have the same width. The counteracting horizontal force can be resisted by the knife if the forces are moderate, or a steel plate has to be provided on the outside as shown in figure 3.8. A threaded insert is required in the column for the attachment of the steel angle. The angle can be reinforced with a triangular plate.

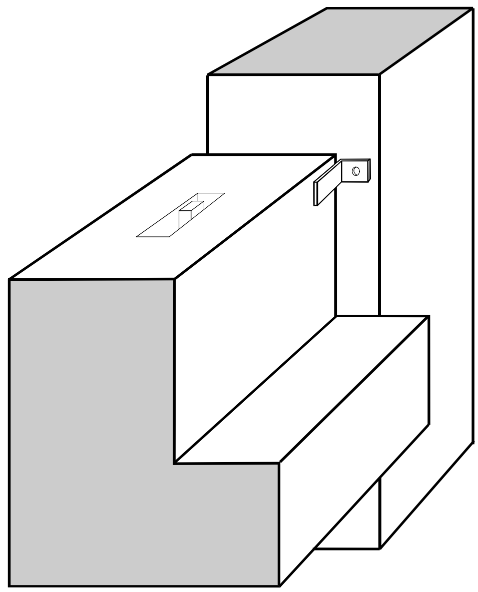

Figure 3.12. Angle clamping.

Alternative 7:

This alternative minimizes any alterations to the beams or columns, and will prevent torsion from both dead loads and live loads:

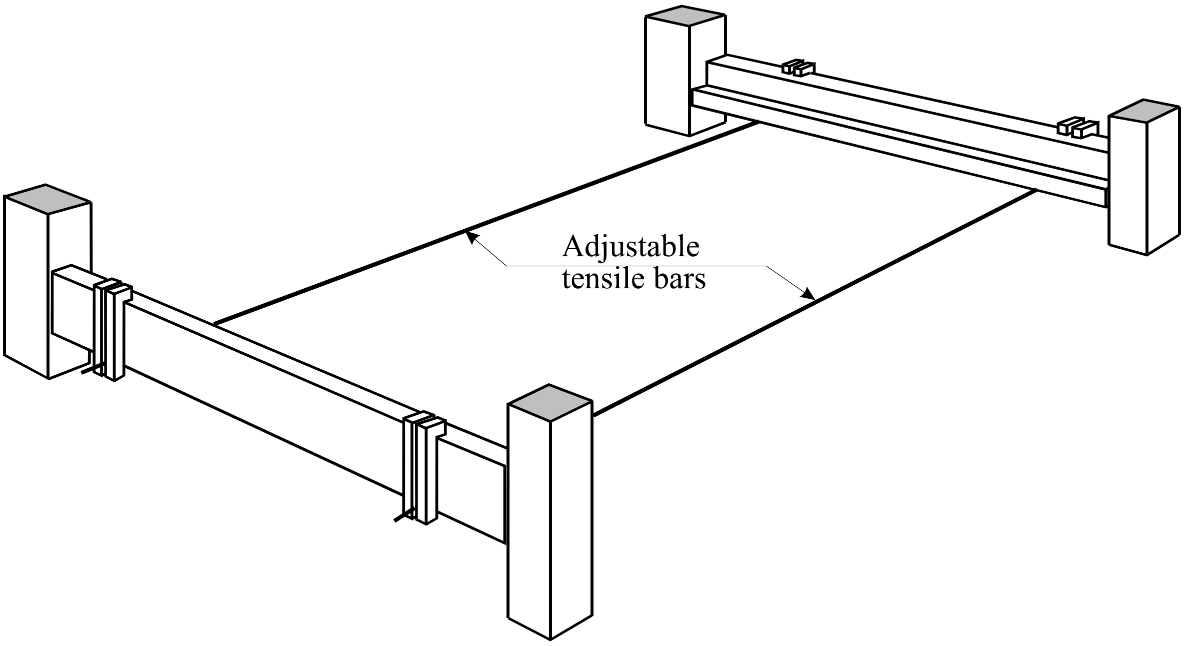

Figure 3.13. Temporary tensile connection between beams.

This method requires that special steel brackets are made that can be attached to the beams as shown in figure 3.14. The brackets can of course be made adjustable in order to fit different beam dimensions. It should be made of two parts, for example steel channels as shown, so that the tensile bar can be slid in from below. The little plate at the bottom of the bracket is hinged, and can be lifted and locked. The purpose is to prevent the tension bar from falling down. It must be expected that as the erection progresses, readjustments will be necessary due to the increasing tension in the bars.

When the erection is complete connections must be established between the slabs and the beams, for example as shown in figures 3.2 and 3.3.

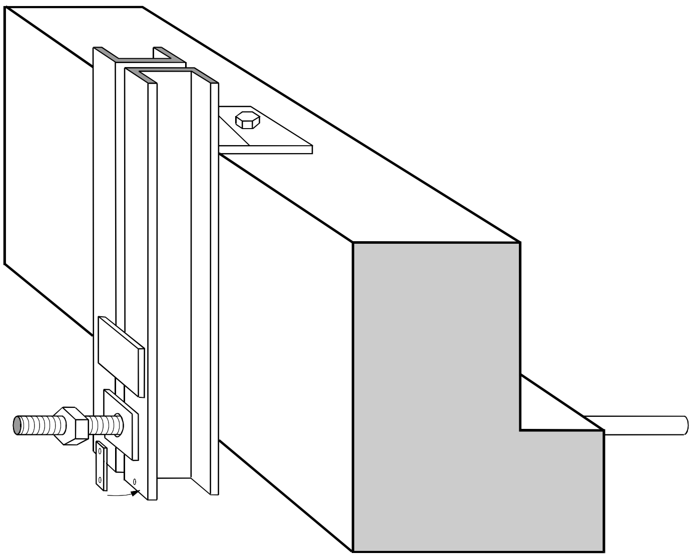

Figure 3.14. Steel bracket for temporary tensile connection.

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Alternative 8:

Fasten a reusable steel bracket to the column for torsional support in the erection stage (see picture)

This method was for example use during erection in a under ground parking garage (14 meter below water level) in Delf, Holland in 2002, where the space was too congested with intermediate horizontal bracers during the erection.