HALFEN HSC Stud Connector

Highly effective reinforcement anchor

The HALFEN HSC Stud Connector is an officially approved reinforcement anchor, optimised for anchorage in concrete. Full reinforcement anchorage can be achieved with minimum transmission lengths.

The HALFEN HSC Stud connector is especially suitable for use in highly reinforced areas such as corbels and beam to column connections. The problems that occur in the layout of reinforcement and distribution of forces with conventional rebar solutions do not apply. The amount of reinforcement steel is considerably reduced and the reinforcement layout is simpler. Apart from saving costs and time a substantial advantage is the increased reliability of the connection.

The advantages at a glance

• innovative anchor head
• reduction of intricate bent reinforcement by using straight anchor bars
• forged anchor head results in extremely short anchorage length
• effective anchorage reduces quantity of reinforcement steel
• time-effective installation and increased application safety thanks to simplified reinforcement
• extensive product range means high design flexibility
• safety in planning with German National Technical Approval, according to European standard Eurocode 2
• screw joints between concreting sections means no cost-intensive formwork penetrations are required

National Technical Approval Z-21.8-1973 for HALFEN HSC Stud connector
National Technical Approval Z-1.5-189 for HALFEN HBS-05 Screw connection

Corbel with HALFEN HSC Stud Connector
HALFEN HSC STUD CONNECTOR

Extremely short anchorage lengths

| Straight reinforcement | Bent reinforcement | HALFEN HSC Stud connector |

Simple reinforcement layout

Comparison of anchor lengths

Corbel with HALFEN HSC Stud connector: secure anchorage, simple reinforcement layout

Conventional corbel reinforcement with large bending diameters, high steel usage and complicated reinforcement

Advantages in planning and design

- approval for predominantly static and non-predominantly static loading cases
- HALFEN provides free easy-to-use corbel dimensioning software
- HALFEN provides a complimentary consultation service for customer’s projects
- head to head and multiple-layered placement of anchor heads allow a high degree of reinforcement

Flexible and economical

- combination with HALFEN HBS-05 Screw connections provides a wide range of applications
- column and corbel reinforcement stirrups can be positioned separately – and do not have to span the joint
- fitting with standard size spanners or wrenches – no special tools required
- high reliability
- visual monitoring is sufficient
- conical thread minimized screw slippage

Wide application range

- corbels
- frame corners
- beam supports
- slab supports
- half joints

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HALFEN HSC STUD CONNECTOR
Application Examples

Corbels → page 7 - 10
Frame corners → page 6
Half joints

Beam supports → page 11
Slab supports → page 11

Examples of corbel application

Corbel with multilayer reinforcement in monolithic element → page 16

Corbel with single layer reinforcement used in concrete sections → page 16

Option 1: indented joint acc. to EN 1992-1-1
Option 2: simplified keyed joint
HALFEN HSC STUD CONNECTOR
Design and Dimensioning, Basics

Application according to approval Z-21.8-1973

Materials

- normal concrete, strength classes C20/25 up to C70/85
- HSC: B500B, for d_{HSC} = 12 mm alternative stainless steel B500NR

Stresses and resistances

- predominantly static and non-predominantly static loads

  - yield strength

\[ f_{yd} = \frac{f_{yk}}{\gamma_s} = \frac{500 \text{ N/mm}^2}{1.15} = 435 \text{ N/mm}^2 \]

Fatigue resistance values of HSC Stud connectors:

- stress ranges for N = 2 \cdot 10^6:
  \[ \Delta \sigma_{RSK} = 80 \text{ N/mm}^2 \text{ for } d_{HSC} = 12 \text{ mm, } d_{HSC} = 16 \text{ mm and } d_{HSC} = 20 \text{ mm} \]
  \[ \Delta \sigma_{RSK} = 70 \text{ N/mm}^2 \text{ for } d_{HSC} = 25 \text{ mm} \]

- Wöhlerline stress exponents:
  \[ k_1 = 3.5 \text{ for } N \leq 2 \cdot 10^6 \]
  \[ k_1 = 3 \text{ for } 2 \cdot 10^6 \leq N \leq 10^7 \]
  \[ k_2 = 5 \]

Design concepts and regulations according to the approval

- design and dimensioning of frame end nodes, corbels, beams and slabs
- simplified anchor verification method by observing the construction regulations
- standardized regulations for multilayer HSC reinforcement anchors and for staggered HSC
- shear joints for subsequently cast concrete sections
- conventional positioning of stirrup reinforcement, or alternatively: separate stirrup arrangement in column and corbel

Installation fundamentals

Placement of anchor heads
Anchor heads may be aligned vertically or horizontally as required.

Spacing of bars
HSC anchors require the same bar spacing as standard reinforcement bars.

When used in several concrete sections the minimum distances a_{HSC} resp. e_{HSC} must be observed to ensure the male bars can be securely installed. See figures and table below.

Minimum head spacings to ensure male bars can be installed and tightened (HSC connection bars)

<table>
<thead>
<tr>
<th>d_{HSC} [mm]</th>
<th>e_{HSC} [mm]</th>
<th>a_{HSC} [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>16</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>20</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>25</td>
<td>25</td>
<td>30</td>
</tr>
</tbody>
</table>

Option 1: anchor heads in alignment
Option 2: reduced spacings with staggered anchor head layout

Vertical anchor head layout

Horizontal anchor head layout

Detailed information on installation can be found in the "HALFEN HSC Stud Connector" assembly instructions.

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HALFEN HSC STUD CONNECTOR
Design and Dimensioning of Frame Corners, Construction Specifications

Frame corner according to approval Z-21.8-1973

Design and dimensioning of the column
Minimal column dimensions are according to the approval: see table "minimum column dimensions acc. to Z-21.8-1973" on page 7.

Longitudinal reinforcement ratio:

\[ \rho_{\text{col}} = \frac{A_{s1,\text{col}}}{b_{\text{col}} \cdot h_{\text{col}}} = \frac{A_{s2,\text{col}}}{b_{\text{col}} \cdot h_{\text{col}}} \geq 0.5 \% \]

The sum of longitudinal reinforcement’s compressive and tensile forces has to be anchored inside the frame corner joint, relevance for transmission length \( l_{b} \) is:

\[ l_{b} = \left[ \frac{\left| T_{1} \right| + \left| C_{1} \right|}{f_{b} \cdot n \cdot \gamma_{C}} \right] \leq h_{\text{beam}} \]

where \( f_{b} \) = bond stress acc. to DIN EN 1992-1-1, chapter 8.4.2.

For non-braced frame corner constructions the column reinforcement at the joint cross sections have to be generally increased by ½ compared to the bending dimensioning values. This additional reinforcement has to be anchored starting from the columns cross sections; compare to DAFStb "German Committee for Structural Concrete" publication no. 532.

Design and dimensioning of the beam
Origin of the beam bending dimensioning is at a distance of 0.3 \( h_{\text{col}} \) from the column’s central axis. The anchor heads have to be positioned behind the longitudinal column reinforcement. Observe the National Technical Approval to verify the anchor.

Stirrup reinforcement
Beam and column have to be reinforced with stirrups in areas defined as \( h_{\text{col}} \) resp. \( h_{\text{beam}} \), measured from the joint cross sections, with a maximum spacing of \( s = 10 \text{ cm} \). See figure 2 below: "minimal stirrup reinforcement".

Shear resistance
Appli ed shear force \( V_{j,\text{h}} \):

\[ V_{j,\text{h}} = A_{s,\text{HSC}} \cdot f_{yd} - V_{j,\text{Ed, col},0} \]

Limitation of the shear force \( V_{j,\text{h}} \) to \( V_{j,\text{h}} \leq \begin{cases} V_{j,Rd} \\ V_{j,Rd,\text{max}} \end{cases} \)

Node resistance \( V_{j,\text{cd}} \) without stirrups [N]:

\[ V_{j,\text{cd}} = 1.55 \left( 1 + 0.3 \cdot \frac{h_{\text{beam}}}{h_{\text{col}}} \right) \frac{1}{7.5} \rho_{\text{col}} \frac{1}{2} \frac{f_{c,k}}{\gamma_{C}} \]

with:

\[ 1.0 \leq \frac{h_{\text{beam}}}{h_{\text{col}}} \leq 2.0 \quad 0.5 \% \leq \rho_{\text{col}} \leq 2.0 \% \]

\[ b_{\text{eff}} = \frac{b_{\text{beam}} + b_{\text{col}}}{2} \leq b_{\text{col}} \]

\[ b_{\text{eff}}, h_{\text{col}} \ldots \text{effective width, height of column cross section in [mm]: } f_{c,k} \text{ in } [\text{N/mm}^2] \]

Shear resistance \( V_{j,Rd} \) with stirrups:

\[ V_{j,Rd} = V_{j,\text{cd}} + 0.475 \cdot A_{s,\text{eff}} \cdot f_{yd} \leq V_{j,Rd,\text{max}} \]

with:

\[ A_{s,\text{eff}} = \text{effective shear reinforcement (aligned between upper edge joint and upper edge compression zone beam)} \]

Maximum node resistance \( V_{j,Rd,\text{max}} \):

\[ V_{j,Rd,\text{max}} = \gamma_{N1} \cdot \gamma_{N2} \cdot 0.3 \frac{f_{c,k}}{\gamma_{C}} \cdot b_{\text{eff}} \cdot h_{\text{col}} \leq 2 \cdot V_{j,\text{cd}} \]
HALFEN HSC STUD CONNECTOR

Design and Dimensioning of Frame Corners and Corbels, Construction Specifications

with:  \[ \gamma_{N1} = 1.5 \cdot \left( 1 + 0.8 \cdot \frac{N_{Ed,\text{col}}}{F_{Ed,\text{col}} \cdot f_{ck}} \right) \leq 1.0 \]
\[ \gamma_{N2} = 1.9 - 0.6 \cdot \frac{h_{\text{beam}}}{h_{\text{col}}} \leq 1.0 \]

Quasi-permanent normal column force
\[ N_{Ed,\text{col}} = 1.0 \cdot N_{C} + 0.3 \cdot \sum N_{Q} \]
(compression force negative)

Shear joint
The shear joint has to be verified if the column and beam are concreted in two segments → page 10.

Corbels according to approval Z-21.8-1973

HALFEN HSC Stud connectors in this application are calculated using the same basic method as for conventional reinforcement. The calculation method is set out in brief below. Always observe the National Technical Approval.

Geometry, actions
short corbels: \[ \frac{a_{c}}{h_{c}} \leq 0.5 \]
long corbels: \[ 0.5 < \frac{a_{c}}{h_{c}} < 1.0 \]

Shear resistance of the corbel
Minimum dimensions of the corbel according to the approval: see table "Constructional Specifications" on page 8.
\[ V_{Ed} \leq V_{Rd,\text{max}} = 0.5 \cdot v \cdot b_{c} \cdot z \cdot \frac{f_{ck}}{\gamma_{c}} \]
with:  \( v = 0.7 - \frac{f_{ck}}{200 \text{ N/mm}^2} \geq 0.5; z = 0.9 \cdot d \)

Calculation of tensile force
\[ Z_{Ed} = F_{Ed} \cdot \frac{a_{c}}{z_{0}} + H_{Ed} \cdot \frac{a_{H} + z_{0}}{z_{0}} \]
with:  \[ \frac{a_{c}}{z_{0}} \geq 0.4 \]
\[ z_{0} = d \cdot \left( 1 - 0.4 \cdot \frac{V_{Ed}}{V_{Rd,\text{max}}} \right) \]

Verifying the required HSC anchor cross section
\[ A_{s,\text{HSC}} = \frac{Z_{Ed}}{f_{yd}} \]
with:  \[ f_{yd} = \frac{f_{yk}}{\gamma_{s}} = \frac{500 \text{ N/mm}^2}{1.15} = 435 \text{ N/mm}^2 \]

Proof of HSC anchorage
The HSC bar anchorage is considered verified if the national technical requirements are observed; compare with figures and tables.
Corbels according to approval Z-21.8-1973

Deviating from the standard layout, HSC can be placed multilayered or staggered, corbel dimensions can also be below minimum given values. In these cases further calculations are required; see approval.

Further verifications and regulations

The transfer of forces to the column in single corbels can be verified using the same design rules as used for frame corners → page 6.

Horizontal cross section: anchor alignment, standard case (single layer, not staggered)

Proof of the compressive stress of concrete on the bearing plate is according to DIN EN 1992-1-1; see approval.

Crack width verification is according to DIN EN 1992-1-1.

Stirrup arrangement → page 9.

Transport safety device → page 9.

Proof of the shear joint within subsequently concreted corbels → page 10.

Assumptions:
- concrete cover $c = 20 \text{ mm}$
- single layer reinforcement, not staggered
- predominantly static loads $H_{Ed} = 0.2 \ F_{Ed}$
- monolithic construction
- bearing plate thickness $d_L = 20 \text{ mm}$

Reference values for corbel resistances

<table>
<thead>
<tr>
<th>Anchor diameter</th>
<th>Concrete</th>
<th>Corbel dimensions</th>
<th>Concrete strength class</th>
<th>Stirrups</th>
<th>Concrete cover</th>
<th>Excess length</th>
</tr>
</thead>
<tbody>
<tr>
<td>$d_{HSC}$ [mm]</td>
<td>$f$ [mm]</td>
<td>$g$ [mm]</td>
<td>$h_{HSC}$ [mm]</td>
<td>$b_{c,min}$ [mm]</td>
<td>$l_{c,min}$ [mm]</td>
<td>$d_{sw}$ [mm]</td>
</tr>
<tr>
<td>12</td>
<td>C20/25</td>
<td>200 200 200</td>
<td>C20/25 … C70/85</td>
<td>$\geq 6$</td>
<td>$\geq 30$</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>C30/37</td>
<td>200 200 200</td>
<td>C30/37 … C50/55</td>
<td>$\geq 6$</td>
<td>$\geq 40$</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>C40/50</td>
<td>200 200 200</td>
<td>C40/50 … C70/85</td>
<td>$\geq 8$</td>
<td>$\geq 50$</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>C55/63</td>
<td>300 300 300</td>
<td>C55/63 … C75/85</td>
<td>$\geq 10$</td>
<td>$\geq 60$</td>
<td></td>
</tr>
</tbody>
</table>

Note: These are estimated reference values. Individual cases require separate verification.
**Corbels according to approval Z-21.8-1973**

**Stirrups for transverse tensile forces**
At least one closed vertical stirrup for transverse tensile forces has to be installed inside the load area for each rebar layer. Correct placement is between the middle of the bearing plate and the HSC anchor heads (see figure). Stirrup diameter is according to the table on page 8.

**Stirrups for tensile splitting forces**
For \( a_c \leq 0.5 \cdot h_c \) and \( V_{Ed} > 0.3 \cdot V_{Rd,max} \):

Option 1:
Closed horizontal or angled stirrups enveloping corbel and column with a total minimum cross section of 50% of the HSC reinforcement.

Option 2:
Closed horizontal and vertical stirrups inside the corbel, with a minimum overall cross section of 50% of the HSC reinforcement (separate stirrup arrangement).

For \( a_c > 0.5 \cdot h_c \) and \( V_{Ed} > V_{Rd,c} \) (\( V_{Rd,c} \) acc. to DIN EN 1992-1-1, chapter 6.2.2):

Closed vertical stirrups for total stirrup forces of \( F_{wd} = 0.7 \cdot F_{Ed} \)

**Transport safety device**
Movement in the joint during transport has to be avoided. A minimum 1.5 cm²/m joint crossing reinforcement in the pressure zone or other methods e.g. securing with tension belts are possible.

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**TECHNICAL SUPPORT**

**HALFEN Technical Support**
Engineering services and technical advice for your projects is available.
Contact addresses for all HALFEN Products can be found at the back side of this catalogue.
Shear joints according to approval Z-21.8-1973

The shear joint can be configured either as an indented joint or as a "simplified key joint", see illustrations. The distance between the joints must not be smaller than the largest possible size of aggregate in the concrete mix.

Proof of the shear joint

\[ V_{Ed} \leq V_{Rdj} = c_j \cdot f_{cd} \cdot b_c \cdot x_j + 1.2 \cdot \mu \cdot A_{ij} \cdot f_{yd} \leq V_{Rdj,\text{max}} \]

with:

\[ V_{Rdj,\text{max}} = 0.5 \cdot \nu_j \cdot f_{cd} \cdot b \cdot h_{c,\text{eff}} \]

\[ x_j = h_c \text{ for indented joint} \]

\[ x_j = h_c - u \leq 500 \text{ mm for simple key joint without longitudinal tensile force (} H_{Ed} \leq 0) \]

\[ x_j = x_c - u \leq 500 \text{ mm for simple key joint with longitudinal tensile force (} H_{Ed} > 0) \]

\[ h_{c,\text{eff}} = h_c \text{ for indented joint} \]

\[ h_{c,\text{eff}} = h_c - u \leq 500 \text{ mm for simple key joint} \]

\[ x_c \ldots \text{ height of compression zone (} x_c = (d-z_0) \cdot 2) \]

\[ b_c, h_c \ldots \text{ width of the joint, height of the joint} \]

\[ A_{ij} \ldots \text{ overall cross section of the tensile zone reinforcement, crossing the joint at 90 degree} \]

\[ c_j, \mu, \nu_j \ldots \text{ joint parameters according to table} \]

\[ f_{cd} \ldots \text{ design value of concrete compressive strength} \]

\[ f_{ctd} = f_{ck,0.05} / \gamma_c \ldots \text{ design value of concrete tensile strength with } \gamma_c = 1.8 \]

Shear joints are usually designed with HSC female bars and HSC-A single headed male bars. For proper installation of the HSC-A bars please refer to the assembly instructions on page 5.

<table>
<thead>
<tr>
<th>Coefficients of shear joints</th>
<th>( c_j )</th>
<th>( \mu )</th>
<th>( \nu_j )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indented joint</td>
<td>0.5</td>
<td>0.9</td>
<td>0.7</td>
</tr>
<tr>
<td>Simplified key joint</td>
<td>0.4</td>
<td>0.7</td>
<td>0.5</td>
</tr>
</tbody>
</table>
**Beam supports and slab supports according to approval Z-21.8-1973**

**Anchorage and load transfer**

In addition to the bonding effect of the ribbed rebar the forged heads can also be used to verify the anchorage for the rebar force. Because of the concentrated load transfer additional construction regulations have to be observed. Reinforcement, for example, stirrups have to be positioned to absorb shear tension loads in the anchorage zone. The diameters of these reinforcement elements should not be smaller than the recommended minimum diameters $d_{sw}$, see table on page 8.

The values in the table for the concrete cover $c_{HSC}$ and the minimum construction dimensions should be observed, see table page 8.

Load transfer for the anchor forces has to be ensured, otherwise additional reinforcement is required.

Always observe the National Technical Approval.

**Beams, solid slabs**

Considering stress spreading triangular in the bearing area (see adjacent figure) and unstaggered one layer tensile reinforcement, the HSC reinforcement may be deemed as **fully anchored**, if the anchorage length below is observed:

$$l_b = 2 \cdot \frac{V_{Ed}}{\sigma^* \cdot b} + \bar{u} \geq 6.7 \cdot d_{HSC}$$

with: $\sigma^*$ = allowable compression at calculated bearing, compare to figure. $\bar{u}$ = head overlap

$$\bar{u} \geq \max \left\{ \frac{c}{2} + h_{HSC}, \frac{d_1}{2} + h_{HSC} - \frac{4 \cdot V_{Ed}}{3 \cdot \sigma^* \cdot b} \right\}$$

$h_{HSC}$ → table page 8

Deviating from the standard layout, HSC can be placed multilayered or staggered, corbel dimensions can also be below minimum given values. In these cases further calculations are required; see approval.

**Bearing area of beams:**

At least one closed vertical stirrup for each layer of reinforcement.

HSC at the anchor head, minimum diameter $d_{sw}$ according to table → page 8

**Bearing area of slabs:**

Transverse reinforcement at least 20% of the tensile moment reinforcement.

At the flanking margins u-shaped stirrups with minimum diameter $d_{sw}$ according to the table on page 8.

The transverse reinforcement has to be calculated according to DIN EN 1992-1-1, valid for $V_{Rd,max}$:

$$V_{Rd,max} = 0.5 \cdot v \cdot b \cdot z \cdot \frac{f_{ck}}{\gamma_c}$$

with: $v = 0.7 - \frac{f_{ck}}{200 \text{ N/mm}^2} \geq 0.5$

Solid slabs requiring no statically shear reinforcement:

shear resistance is sufficient also in the load initial area of HSC anchors.

Solid slabs requiring statically shear reinforcement, beams: observing the minimum shear reinforcement in area $l_{sw} = d$ from the leading edge of the support:

$$A_{sw,v} \geq 0.7 \cdot \frac{V_{Ed}}{f_{yd,sw}}$$

Slabs:

vertical reinforcement

Beams:

closed vertical stirrups

Solid slabs requiring no statically shear reinforcement:

shear resistance is sufficient also in the load initial area of HSC anchors.

Deviating from the standard layout, HSC can be placed multilayered or staggered, corbel dimensions can also be below minimum given values. In these cases further calculations are required; see approval.

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HSC at the anchor head, minimum diameter $d_{sw}$ according to table → page 8

Bearing area of slabs:

Transverse reinforcement at least 20% of the tensile moment reinforcement. At the flanking margins u-shaped stirrups with minimum diameter $d_{sw}$ according to the table on page 8.

The transverse reinforcement has to be calculated according to DIN EN 1992-1-1, valid for $V_{Rd,max}$:

$$V_{Rd,max} = 0.5 \cdot v \cdot b \cdot z \cdot \frac{f_{ck}}{\gamma_c}$$

with: $v = 0.7 - \frac{f_{ck}}{200 \text{ N/mm}^2} \geq 0.5$

Solid slabs requiring no statically shear reinforcement:

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Solid slabs requiring statically shear reinforcement, beams: observing the minimum shear reinforcement in area $l_{sw} = d$ from the leading edge of the support:

$$A_{sw,v} \geq 0.7 \cdot \frac{V_{Ed}}{f_{yd,sw}}$$

Slabs:

vertical reinforcement

Beams:

closed vertical stirrups

Solid slabs requiring no statically shear reinforcement:

shear resistance is sufficient also in the load initial area of HSC anchors.
Calculation example corbel according to approval Z-21.8-1973

Calculation example:

Proof of concrete compression under the bearing plate

\[ A_{C0} = 200 \cdot 200 \text{mm}^2 = 40000 \text{mm}^2 \quad A_{C1} = 253 \cdot 253 \text{mm}^2 = 64009 \text{mm}^2 \]

\[ F_{Rd,u} = A_{C0} \cdot f_{cd} \cdot \sqrt{\frac{A_{C0}}{A_{C1}}} = 40000 \cdot 1.7 \cdot \sqrt{\frac{64009}{40000}} = 860200 \text{N} = 860.2 \text{kN} \]

\[ < 3 \cdot f_{cd} \cdot A_{C0} = 3 \cdot 1.7 \cdot 400 = 2040 \text{kN} > 34512 \text{kN} = F_{Ed} \checkmark \]

Shear resistance of the corbel

\[ V_{Rd,max} = 0.5 \cdot \nu \cdot b_c \cdot z \cdot \frac{f_{ck}}{\gamma_c} \quad \nu = 0.7 \quad \frac{f_{ck}}{200 \text{N/mm}^2} = 0.7 \quad \frac{30}{200} = 0.55 \geq 0.5 \checkmark \]

\[ z = 0.9 \cdot d = 0.9 \cdot (40.0 - 5.3) = 31.2 \text{cm} \]

\[ V_{Rd,max} = 0.5 \cdot 0.55 \cdot 40 \cdot 31.2 \cdot \frac{3.0}{1.5} = 687.1 \text{kN} > V_{Ed} = 345 \text{kN} \checkmark \]

HSC reinforcement

\[ Z_{Ed} = F_{Ed} \cdot \frac{a_c}{z_0} + H_{Ed} \cdot \frac{a_h + z_0}{z_0} \quad z_0 = d \cdot \left( 1 - 0.4 \cdot \frac{V_{Ed}}{V_{Rd,max}} \right) = 34.7 \left( 1 - 0.4 \cdot \frac{345}{687} \right) = 27.7 \text{cm} \]

\[ Z_{Ed} = 345 \cdot 0.632 + 69 \cdot \left( 7.3 + 27.7 \right) = 305.2 \text{kN} \quad \frac{a_c}{z_0} = \frac{17.5}{27.7} = 0.632 > 0.4 \checkmark \]

\[ A_{s,HSC,req} = \frac{Z_{Ed}}{f_{yd}} = \frac{305.2 \text{kN}}{43.5 \text{kN/cm}^2} = 7.02 \text{cm}^2 \]

chosen: 3 diam. 20: \( A_{s,HSC,prov} = 9.42 \text{cm}^2 > 7.02 \text{cm}^2 = A_{s,HSC,req} \)

(single layer layout sufficient)

Crack width proof necessary

Proof of HSC anchorage
(indirectly by observing building regulation)

Minimum corbel dimensions: \( b_c / l_c = 40 \text{cm} / 35 \text{cm} > 24 \text{cm} / 20 \text{cm} = b_{c,min} / l_{c,min} \checkmark \)

Extension: \( \bar{u}_{req} \geq \max \left\{ \frac{c}{2} + h_{HSC} - \frac{2.0 \text{cm}}{2} + 1.2 \text{cm} - 2.2 \text{cm} \right\} \)

Extension: \( \bar{u}_{req} \geq \max \left\{ \frac{d_1}{2} + h_{HSC} - \frac{a_L}{2} - \frac{5.3 \text{cm}}{2} + 1.2 \text{cm} - \frac{20.0 \text{cm}}{2} = - 6.2 \text{cm} \right\} \)

\[ \bar{u}_{req} = 2.2 \text{cm} < \bar{u}_{prov} = 7.5 \text{cm} - 2.0 \text{cm} = 5.5 \text{cm} \checkmark \]

Specifications
- column, see figure below
- concrete C30/37
- \( c_{nom} = 20 \text{mm} \)
- column reinforcement: each flank 4 diam. 20

Calculation assumptions
- vertical anchor head placement
- single layer HSC reinforcement, \( d_{HSC} = 20 \text{mm} \)
- dimensions of the bearing plate: 20.0 / 20.0 / 2.0 cm
- bearing plate centred on corbel

Actions
\[ V_{Ed} = 1.35 \cdot 100 \text{kN} + 1.5 \cdot 140 \text{kN} = 345 \text{kN} \]
\[ H_{Ed} = 0.20 \cdot 345 \text{kN} = 69 \text{kN} \text{ (minimum value)} \]

Dimensions in [cm]
Concrete cover to the sides of anchors: 
\[ c_{eq} = c_{HSC} - \frac{f - d_{HSC}}{2} = 5.0\text{ cm} - \frac{4.4\text{ cm}}{2} = 3.8\text{ cm} \]
\[ \rightarrow \text{ concrete cover on anchor head sides } = 3.8\text{ cm} \]

Minimum column dimensions:
\[ b_{col}/h_{col} = 40\text{ cm}/40\text{ cm} > 30\text{ cm}/30\text{ cm} = b_{col,min}/h_{col,min} \checkmark \]

Column reinforcement diameter: \( d_{s,\text{col}} = 2.0\text{ cm} \geq 1.6\text{ cm} = d_{s,\text{col,min}} \checkmark \)

**Proof of the shear joint**

Assumption: designed as simplified keyed joint

\[ V_{Rdj} = c_{j} \cdot f_{cd} \cdot b \cdot x_{j} + 1.2 \cdot \mu \cdot A_{sj} \cdot f_{yd} \leq V_{Rdj,max} \]

\[ x_{j} = x_{c} - u = (d - z_{0}) \cdot 2 - u \quad \text{Assumption: } u = 20\text{ mm} \]

\[ x_{j} = (347 - 277) \cdot 2 - 20 = 120\text{ mm} < 500\text{ mm} \]

\[ V_{Rd,max} = 0.5 \cdot V_{j} \cdot f_{cd} \cdot b \cdot h_{c,\text{eff}} = 0.5 \cdot 0.5 \cdot 0.85 \cdot 3.0 \cdot 40 \cdot 38 = 646\text{ kN} \]

\[ V_{Rdj} = 0.4 \cdot \frac{2.03}{1.8} \cdot 400 \cdot 120 + 1.2 \cdot 0.7 \cdot 9.42 \cdot 10^{2} \cdot 435 = 365860\text{ N} = 365.9\text{ kN} \]

\[ < 646\text{ kN} = V_{Rd,max} \quad > 345\text{ kN} = V_{Ed} \checkmark \]

**Node resistance**

Acting shear force: 
\[ V_{jh} = A_{s,HSC} \cdot f_{yd} - V_{Ed,\text{col},o} = 9.42 \cdot 43.5 = 409.7\text{ kN} \]

Node resistance without stirrups: 
\[ V_{j,cd} = 1.55 \cdot \left( \frac{1.2 - 0.3}{h_{\text{beam}}/h_{\text{col}}} \right) \left( 1 + \frac{\rho_{\text{col}} - 0.5}{7.5} \right) \cdot b_{\text{eff}} \cdot h_{\text{col}} \cdot \frac{f_{ck}}{V_{c}}^{1/4} \]

\[ h_{\text{beam}}/h_{\text{col}} = 1.0 \quad \frac{40}{40} = 1.0 \geq 1.0 \checkmark \quad \frac{\rho_{\text{col}} - 0.5}{7.5} = 0.79\% \geq 0.5\% \checkmark \quad \leq 2.0\% \checkmark \]

\[ b_{\text{eff}} = \frac{b_{\text{beam}} + b_{\text{col}}}{2} = \frac{40 + 40}{2} = 40\text{ cm} \leq b_{\text{col}} = 40\text{ cm} \]

\[ V_{j,cd} = 1.55 \cdot \left( 1.2 - 0.3 \cdot 1.0 \right) \cdot \left( 1 + \frac{0.79 - 0.5}{7.5} \right) \cdot 400 \cdot 400 \cdot \frac{30}{1.5}^{1/4} = 490262\text{ N} = 490.3\text{ kN} > 409.7\text{ kN} = V_{jh} \quad \rightarrow \text{ no further stirrups necessary} \]

Maximum node resistance: 
\[ V_{j,Rd,max} = \gamma_{N1} \cdot \gamma_{N2} \cdot 0.3 \cdot \frac{f_{ck}}{\gamma_{C}} \cdot b_{\text{eff}} \cdot h_{\text{col}} \leq 2 \cdot V_{j,cd} \]

\[ N_{\text{Ed,\text{col}}} = 1.0 \cdot N_{C} + 0.3 \cdot \sum N_{Q} = -100 - 0.3 \cdot 140 = -142\text{ kN} \]

\[ \gamma_{N1} = 1.5 \cdot \left( 1 + 0.8 \cdot \frac{N_{\text{Ed,\text{col}}}}{A_{s,\text{col}} \cdot f_{ck}} \right) \leq 1.0 \quad \gamma_{N1} = 1.5 \cdot \left( 1 - 0.8 \cdot \frac{142}{40 \cdot 3.0} \right) = 1.46 > 1.0 \]

\[ \gamma_{N2} = 1.9 - 0.6 \cdot \frac{h_{\text{beam}}}{h_{\text{col}}} = 1.9 - 0.6 \cdot \frac{40}{40} = 1.3 > 1.0 \]

\[ V_{j,Rd,max} = 1.0 \cdot 1.0 \cdot 3.0 \cdot \frac{30}{1.5} \cdot 40.0 \cdot 40.0 - 960\text{ kN} \leq 2 \cdot V_{j,cd} - 2 \cdot 490.3\text{ kN} = 980.6\text{ kN} \]

\[ V_{jh} = 409.6\text{ kN} < 960\text{ kN} = V_{j,Rd,max} \checkmark \]
**Calculation example corbel according to approval Z-21.8-1973**

**Stirrups for transverse tensile forces**
One closed stirrup diam. 8mm near the anchor heads

**Stirrups for tensile splitting forces**

Boundary conditions: \( V_{Ed} = 345 \text{kN} > 0.3 \cdot V_{Rd,\text{max}} = 288 \text{kN} \)

\[
\frac{a_c}{h_c} = \frac{17.5}{40} = 0.44 < 0.5
\]

separate stirrups for column and corbel

\[
A_{sw,h,\text{req}} = A_{sw,v,\text{req}} \geq 0.5 \cdot A_s,\text{HSC}
\]

\[
A_{sw,\text{req}} = 0.5 \cdot 7.02 \text{cm}^2 = 3.51 \text{cm}^2
\]

\[
A_{sw,h,\text{prov}} = A_{sw,v,\text{prov}} \geq \frac{\pi}{4} \cdot 0.8^2 \cdot 4 \cdot 2 = 4.02 \text{cm}^2
\]

selected: 4 \( \varnothing 8 \) stirrups horizontally and vertically

**Secure transport**
Secure during transport using suitable cargo tension belts

**Design and dimensioning of the column**
(as conventional corbel reinforcement)

Longitudinal column reinforcement ratio:

\[
\rho_{\text{col}} = \frac{A_{s1,\text{col}}}{b_{\text{col}} \cdot h_{\text{col}}} = \frac{A_{s2,\text{col}}}{b_{\text{col}} \cdot h_{\text{col}}} = \frac{\pi \cdot 2.0^2}{40^2} = 0.79\% > 0.5\% \checkmark
\]

Anchorage of longitudinal column reinforcement:

\[
l_{b,\text{req}} = \frac{\sigma \cdot A_{s,\text{req}}}{f_{bd} \cdot \pi \cdot d \cdot n} = \frac{43.5 \cdot 3.60}{0.3 \cdot n \cdot 2.0 \cdot 4} = 20.8 \text{cm} < 38 \text{cm} = l_{b,\text{prov}} \checkmark
\]

minimum stirrup reinforcement inside the node: diam. 8 mm, \( s = 100 \text{mm} \)

HALFEN offers a free easy-to-use calculation software.
The latest version of the calculation software can be downloaded at www.halfen.com.

System requirements for HALFEN calculation software:
- Windows 7, Windows 8.1, Windows 10
- Microsoft .Net Framework 3.5, SP1 (Windows 10 system requires eventually an installation afterwards)
- Microsoft Excel 2010, 2013 or 2016 local host installed

A DVD containing calculation software, catalogues and approvals is available.
Data sheet, input values

Please send the completed form to your local HALFEN distributor by fax or by E-Mail. Adresses are listed on the catalogue cover.
Trained engineers are available to help you plan with the HALFEN HSC Stud Connector system.

Column geometry

<table>
<thead>
<tr>
<th>Item</th>
<th>b_{col}</th>
<th>mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column width</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Column depth</td>
<td>h_{col}</td>
<td>mm</td>
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</tbody>
</table>

Corbel geometry

<table>
<thead>
<tr>
<th>Item</th>
<th>b_{c}</th>
<th>mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corbel width</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corbel length</td>
<td>l_{c}</td>
<td>mm</td>
</tr>
<tr>
<td>Corbel haunch length</td>
<td>l_{c}'</td>
<td>mm</td>
</tr>
<tr>
<td>Corbel height</td>
<td>h_{c}</td>
<td>mm</td>
</tr>
<tr>
<td>Corbel haunch height</td>
<td>h_{c}'</td>
<td>mm</td>
</tr>
</tbody>
</table>

Geometry of bearing plate and point of load application

<table>
<thead>
<tr>
<th>Item</th>
<th>d_{L}</th>
<th>mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bearing plate thickness</td>
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<tr>
<td>Bearing plate width</td>
<td>b_{L}</td>
<td>mm</td>
</tr>
<tr>
<td>Bearing plate length</td>
<td>a_{L}</td>
<td>mm</td>
</tr>
<tr>
<td>Point of load application</td>
<td>a_{c}</td>
<td>mm</td>
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Loads

<table>
<thead>
<tr>
<th>Item</th>
<th>F_{Ed}</th>
<th>kN</th>
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<tbody>
<tr>
<td>Vertical load</td>
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</tr>
<tr>
<td>Horizontal load</td>
<td>H_{Ed}</td>
<td>kN</td>
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</table>

Boundary conditions

<table>
<thead>
<tr>
<th>Concrete class</th>
<th>C</th>
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</thead>
<tbody>
<tr>
<td>Concrete cover</td>
<td>c_{nom}</td>
</tr>
<tr>
<td>Monolithic corbel design?</td>
<td>or several concrete steps?</td>
</tr>
<tr>
<td>Unilateral corbel?</td>
<td>or bilateral corbel?</td>
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</table>

Column data above the corbel

<table>
<thead>
<tr>
<th>Item</th>
<th>N_{Ed,col,o}</th>
<th>kN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical load</td>
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<tr>
<td>Horizontal load</td>
<td>V_{Ed,col,o}</td>
<td>kN</td>
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<tr>
<td>Outer column reinforcement (longitudinal)</td>
<td>Number</td>
<td>pcs</td>
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<td></td>
<td>Diam.</td>
<td>mm</td>
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Proof of fatigue resistance

<table>
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<tr>
<th>Item</th>
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<td>Max. vertical force</td>
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</tr>
<tr>
<td>Min. vertical force</td>
<td>V_{Ed,min}</td>
<td>kN</td>
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</table>

Minimum element dimensions according to approval no. Z21.8-1973, appendices 3 and 4

<table>
<thead>
<tr>
<th>Anchor diam. HSC</th>
<th>Concrete strength class</th>
<th>Minimum constructional dimensions</th>
<th>Column</th>
<th>Corbel</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>C20/25-C70/85</td>
<td>b_{col,min} h_{col,min} b_{c,min} l_{c,min}</td>
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<tr>
<td>12</td>
<td>300/300</td>
<td>240/240 200/200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
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<td>25</td>
<td>300/300</td>
<td>240/240 200/200</td>
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</table>
HALFEN HSC STUD CONNECTOR
Product Range, References for Length Calculation

HSC-S Single headed female bars

Material: Concrete steel B500B Ⓡ

<table>
<thead>
<tr>
<th>Article name type bar diam. ds / L [mm]</th>
<th>L.min [mm]</th>
<th>Article No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>HSC - S - 12 / . . .</td>
<td>155</td>
<td>0060.300 Ⓡ</td>
</tr>
<tr>
<td>HSC - S - 16 / . . .</td>
<td>180</td>
<td>0060.310 Ⓡ</td>
</tr>
<tr>
<td>HSC - S - 20 / . . .</td>
<td>200</td>
<td>0060.320 Ⓡ</td>
</tr>
<tr>
<td>HSC - S - 25 / . . .</td>
<td>230</td>
<td>0060.330 Ⓡ</td>
</tr>
</tbody>
</table>

① required length, please indicate with your order, see page bottom.

HSC-A Single headed male bars

Material: Concrete steel B500B Ⓡ

<table>
<thead>
<tr>
<th>Article name type bar diam. ds / L [mm]</th>
<th>L.min [mm]</th>
<th>Screw depth L3 [mm]</th>
<th>Article No.</th>
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</thead>
<tbody>
<tr>
<td>HSC - A - 12 / . . .</td>
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<td>16,5</td>
<td>0060.400 Ⓡ</td>
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<tr>
<td>HSC - A - 16 / . . .</td>
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<td>22,5</td>
<td>0060.410 Ⓡ</td>
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<tr>
<td>HSC - A - 20 / . . .</td>
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<td>28,5</td>
<td>0060.420 Ⓡ</td>
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<tr>
<td>HSC - A - 25 / . . .</td>
<td>190</td>
<td>36</td>
<td>0060.430 Ⓡ</td>
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</tbody>
</table>

① please state required length when ordering, see bottom of page.

*) Constructional column requirements and country-specific approvals (if applicable) have to be considered. Applies to concrete cover cnom = 30 mm.

Design with simplified keyed joint, order length

HSC-S standard lengths

<table>
<thead>
<tr>
<th>Type</th>
<th>Article No.</th>
<th>Diam. ds [mm]</th>
<th>Length L [mm]</th>
<th>For column dimensions hcol [mm]</th>
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<tr>
<td>HSC-S</td>
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*) Constructional column requirements and country-specific approvals (if applicable) have to be considered. Applies to concrete cover cnom = 30 mm.

HSC-A standard lengths

<table>
<thead>
<tr>
<th>Type</th>
<th>Article No.</th>
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<th>Length L [mm]</th>
<th>For corbel extensions l3 [mm]</th>
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<td>0060.400-00002</td>
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<td>0060.420-00005</td>
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<td>408</td>
<td>400</td>
<td></td>
</tr>
</tbody>
</table>

Design with indented joint, order length

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HALFEN HSC STUD CONNECTOR
Product Range, References for Length Calculation

HSC-SD Double female bar

Material: Concrete steel B500B

HSC-HD Double headed bar

Material: Concrete steel B500B

Formwork accessories

Nailing plate, plastic 3905
Magnetic plate 6365
Nailing plate, metal 3916

Depending on performance and to find the required order length L the following has to be considered:

- column dimensions h_{col}
- corbel length l_c
- concrete cover c acc. to structural analysis
- thickness H of the nailing/magnetic plates
- thread length L_3 of HSC-A bars according to bar diameter
- key joint depth t_j
- minimum constructional dimensions according to approval, see table on page 7-8.

HSC-H Single headed anchor bar

Material: Concrete steel B500B

Article name for bar diam. d_s / L [mm] L_{min} [mm] Article No.

HSC - SD - 12 / ... 205 0060.500
HSC - SD - 16 / ... 215 0060.510
HSC - SD - 20 / ... 230 0060.520
HSC - SD - 25 / ... 275 0060.530

© please state required length when ordering, see bottom of page

Article name for bar diam. d_s / L [mm] L_{min} [mm] Article No.

HSC - HD - 12 / ... 175 0060.200
HSC - HD - 16 / ... 175 0060.210
HSC - HD - 20 / ... 175 0060.220
HSC - HD - 25 / ... 180 0060.230

© please state required length when ordering

Table of Article names and specifications:

<table>
<thead>
<tr>
<th>Article name</th>
<th>For bar diam. d_s [mm]</th>
<th>D [mm]</th>
<th>H [mm]</th>
<th>Article No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3905 - 12</td>
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<td>3905 - 16</td>
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<td>0725.020-00004</td>
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<td>3905 - 20</td>
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<td>10</td>
<td>0725.020-00005</td>
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<tr>
<td>3916 - 25</td>
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<td>12</td>
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<td>6365 - 20</td>
<td>20</td>
<td>55</td>
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<td>0741.180-00003</td>
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</table>

Dimensions HSC anchor head

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<tr>
<th>HSC - Type</th>
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<th>16</th>
<th>20</th>
<th>25</th>
</tr>
</thead>
<tbody>
<tr>
<td>bar diameter Ø_{ds} [mm]</td>
<td>12</td>
<td>16</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>anchor head width f [mm]</td>
<td>30</td>
<td>35</td>
<td>44</td>
<td>55</td>
</tr>
<tr>
<td>anchor head length g [mm]</td>
<td>35</td>
<td>53</td>
<td>66</td>
<td>83</td>
</tr>
<tr>
<td>contact-surface under-head A_{c0} [mm²]</td>
<td>906</td>
<td>1599</td>
<td>2504</td>
<td>3940</td>
</tr>
</tbody>
</table>

Notes

Flash butt welding in accordance with EN ISO 17660-1 is mandatory for factory-welded butt-joints on HSC anchors when welding special lengths and designs. The EN ISO 17660-1 guidelines are generally only valid for predominantly static loads. For fatigue susceptible building elements a distinct decrease in fatigue strength of the B500B reinforcement should be taken into account.

Please contact HALFEN Technical Support if you require technical assistance for your individual projects.

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HALFEN HSC STUD CONNECTOR

HSC Stud Connector

Text for invitation to tender

HALFEN HSC Stud Connector type HSC-S-16/L

HALFEN HSC Stud Connector type HSC-S reinforcement bar with sleeve and with unilateral forged anchor heads, for connection and anchorage of reinforcement steel bars, with National Technical Approval, for predominantly and non-predominantly static loads,

suitable as multilayer and staggered reinforcement,
using rectangle shaped stud heads optimized for minimum bar spacing, short bond lengths and high degree of reinforcement, material B500B,

type HSC-S-16/L
16 = diameter [mm],
L = length ... [mm],

or equivalent; deliver and install according to manufacturer's instructions.

HALFEN HSC Stud Connector type HSC-HD-20/L

HALFEN HSC Stud Connector type HSC-HD reinforcement bar with two forged anchor head, for connection and anchorage of reinforcement steel bars, with National Technical Approval, for predominantly and non-predominantly static loads,

suitable as multilayer and staggered reinforcement,
using rectangle shaped stud heads optimized for minimum bar spacing, short bond lengths and high degree of reinforcement, material B500B,

type HSC-HD-20/L
20 = diameter [mm],
L = length ... [mm],

or equivalent; deliver and install according to manufacturer's instructions.

Further tender texts are available at www.halfen.com
HALFEN HSC STUD CONNECTOR

HSC Stud Connector

Order form

[ ] Enquiry  [ ] Order

(Please tick appropriate)

Please send the completed form to your local HALFEN distributor by fax or by E-mail. Addresses are listed on the catalogue cover. Trained engineers are available to help you plan with the HALFEN HSC Stud Connector system.

Organisation/facility

Address

Contact person

Phone

Fax

E-mail

Construction project

HSC-S
single headed female bar

HSC-A
single headed male bar

HSC-SD
double sleeve female bar

HSC-HD
double headed bar

HSC-H
single headed bar

Formwork accessories

Nailing plate, plastic

Magnetic plate

Nailing plate, metal

h = 9 mm

pos. No. [pcs.]

Type

Bar diam. \(d_s\) [mm]

Length [mm]

Article no.

Price per unit [EUR]

Total price per pos. [EUR]

Amount EUR

packaging and freight charges added

Delivery address

(only if different from order address)

Date, signature

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## CONTACT HALFEN WORLDWIDE

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<table>
<thead>
<tr>
<th>Country</th>
<th>Address</th>
<th>Phone</th>
<th>E-Mail</th>
<th>Internet</th>
<th>Fax</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>HALFEN Gesellschaft m.b.H. Leonard-Bernstein-Str. 10 1220 Wien</td>
<td>+43-1-259 6770</td>
<td><a href="mailto:office@halfen.at">office@halfen.at</a></td>
<td><a href="http://www.halfen.at">www.halfen.at</a></td>
<td>+43-1-259-677099</td>
</tr>
<tr>
<td>Belgium/Luxembourg</td>
<td>HALFEN N.V. Borkelstraat 131 2900 Schoten</td>
<td>+32-3-658 07 20</td>
<td><a href="mailto:info@halfen.be">info@halfen.be</a></td>
<td><a href="http://www.halfen.be">www.halfen.be</a></td>
<td>+32-3-658 15 33</td>
</tr>
<tr>
<td>China</td>
<td>HALFEN Construction Accessories Distribution Co.Ltd. Room 601 Tower D, Vantone Centre No. A6 Chao Yang Men Wai Street Chaoyang District Beijing - P.R. China 100020</td>
<td>+86-10 5907 3200</td>
<td><a href="mailto:info@halfen.cn">info@halfen.cn</a></td>
<td><a href="http://www.halfen.cn">www.halfen.cn</a></td>
<td>+86-10 5907 3218</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>HALFEN s.r.o. Business Center Šafránkova Šafránkova 1238/1 155 00 Praha 5</td>
<td>+420-311-690 060</td>
<td><a href="mailto:info@halfen-deha.cz">info@halfen-deha.cz</a></td>
<td><a href="http://www.halfen-deha.cz">www.halfen-deha.cz</a></td>
<td>+420-235-314 308</td>
</tr>
<tr>
<td>France</td>
<td>HALFEN S.A.S. 18, rue Goubet 75019 Paris</td>
<td>+33-1-44523100</td>
<td><a href="mailto:halfen@halfen.fr">halfen@halfen.fr</a></td>
<td><a href="http://www.halfen.fr">www.halfen.fr</a></td>
<td>+33-1-44523152</td>
</tr>
<tr>
<td>Germany</td>
<td>HALFEN Vertriebsgesellschaft mbH Liebigstr. 14 40764 Langenfeld</td>
<td>+49-2173-970-0</td>
<td><a href="mailto:info@halfen.de">info@halfen.de</a></td>
<td><a href="http://www.halfen.de">www.halfen.de</a></td>
<td>+49-2173-970 225</td>
</tr>
<tr>
<td>Italy</td>
<td>HALFEN S.r.l. Soc. Unipersonale Via F.Lli Bronzetti N° 28 24124 Bergamo</td>
<td>+39-035-0760711</td>
<td><a href="mailto:tecnico@halfen.it">tecnico@halfen.it</a></td>
<td><a href="http://www.halfen.it">www.halfen.it</a></td>
<td>+39-035-0760799</td>
</tr>
<tr>
<td>Netherlands</td>
<td>HALFEN b.v. Oostermaat 3 7623 CS Borne</td>
<td>+31-74-267 14 49</td>
<td><a href="mailto:info@halfen.nl">info@halfen.nl</a></td>
<td><a href="http://www.halfen.nl">www.halfen.nl</a></td>
<td>+31-74-267 26 59</td>
</tr>
<tr>
<td>Norway</td>
<td>HALFEN AS Postboks 2080 4095 Stavanger</td>
<td>+47-51 82 34 00</td>
<td><a href="mailto:post@halfen.no">post@halfen.no</a></td>
<td><a href="http://www.halfen.no">www.halfen.no</a></td>
<td>+47-51 82 34 01</td>
</tr>
<tr>
<td>Poland</td>
<td>HALFEN Sp. z o.o. U1. Obornicka 287 60-691 Poznan</td>
<td>+48-61-622 14 14</td>
<td><a href="mailto:info@halfen.pl">info@halfen.pl</a></td>
<td><a href="http://www.halfen.pl">www.halfen.pl</a></td>
<td>+48-61-622 14 15</td>
</tr>
<tr>
<td>Sweden</td>
<td>Halfen AB Vädersgatan 5 412 50 Göteborg</td>
<td>+46-31-98 58 00</td>
<td><a href="mailto:info@halfen.se">info@halfen.se</a></td>
<td><a href="http://www.halfen.se">www.halfen.se</a></td>
<td>+46-31-98 58 01</td>
</tr>
<tr>
<td>Switzerland</td>
<td>HALFEN Swiss AG Hertistrasse 25 8304 Wallisellen</td>
<td>+41-44 849 78 78</td>
<td><a href="mailto:info@halfen.ch">info@halfen.ch</a></td>
<td><a href="http://www.halfen.ch">www.halfen.ch</a></td>
<td>+41-44 849 78 79</td>
</tr>
<tr>
<td>United Kingdom/Ireland</td>
<td>HALFEN Ltd. A1/A2 Portland Close Houghton Regis LUS 5AW</td>
<td>+44-1582-47 03 00</td>
<td><a href="mailto:info@halfen.co.uk">info@halfen.co.uk</a></td>
<td><a href="http://www.halfen.co.uk">www.halfen.co.uk</a></td>
<td>+44-1582-47 03 04</td>
</tr>
<tr>
<td>United States of America</td>
<td>HALFEN USA Inc. 8521 FM 1976 P.O. Box 547 Converse, TX 78109</td>
<td>+1 800.423.91 40</td>
<td><a href="mailto:info@halfenusa.com">info@halfenusa.com</a></td>
<td><a href="http://www.halfenusa.com">www.halfenusa.com</a></td>
<td>+1 877.683.4910</td>
</tr>
</tbody>
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For countries not listed:

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<table>
<thead>
<tr>
<th>Address</th>
<th>Phone</th>
<th>E-Mail</th>
<th>Internet</th>
<th>Fax</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liebigstr. 14 40764 Langenfeld/Germany</td>
<td>+49-2173-970-0</td>
<td><a href="mailto:info@halfen.com">info@halfen.com</a></td>
<td><a href="http://www.halfen.com">www.halfen.com</a></td>
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