HALFEN HSC STUD CONNECTOR

TECHNICAL PRODUCT INFORMATION

HALFEN HSC STUD CONNECTOR

CONCRETE

HSC 13-E

NEW!

- with RAL-Quality Mark RAL-GZ 658/2
- approval acc. to Eurocode 2
- extended range, now with 12 mm bar diameter
- beam and slab supports approved by Z-21.8-1973

RAL GÜTEZEICHEN Verankerungs- und Bewehrungstechniken RAL-GZ 658/2

HALFEN

YOUR BEST CONNECTIONS

General

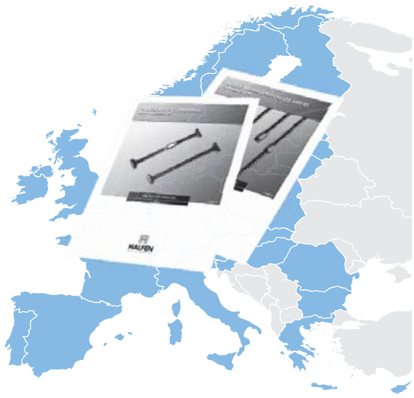
Highly effective reinforcement anchor

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.

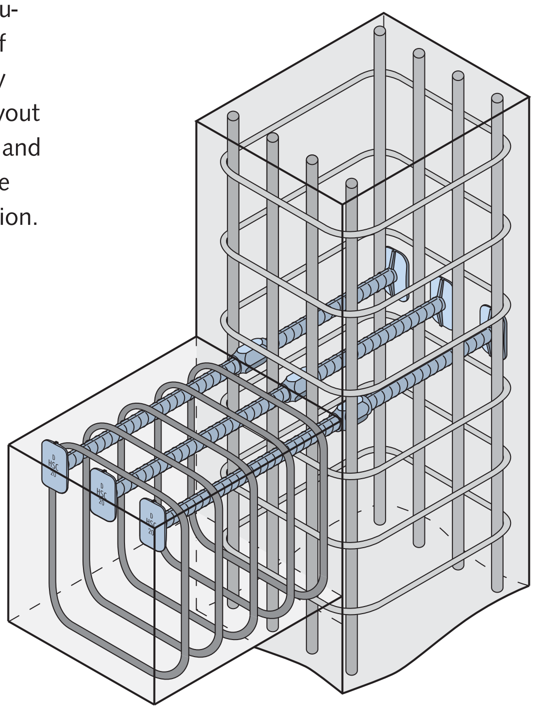
The HALFEN HSC Stud connector is especially suitable for use in highly reinforced areas such as corbels and beam to column connections.
The problems that occur in the layout of reinforcement and distribution of forces with conventional rebar solutions do not apply. The amount of reinforcement steel is considerably reduced and the reinforcement layout is simpler. Apart from saving cost and time a substantial advantage is the increased reliabilty 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 Building Authority Approval, according to DIN 1045-1 and European standard Eurocode 2
- screw joints between concreting sections means no cost-intensive formwork penetrations are required

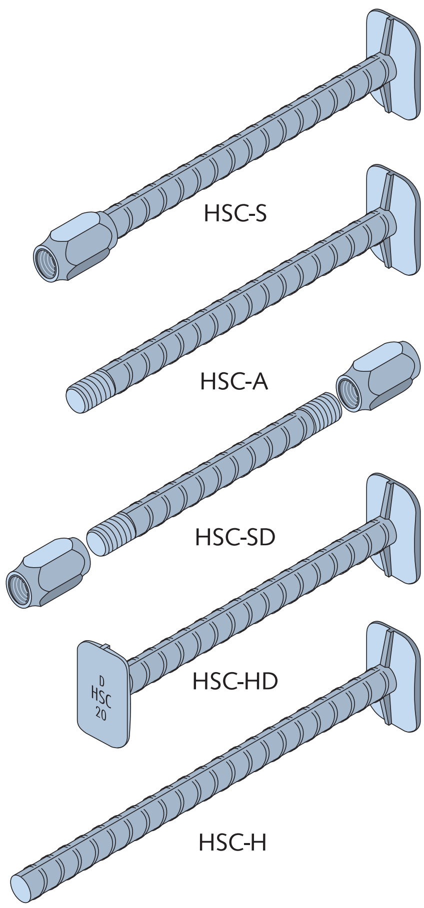


Building Authority Approval Z-21.8-1973 for HALFEN HSC Stud connector
Building Authority Approval Z-1.5-189 for HALFEN HBS-05 Screw connection



Corbel with HALFEN HSC Stud Connector

HALFEN HSC bar types



RAL
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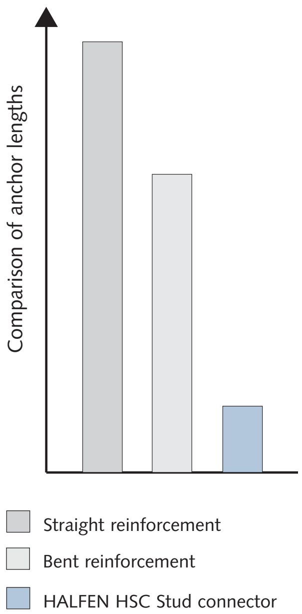
Verankerungs- und Bewehrungstechniken
RAL-GZ 658/2

The RAL Quality Mark guarantees compliance with the technical product requirements and the related services regarding:

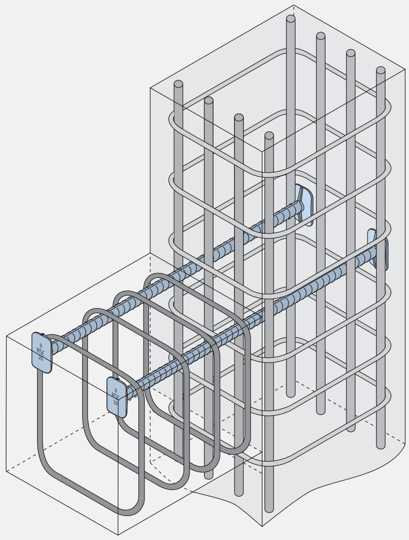
- Specification, quality management logistics, competent technical advice, high-quality technical documentation and software, fulfilment of the guaranteed benefits and guaranteeing the neutrality of tender documents.

Biannual monitoring provided by German LLoyd guarantees that the recommended requirements of the quality control association for anchor and reinforcement technology (Gütegemeinschaft Verankerungs und Bewehrungstechnik e.V) are maintained.

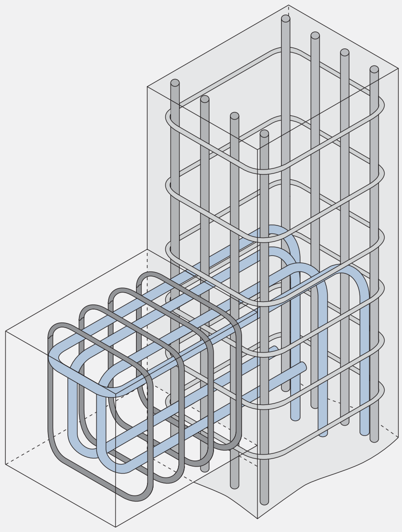
Extremely short anchorage lengths



Simple reinforcement layout

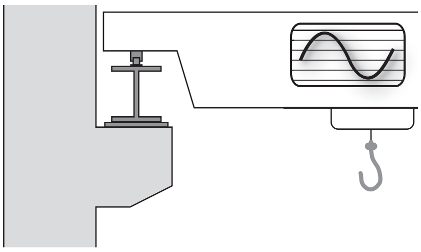


Corbel with HALFEN HSC Stud connector: secure anchorage, simple reinforcement layout



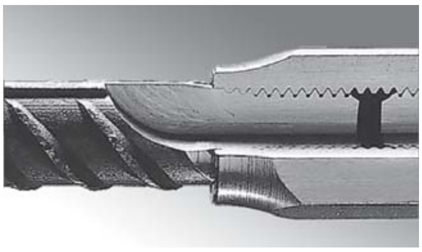
Conventional corbel reinforcement with large bending diameters, high steel usage and complicated reinforcement

Advantages in planning and design



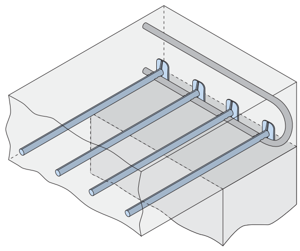
- Approval for predominantly static and non-predominantly static loading cases
- approved for predominantly static and non-predominantly static loads
- standard-anchors available from stock
- HALFEN provides free easy-to-use corbel dimensioning software
- HALFEN provides a complimentary consultation 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

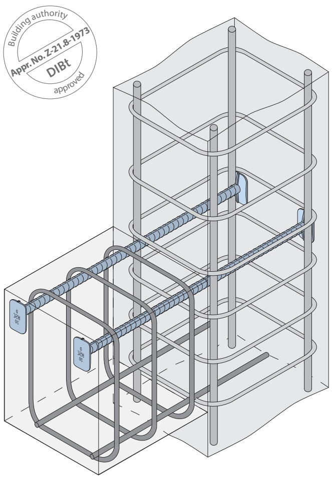
Wide application range



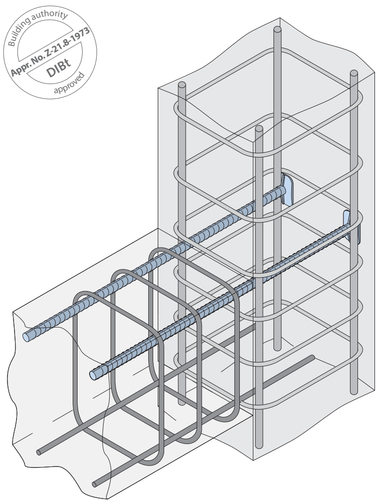
- corbels
- frame corners
- beam supports
- slab supports
- half joints
- frame corners exposed to positive bending moments

Application Examples

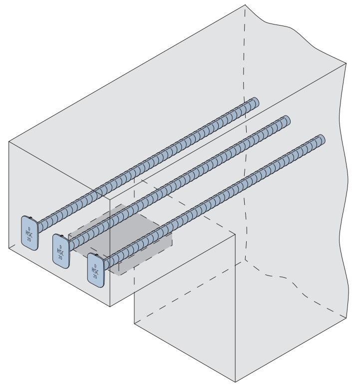
Corbels → page 7 - 10



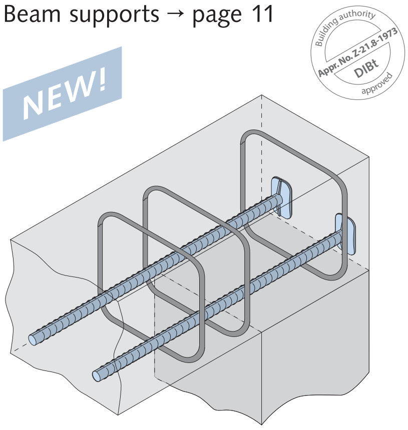
Frame corners → page 6



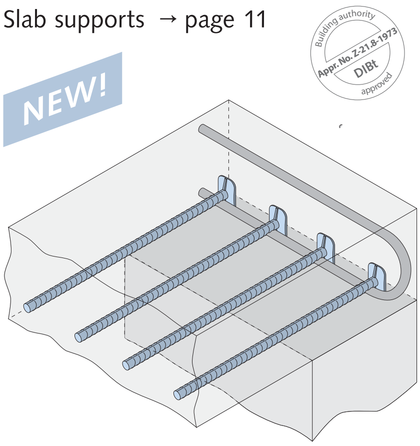
Half joints



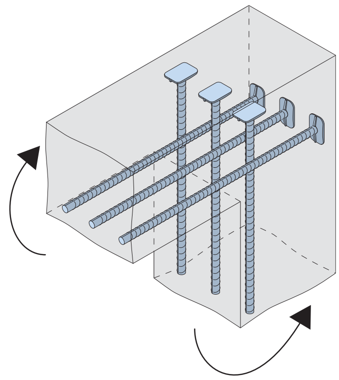
Beam supports → page 11



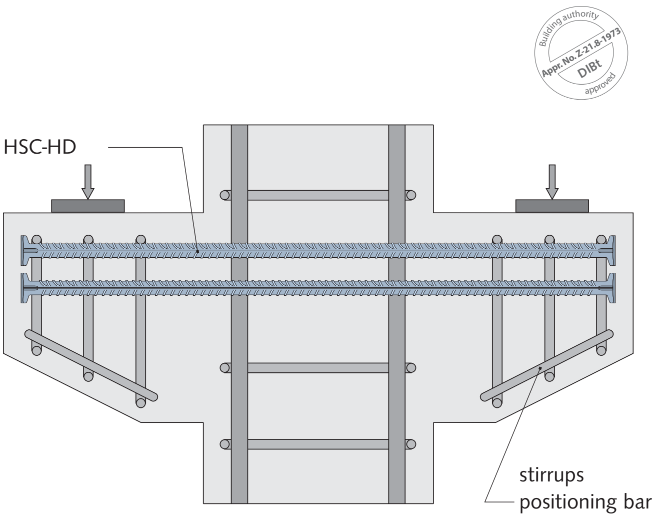
Slab supports → page 11



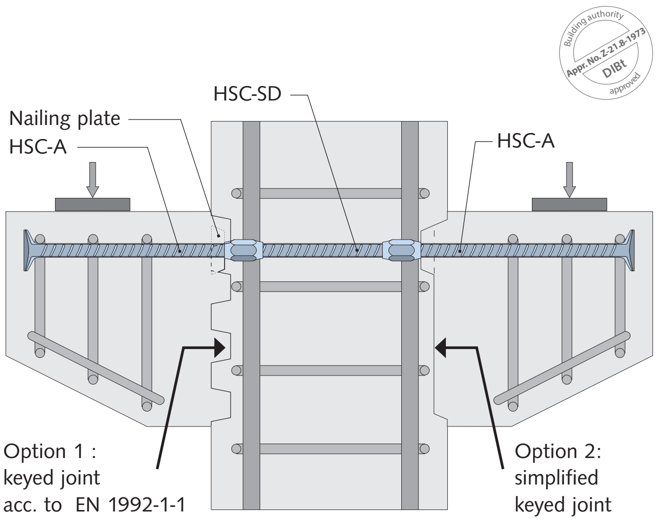
Frame corners exposed to positive bending moments



Examples of corbel application



Corbel with multilayer reinforcement in monolithic element → page 16



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

HALFEN HSC STUD CONNECTOR

Design and Dimensioning, Basics

Application according to approval Z-21.8-1973

Materials

- normal-weight concrete, strength classes C20/25 up to C70/85
- HSC: B500B

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 $N = 2 \cdot 10^6$:
  $\Delta\sigma_{RSK} = 80$ N/mm² for $d_{HSC} = 12$ mm, $d_{HSC} = 16$ mm and $d_{HSC} = 20$ mm
  $\Delta\sigma_{RSK} = 70$ N/mm² for $d_{HSC} = 25$ mm
- Wöhlerline stress exponents:
  $k_1 = 3.5$ for $N \leq 2 \cdot 10^6$
  $k_1 = 3$ 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 nodes, corbels, beams and slabs
- simplfied 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 column and corbel design and reinforcement

Installation fundamentals

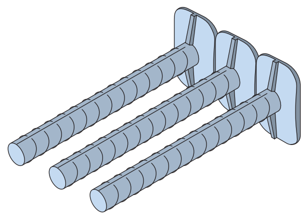
Placement of anchor heads

Anchor heads may be aligned vertically or horizontally as required.

Spacing of bars

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

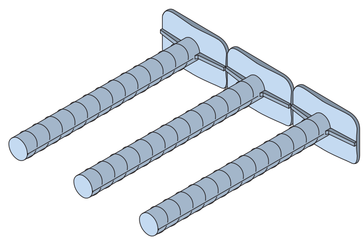
When used in several concrete sections the minimum distances a_{HSC} resp. e_{HSC} must be observed to ensure the male bars can be securely installed. See figures and table below.



Vertical anchor head layout

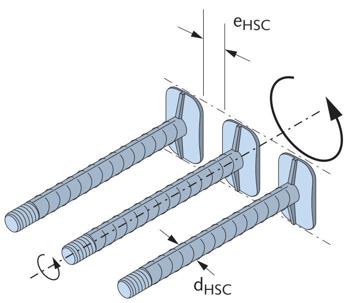
Minimum head spacings to ensure male bars can be installed and tightened (HSC connection bars)

d_{HSC} [mm]	e_{HSC} [mm]	a_{HSC} [mm]
12	10	15
16	20	20
20	20	25
25	25	30

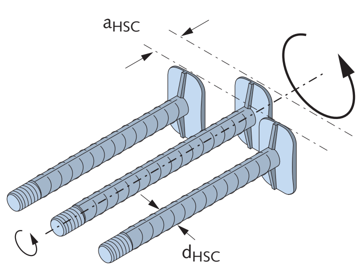


Horizontal anchor head layout

Option 1: anchor heads in alignment



Option 2: reduced spacings with staggered anchor head layout



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

TECHNICAL SUPPORT

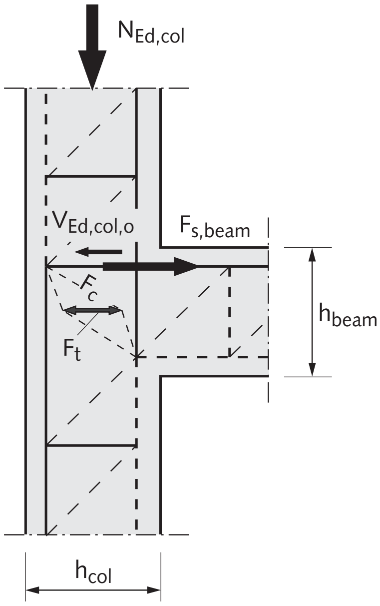
HALFEN Technical Support

engineering services and technical advice for your projects is available

Contact addresses for all HALFEN Products can be found at the back of this catalogue.

Frame corner according to approval Z-21.8-1973

Figure 1 : Strut and tie model



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 Building Authority Approval.

Design and dimensioning of the column
Minimal column dimensions are according to the approval: see table "minimum dimensions" on page 7.
Longitudinal reinforcement ratio:

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

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:

$$l_b = \frac{|T| + |C_s|}{f_b \cdot n \cdot U} \leq h_{beam}$$

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 ⅓ compared to the bending dimensioning values. This additional reinforcement has to be anchored starting from the columns cross sections; compare to, DAfStb publication no.532.

Design and dimensioning of the beam
Origin of the beam bending dimensioning is at a distance of 0.3 h_{col} from the column's central axis. The anchor heads have to be positioned behind the longitudinal column reinforcement. Observe the Building Authority approval to verify the anchor.

Stirrup reinforcement
Beam and column have to be reinforced with stirrups with length h_{col} / h_{beam}, measured from the joint cross sections, with a maximum spacing of s = 10 cm. See figure 2 below: "minimal stirrup reinforcement".

Shear resistance

Applied shear force V_{jh}:

$$V_{jh} = A_{s,HSC} \cdot f_{yd} - V_{Ed,col,o}$$

Limitation of the shear force V_{jh} to $V_{jh} \leq \begin{cases} V_{j,Rd} \\ V_{j,Rd,max} \end{cases}$

Node resistance $V_{j,cd}$ **without** stirrups [N]:

$$V_{j,cd} = 1.55 \cdot \left(1.2 - 0.3 \cdot \frac{h_{beam}}{h_{col}}\right) \cdot \left(1 + \frac{\rho_{col} - 0.5}{7.5}\right) \cdot b_{eff} \cdot h_{col} \cdot \left(\frac{f_{ck}}{\gamma_c}\right)^{\frac{1}{4}}$$

with: $1.0 \leq \frac{h_{beam}}{h_{col}} \leq 2.0$ $\quad 0.5\% \leq \rho_{col} \leq 2.0\%$

$$b_{eff} = \frac{b_{beam} + b_{col}}{2} \leq b_{col}$$

b_{eff}, h_{col} ... effective width, height of column cross section in [mm]; f_{ck} in [N/mm²]

Shear resistance $V_{j,Rd}$ **with** stirrups:

$$V_{j,Rd} = V_{j,cd} + 0.475 \cdot A_{sj,eff} \cdot f_{yd} \leq V_{j,Rd,max}$$

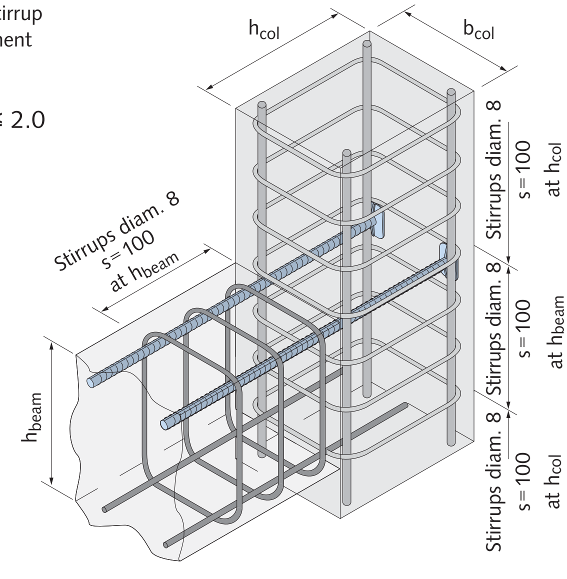
with: $A_{sj,eff}$ = effective shear reinforcement (Aligned between upper edge joint and upper edge compression zone beam)

Maximum node resistance $V_{j,Rd,max}$:

$$V_{j,Rd,max} = \gamma_{N1} \cdot \gamma_{N2} \cdot 0.3\ \frac{f_{ck}}{\gamma_c} \cdot b_{eff} \cdot h_{col} \leq 2 \cdot V_{j,cd}$$

Figure 2: Geometry, minimal stirrup reinforcement

$$\frac{h_{beam}}{h_{col}} \leq 2.0$$



with: $\gamma_{N1} = 1.5 \cdot \left(1 + 0.8 \cdot \frac{N_{Ed,col}}{A_{c,col} \cdot f_{ck}} \right) \leq 1.0$

$$\gamma_{N2} = 1.9 - 0.6 \cdot \frac{h_{beam}}{h_{col}} \leq 1.0$$

Quasi-permanent normal column force

$$N_{Ed,col} = 1.0 \cdot N_G + 0.3 \cdot \sum N_Q$$

(Compression force negative)

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

Minimum dimensions

Anchor diameter	Column			Concrete strength class
d_{HSC} [mm]	$b_{col,min}$ [mm]	$h_{col,min}$ [mm]	$d_{s,col,min}$ [mm]	
12	240	240	12	C20/25 - C70/85
16	240	240	12	C20/25 - C70/85
20	300	300	16	C20/25 - C35/45
	240	240		C40/50 - C70/85
25	300	400	20	C20/25
	300	350		C25/30 - C30/37
	300	300		C35/45 - C70/85

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 Building Authority approval.

Geometry, actions
short corbels: $a_c / h_c \leq 0.5$
long corbels: $0.5 < a_c / h_c < 1.0$

$V_{Ed} = F_{Ed}$
$H_{Ed} \geq 0.2 \cdot F_{Ed}$ (Unless frictional forces resulting from constraint deformation can not be excluded)

Shear resistance of the corbel
Minimum dimensions according to the approval:
see table on page 8.

$$V_{Ed} \leq V_{Rd,max} = 0.5 \cdot \nu \cdot b_c \cdot z \cdot \frac{f_{ck}}{\gamma_c}$$

with: $\nu = 0.7 - \frac{f_{ck}}{200\ \text{N/mm}^2} \geq 0.5;\ z = 0.9 \cdot d$

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: $\frac{a_c}{z_0} \geq 0.4$

$$z_0 = d \cdot \left(1 - 0.4 \cdot \frac{V_{Ed}}{V_{Rd,max}} \right)$$

Verifying the required HSC anchor cross section

$A_{s,HSC} = \frac{Z_{Ed}}{f_{yd}}$ 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 Building Authority requirements are observed; compare with figures and tables.

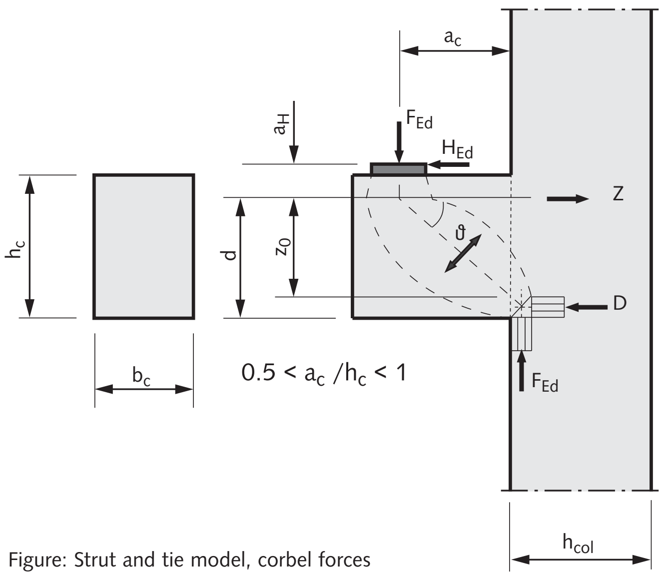


Figure: Strut and tie model, corbel forces

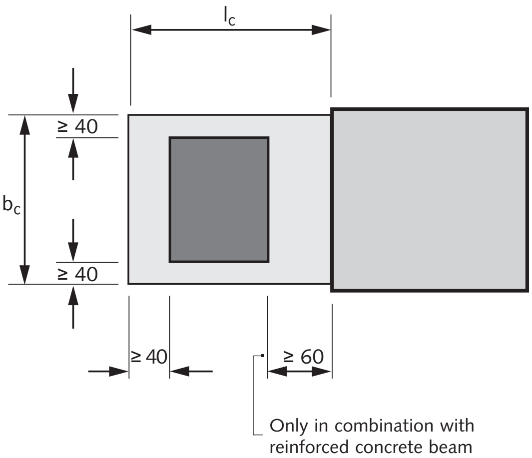


Figure: Bearing plate, top view

Design and Dimensioning of Corbels, Construction Specifications

Corbels according to approval Z-21.8-1973

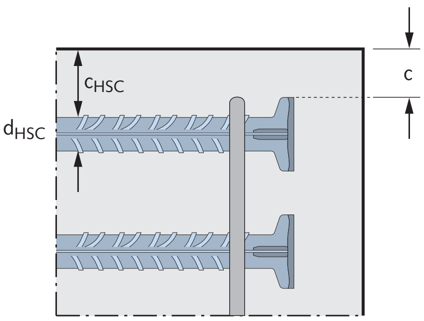
Deviating from the standard layout, HSC can be placed multilayered or staggered, corbel dimensions can also be below minimum given values. In these cases further calculations are required; see approval.

Further verifications and regulations

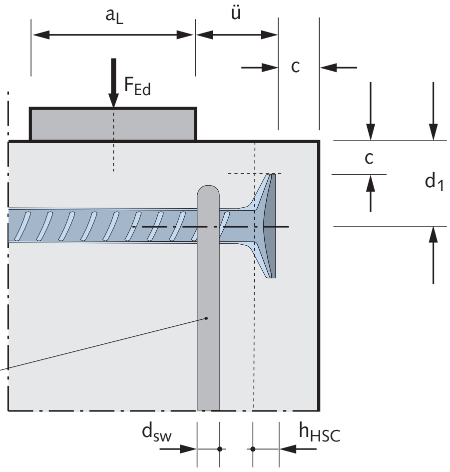
The transfer of forces to the column in single corbels can be verified using the same design rules as used for frame corners → see page 6.

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 → see page 9.
Transport safety device → see page 9.
Proof of the keyed joint within subsequently concreted corbels → see page 10.

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

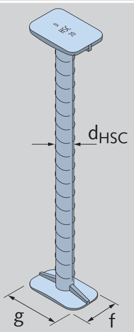


Vertical section



Stirrups to absorb transverse tensile forces

Constructional specifications



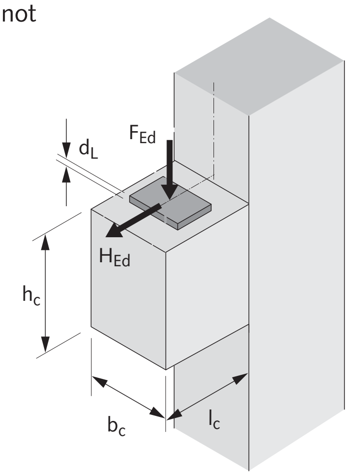
Anchor dimensions				Corbel dimensions		Concrete strength class	Stirrups	Concrete cover		Excess length
d_{HSC} [mm]	f [mm]	g [mm]	h_{HSC} [mm]	$b_{c,min}$ [mm]	$l_{c,min}$ [mm]	[-]	d_{sw} [mm]	c_{HSC} [mm]	c [mm]	ü [mm]
12	30	35	8	200	200	C20/25 ... C70/85	≥ 6	≥ 30	acc. to DIN EN 1992-1-1	$ü \geq \max \begin{cases} \frac{c}{2} + h_{HSC} \\ \frac{d_1}{2} + h_{HSC} - \frac{a_L}{2} \end{cases}$ (HSC single layer, not staggered)
16	35	53	10	200	200	C20/25 ... C70/85	≥ 6	≥ 40		
20	44	66	12	300	300	C20/25 ... C25/30	≥ 8	≥ 50		
				240	200	C30/37 ... C35/45				
				200	200	C40/50 ... C70/85				
25	55	83	14	300	400	C20/25	≥ 10	≥ 60		
				300	350	C25/30 ... C30/37				
				300	300	C35/45 ... C70/85				

Reference values for corbel resistances

Anchor diameter	Concrete	Corbel dimensions			**max V_{Ed}**
d_{HSC}		b_c	l_c	h_c (= b_c)	**(≤ $V_{Rd,max}$)**
[mm]	[-]	[mm]	[mm]	[mm]	**[kN]**
12	C20/25	200	200	200	**119**
12	C30/37	200	200	200	**163**
12	C40/50	200	200	200	**195**
16	C20/25	200	200	200	**117**
16	C30/37	200	200	200	**152**
16	C40/50	200	200	200	**184**
20	C20/25	300	300	300	**279**
20	C30/37	240	200	240	**235**
20	C40/50	200	200	200	**190**
25	C20/25	300	400	300	**273**
25	C30/37	300	350	300	**375**
25	C40/50	300	300	300	**455**

Note: These are estimated reference values.
Individual cases require separate verification.

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



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:

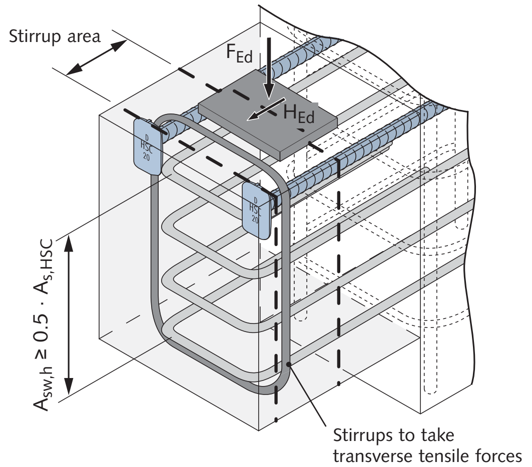
Closed horizontal **and** vertical stirrups inside the corbel, with a minimum overall cross section of 50% of the HSC reinforcement (separate stirrup arrangement).

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
$F_{wd} = 0.7 \cdot F_{Ed}$

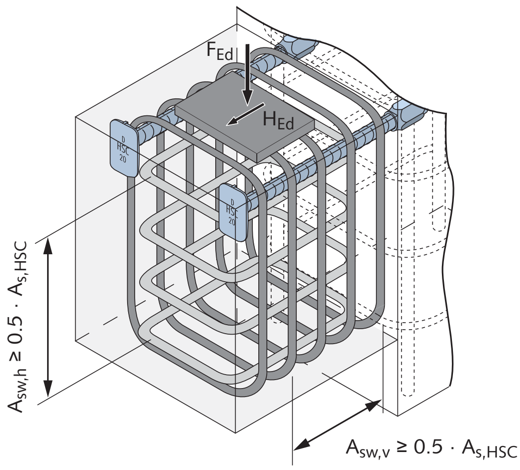
Transport safety device

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 i.e. securing with tension belts are possible.

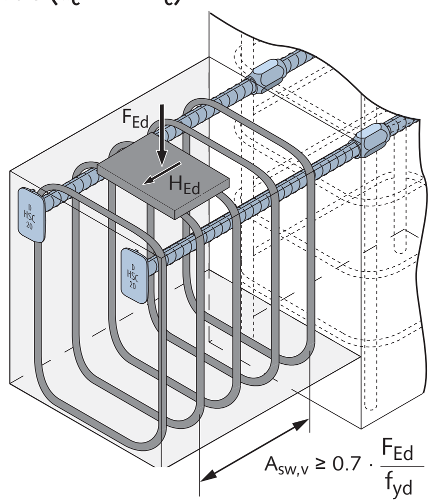
Short corbels ($a_c \leq 0.5\ h_c$)
Option 1: continuous tensile splitting reinforcement



Short corbels ($a_c \leq 0.5\ h_c$)
Option 2: separate stirrup arrangement



Long corbels ($a_c > 0.5\ h_c$)



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 of this catalog.

Shear joints according to approval Z-21.8-1973

The shear joint can be configured either as a key joint or as 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

$V_{Ed} \leq V_{Rdj} = c_j \cdot f_{ctd} \cdot b_c \cdot x_j + 1.2 \cdot \mu \cdot A_{sj} \cdot f_{yd} \leq V_{Rdj,max}$

with:

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

x_j = h_c for key joint

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

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

$h_{c,eff}$ = h_c for key joint

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

x_c ... height of compression zone ($x_c = (d - z_0) \cdot 2$)

b_c, h_c ... width of the joint, height of the joint

A_{sj} ... overall cross section of the tensile zone reinforcement, crossing the joint at 90 degree

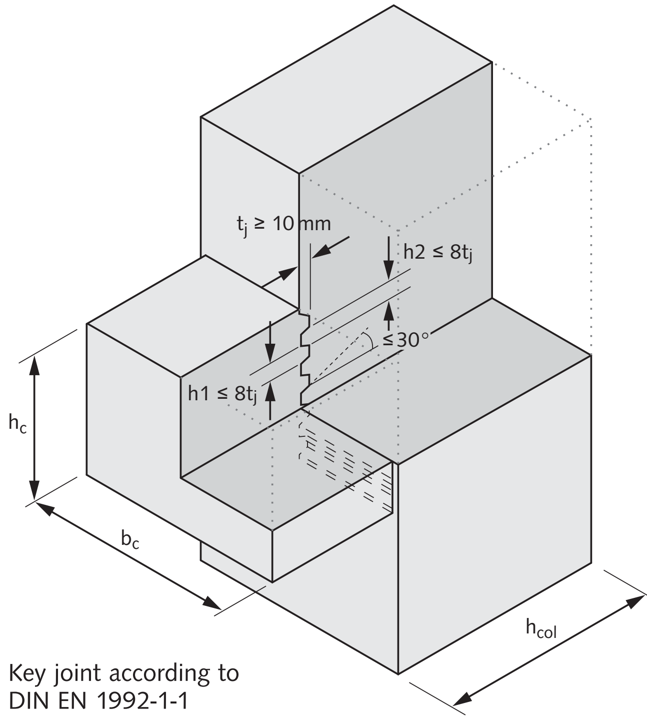
c_j, μ, ν_j, ... joint parameters according to table

f_{cd} ... design value of concrete compressive strength

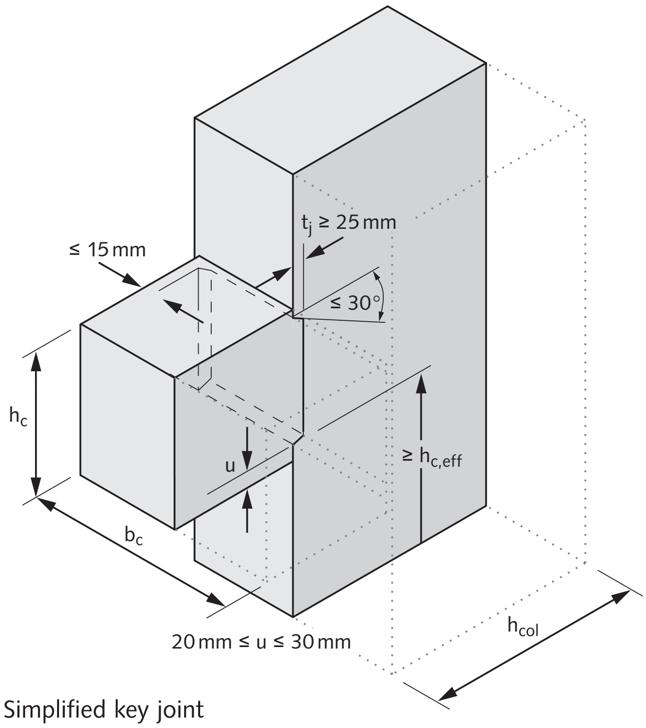
f_{ctd} = $f_{ctk;0.05} / \gamma_c$ ... design value of concrete tensile strength with $\gamma_c = 1.8$

Shear joints are usually designed with female bars and threaded bars. To ensure a good screw connection for HSC-A bars please refer to the assembly instructions on page 5.

Coefficients of shear joints			
Joint design	c_j	μ	ν_j
Key joint	0.5	0.9	0.7
Simplified keyed joint	0.4	0.7	0.5



Key joint according to DIN EN 1992-1-1



Simplified key joint

End Anchorage in Beams and Slabs

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 side 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 Building Authority 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:

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

with: σ* = allowable compression at calculated bearing, compare to figure. ü = head overlap

$$ü \geq \max \begin{cases} \frac{c}{2} + h_{HSC} \\ \frac{d_1}{2} + h_{HSC} - \frac{4 \cdot V_{Ed}}{3 \cdot \sigma^* \cdot b} \end{cases}$$

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} accorrding to the table on page 8.

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

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

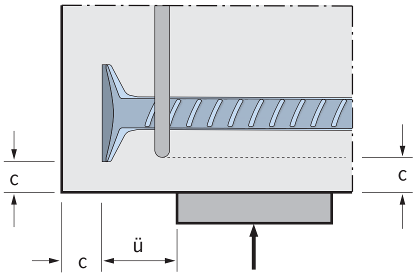
with: $\nu = 0.7 - \frac{f_{ck}}{200\ \text{N/mm}^2} \geq 0.5$

Solid slabs **requiring no** statically shear reinforcement:
shear resistance is sufficient also in the load initial area of HSC anchors.

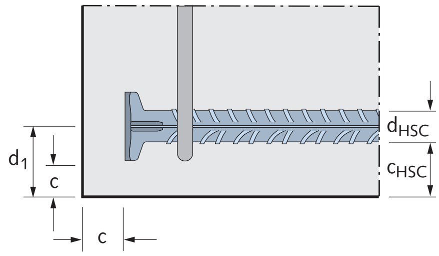
Solid slabs **requiring** statically shear reinforcement, beams: observing the minimum shear reinforcement in area l_{sw} = d from the leading edge of the support:

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

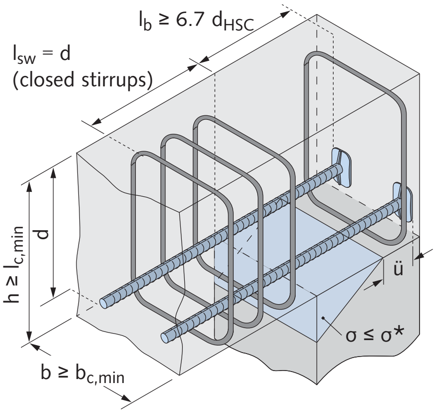
Slabs:
vertical reinforcement
Beams:
closed vertical stirrups



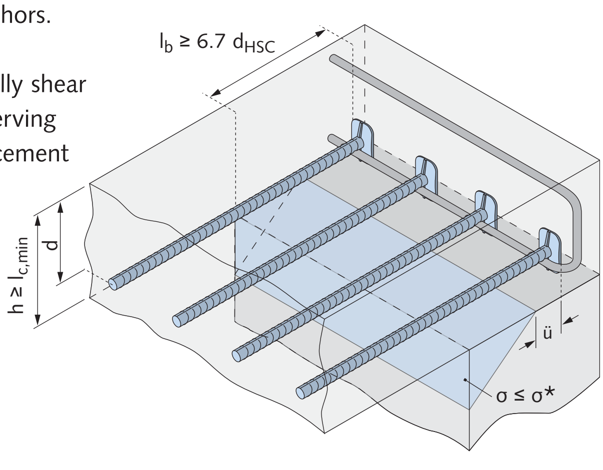
Concrete cover; head extension, vertical section



Concrete cover; horizontal section



Beam support; minimum requirements



Slab support; minimum requirements

Calculation example corbel according to approval Z-21.8-1973

Calculation example:

Proof of concrete compression under the bearing plate

$A_{c0} = 200 \cdot 200\,mm^2 = 40000\,mm^2$ $A_{c1} = 253 \cdot 253\,mm^2 = 64009\,mm^2$

$$F_{Rdu} = A_{c0} \cdot f_{cd} \cdot \sqrt{\frac{A_{c1}}{A_{c0}}} = 40000 \cdot 1.7 \cdot \sqrt{\frac{64009}{40000}} = 860200\,N = 860.2\,kN$$

$$< 3 \cdot f_{cd} \cdot A_{c0} = 3 \cdot 1.7 \cdot 400 = 2040\,kN > 34512\,kN = F_{Ed}\ ✓$$

Shear resistance of the corbel

$$V_{Rd,max} = 0.5 \cdot \nu \cdot b_c \cdot z \cdot \frac{f_{ck}}{\gamma_c} \qquad \nu = 0.7 - \frac{f_{ck}}{200\,N/mm^2} = 0.7 - \frac{30}{200} = 0.55 \geq 0.5\ ✓$$

$$z = 0.9 \cdot d = 0.9 \cdot (40.0 - 5.3) = 31.2\,cm$$

$$V_{Rd,max} = 0.5 \cdot 0.55 \cdot 40 \cdot 31.2 \cdot \frac{3.0}{1.5} = 687.1\,kN > V_{Ed} = 345\,kN\ ✓$$

HSC reinforcement

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

$$Z_{Ed} = 345 \cdot 0.632 + 69 \cdot \frac{7.3 + 27.7}{27.7} = 305.2\,kN \qquad \frac{a_c}{z_0} = \frac{17.5}{27.7} = 0.632 > 0.4\ ✓$$

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

chosen: 3 diam. 20: $A_{s,HSC,prov}$ = 9.42 cm² > 7.02 cm² = $A_{s,HSC,req}$
(single layer layout sufficient)
Crack width proof necessary

Proof of HSC anchorage
(indirectly by observing building regulation)

Minimum corbel dimensions: $b_c / l_c = 40\,cm/35\,cm > 24\,cm/20\,cm = b_{c,min}/l_{c,min}$ ✓

$$\text{Extension:}\quad ü_{req} \geq \max \begin{cases} \frac{c}{2} + h_{HSC} = \frac{2.0\,cm}{2} + 1.2\,cm = 2.2\,cm \\ \frac{d_1}{2} + h_{HSC} - \frac{a_L}{2} = \frac{5.3\,cm}{2} + 1.2\,cm - \frac{20.0\,cm}{2} = -6.2\,cm \end{cases}$$

$$ü_{req} = 2.2\,cm < ü_{prov} = 7.5\,cm - 2.0\,cm = 5.5\,cm\ ✓$$

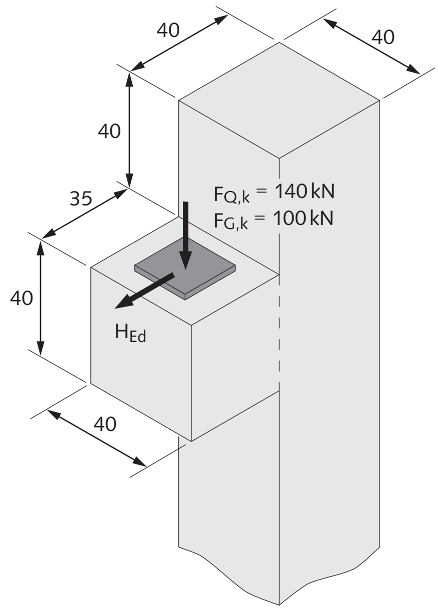
Specifications
- column, see figure below
- concrete C30/37
- c_{nom} = 20 mm
- column reinforcement: each flank 4 diam. 20

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

Actions

V_{Ed} = 1.35 · 100 kN + 1.5 · 140 kN = 345 kN

H_{Ed} = 0.20 · 345 kN = 69 kN (minimum value)



Dimensions in [cm]

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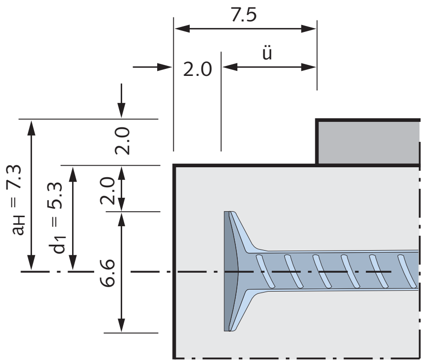
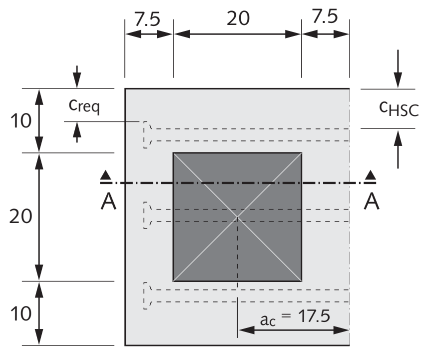
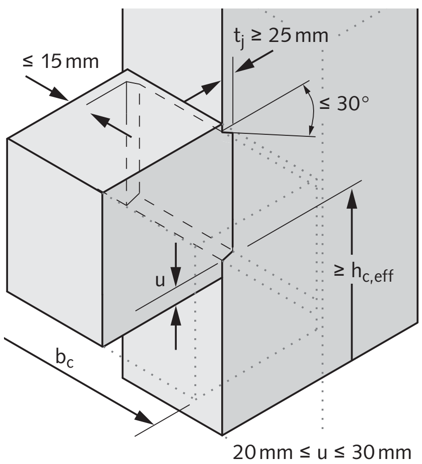


Section A - A [cm]



Corbel view from top [cm]



Simplified key joint; detail from page 10

Concrete cover to the sides of anchors:

$$c_{req} = c_{HSC} - \frac{f - d_{HSC}}{2} = 5.0\,\text{cm} - \frac{4.4\,\text{cm} - 2\,\text{cm}}{2} = 3.8\,\text{cm}$$

→ concrete cover on anchor head sides = 3.8 cm

Minimum column dimensions:

$b_{col}/h_{col} = 40\,\text{cm}/40\,\text{cm} > 30\,\text{cm}/30\,\text{cm} = b_{col,min}/h_{col,min}$ ✓

Column reinforcement diameter: $d_{s,col} = 2.0\,\text{cm} > 1.6\,\text{cm} = d_{s,col,min}$ ✓

Proof of the shear joint

Assumption: designed as simplified keyed joint

$$V_{Rdj} = c_j \cdot f_{ctd} \cdot b \cdot x_j + 1.2 \cdot \mu \cdot A_{sj} \cdot f_{yd} \leq V_{Rdj,max}$$

$x_j = x_c - u = (d - z_0) \cdot 2 - u$ Assumption: $u = 20\,\text{mm}$

$$x_j = (347 - 277) \cdot 2 - 20 = 120\,\text{mm} < 500\,\text{mm}$$

$$V_{Rd,max} = 0.5 \cdot \nu_j \cdot f_{cd} \cdot b \cdot h_{c,eff} = 0.5 \cdot 0.5 \cdot 0.85 \cdot \frac{3.0}{1.5} \cdot 40 \cdot 38 = 646\,\text{kN}$$

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

$< 646\,\text{kN} = V_{Rd,max}$ $> 345\,\text{kN} = V_{Ed}$ ✓

Node resistance

Acting shear force:

$$V_{jh} = A_{s,HSC} \cdot f_{yd} - V_{Ed,col,o} = 9.42 \cdot 43.5 = 409.7\,\text{kN}$$

Node resistance without stirrups:

$$V_{j,cd} = 1.55 \cdot \left(1.2 - 0.3 \cdot \frac{h_{beam}}{h_{col}}\right) \cdot \left(1 + \frac{\rho_{col} - 0.5}{7.5}\right) \cdot b_{eff} \cdot h_{col} \cdot \left(\frac{f_{ck}}{\gamma_c}\right)^{1/4}$$

$$\frac{h_{beam}}{h_{col}} = \frac{40}{40} = 1.0 \begin{cases} \geq 1.0\ ✓ \\ \leq 2.0\ ✓ \end{cases} \qquad \rho_{col} = 0.79\% \begin{cases} \geq 0.5\%\ ✓ \\ \leq 2.0\%\ ✓ \end{cases}$$

$$b_{eff} = \frac{b_{beam} + b_{col}}{2} = \frac{40 + 40}{2} = 40\,\text{cm} \leq b_{col} = 40\,\text{cm}$$

$$V_{j,cd} = 1.55 \cdot (1.2 - 0.3 \cdot 1.0) \cdot \left(1 + \frac{0.79 - 0.5}{7.5}\right) \cdot 400 \cdot 400 \cdot \left(\frac{30}{1.5}\right)^{1/4}$$

$= 490262\ \text{N} = 490.3\,\text{kN} > 409.7\,\text{kN} = V_{jh}$ ✓ → no further stirrups necessary

Maximum node resistance:

$$V_{j,Rd,max} = \gamma_{N1} \cdot \gamma_{N2} \cdot 0.3 \cdot \frac{f_{ck}}{\gamma_c} \cdot b_{eff} \cdot h_{col} \leq 2 \cdot V_{j,cd}$$

$$N_{Ed,col} = 1.0 \cdot N_G + 0.3 \cdot \sum N_Q = -100 - 0.3 \cdot 140 = -142\,\text{kN}$$

$$\gamma_{N1} = 1.5 \cdot \left(1 + 0.8 \cdot \frac{N_{Ed,col}}{A_{c,col} \cdot f_{ck}}\right) \leq 1.0 \quad \gamma_{N1} = 1.5 \cdot \left(1 - 0.8 \cdot \frac{142}{40^2 \cdot 3.0}\right) = 1.46 > 1.0$$

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

$$V_{j,Rd,max} = 1.0 \cdot 1.0 \cdot 0.3 \cdot \frac{3.0}{1.5} \cdot 40.0 \cdot 40.0 = 960\,\text{kN} \leq 2 \cdot V_{j,cd} = 2 \cdot 490.3\,\text{kN} = 980.6\,\text{kN}$$

$V_{jh} = 409.6\,\text{kN} < 960\,\text{kN} = V_{j,Rd,max}$ ✓

Calculation example corbel according to approval Z-21.8-1973

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

Stirrups for tensile splitting forces

Boundary conditions: $V_{Ed} = 345\,kN > 0.3\ V_{Rd,max} = 288\,kN$

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

separate stirrups for column and corbel

$A_{sw,h,req} = A_{sw,v,req} \geq 0.5 \cdot A_{s,HSC}$

$A_{sw,req} = 0.5 \cdot 7.02\,cm^2 = 3.51\,cm^2$

$A_{sw,h,prov} = A_{sw,v,prov} \geq \pi/4 \cdot 0.8^2 \cdot 4 \cdot 2 = 4.02\,cm^2$

selected: 4 ⌀ 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)

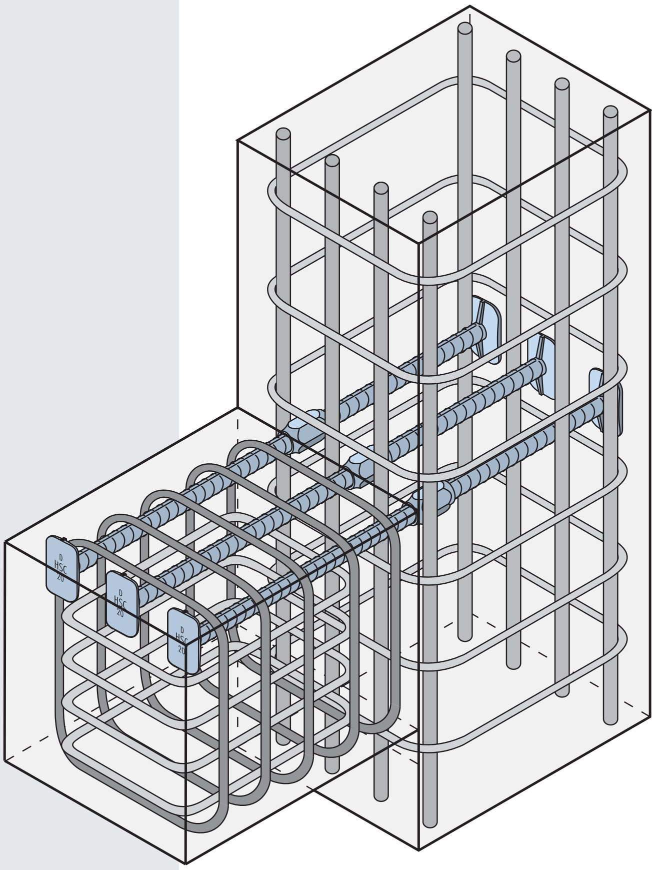
Longitudinal column reinforcement ratio:

$$\rho_{col} = \frac{A_{s1,col}}{b_{col} \cdot h_{col}} = \frac{A_{s2,col}}{b_{col} \cdot h_{col}} = \frac{\pi \cdot 2.0^2}{40^2} = 0.79\% > 0.5\% \ ✓$$

Anchorage of longitudinal column reinforcement:

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

minimum stirrup reinforcement inside the node: diam. 8 mm, s = 100 mm



Corbel reinforcement with
HALFEN HSC Stud Connector
according to this calculation example

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

System requirements for HALFEN calculation software:
- Windows XP, Vista, Windows 7
- Microsoft .Net Framework 3.5, SP1
- Microsoft Excel 2003, 2007 or 2010 local host installed

A DVD containing all available calculation software, catalogues and approvals is available.

Data sheet, input values

Organisation/plant ______________________

Contact person ______________________

Phone ______________ Fax ______________

e-mail ______________________

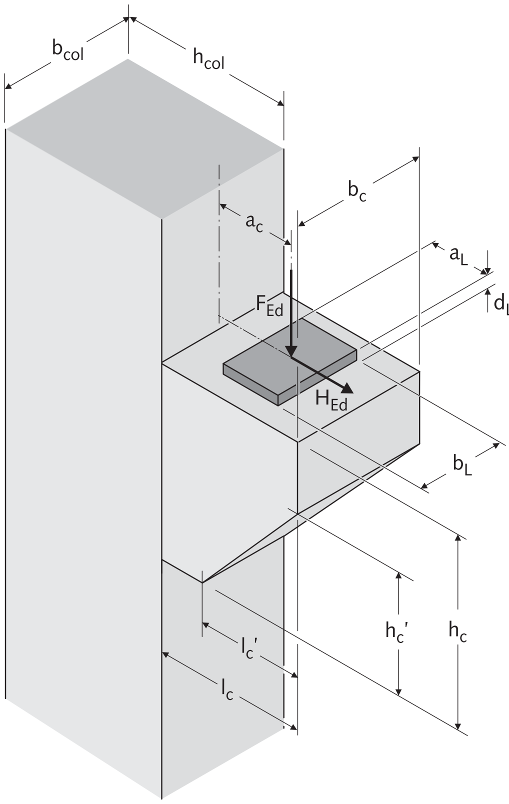
Construction project ______________________

____

Site location ______________________

____

Item ______________________



Minimum element dimensions according to approval no. Z-21.8-1973, appendices 3 and 4

Anchor diam. dA	Concrete strength class	Minimum constructional dimensions	
		Column	Corbel
		$b_{col,min}/h_{col,min}$	$b_{c,min}/l_{c,min}$
12	C20/25-C70/85	240/240	200/200
16	C20/25-C70/85	240/240	200/200
20	C20/25-C25/30	300/300	300/300
	C30/37-C35/45	300/300	240/200
	C40/50-C70/85	240/240	200/200
25	C20/25	300/400	300/400
	C25/30-C30/37	300/350	300/350
	C35/45-C70/85	300/300	300/300

Please send the completed form to HALFEN by fax
+49 (0) 2173 970-420 or by E-Mail to ***es.res@halfen.com***
Trained engineers are available to help you plan with the HALFEN HSC Stud Connector system

Column geometry

Column width	b_{col}		mm
Column depth	h_{col}		mm

Corbel geometry

Corbel width	b_c		mm
Corbel length	l_c		mm
Corbel haunch length	l_c'		mm
Corbel height	h_c		mm
Corbel haunch height	h_c'		mm

Geometry of bearing plate and point of load application

Bearing plate thickness	d_L		mm
Bearing plate width	b_L		mm
Bearing plate length	a_L		mm
Point of load application	a_c		mm

Loads

Vertical load	F_{Ed}		kN
Horizontal load	H_{Ed}		kN

Boundary conditions

Concrete class	C		
Concrete cover	c_{nom}		mm
Monolithic corbel design? ☐		or several concrete steps? ☐	
Unilateral corbel? ☐		or bilateral corbel? ☐	

Column data above the corbel

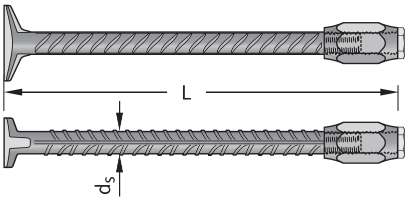
Vertical load	$N_{Ed,col,o}$		kN
Horizontal load	$V_{Ed,col,o}$		kN
Outer column reinforcement (longitudinal)	Number		pcs
	Diam.		mm

Proof of fatigue resistance

Max. vertical force	$V_{Ed,max}$		kN
Min. vertical force	$V_{Ed,min}$		kN

Product Range, References for Length Calculation

HSC-S single headed female bars



Material:
Concrete steel
B500B

Designation type bar diam. d_s / L [mm]	L_{min} [mm]	Article No.
HSC - S - 12 / . . .	185	0060.300 ①
HSC - S - 16 / . . .	185	0060.310 ①
HSC - S - 20 / . . .	200	0060.320 ①
HSC - S - 25 / . . .	240	0060.330 ①

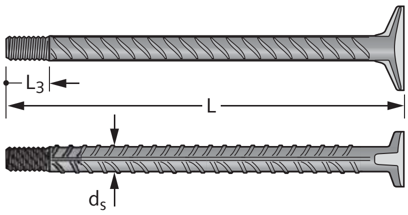
① required length, please indicate with your order, see page bottom.

HSC-A bars (in-stock)

Type	Article No.	Diam. d_s [mm]	Length L [mm]	For column dimensions *) h_{col} [mm]
HSC-S	0060.300-00001	12	360	400
	0060.300-00002	12	460	500
	0060.310-00001	16	360	400
	0060.310-00002	16	460	500
	0060.320-00001	20	360	400
	0060.320-00002	20	460	500

In-stock:
*) Constructional column requirements and country-specific approvals - if applicable - have to be considered.
Applies to concrete cover c_{nom} = 30 mm.

HSC-A single headed male bars



Material:
Concrete steel
B500B

Designation type bar diam. d_s / L [mm]	L_{min} [mm]	Screw depth L_3 [mm]	Article No.
HSC - A - 12 / . . .	150	16,5	0060.400 ①
HSC - A - 16 / . . .	150	22,5	0060.410 ①
HSC - A - 20 / . . .	160	28,5	0060.420 ①
HSC - A - 25 / . . .	190	36	0060.430 ①

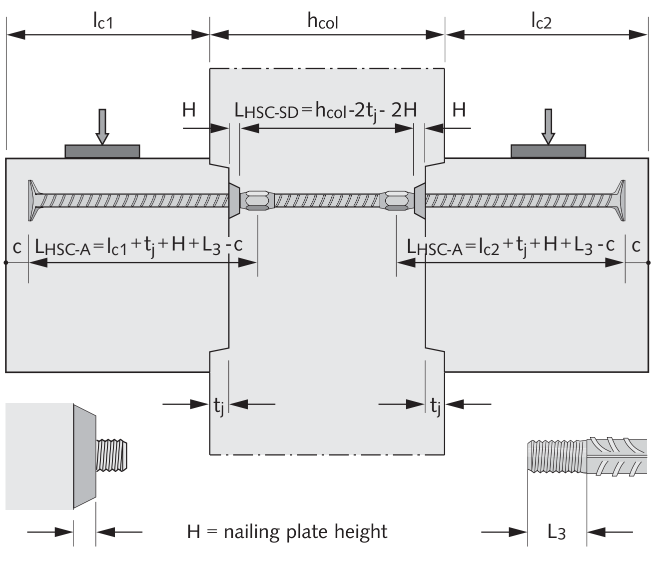
① please state required length when ordering, see bottom of page.

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

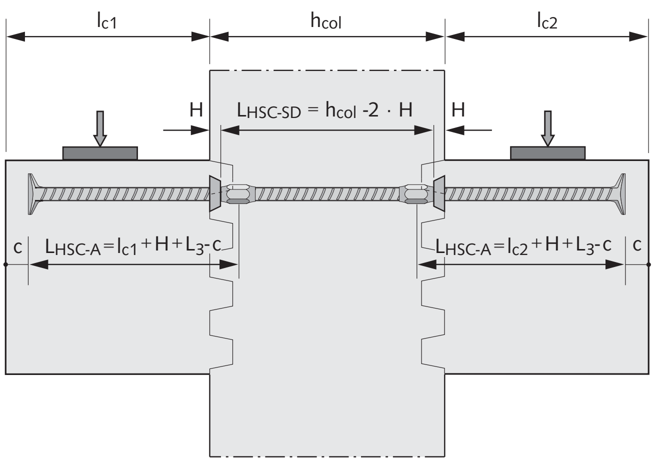
HSC-A bars (in-stock)

Type	Article No.	Diam. d_s [mm]	Length L [mm]	For corbel extensions *) l_c [mm]
HSC-A	0060.400-00001	12	195	200
	0060.400-00002	12	245	250
	0060.400-00003	12	295	300
	0060.400-00004	12	345	350
	0060.400-00005	12	395	400
	0060.410-00001	16	202	200
	0060.410-00002	16	252	250
	0060.410-00003	16	302	300
	0060.410-00004	16	352	350
	0060.410-00005	16	402	400
	0060.420-00001	20	208	200
	0060.420-00002	20	258	250
	0060.420-00003	20	308	300
	0060.420-00004	20	358	350
	0060.420-00005	20	408	400

Design with simplified keyed joint, order length



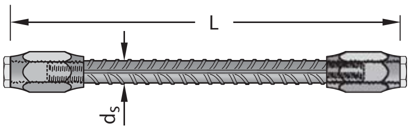
Design with keyed joint, order length



HALFEN HSC STUD CONNECTOR

Product Range, References for Length Calculation

HSC-SD double female bar

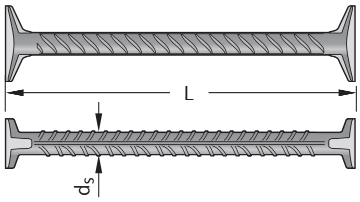


Material:
Concrete steel
B500B

Designation type bar diam. d_s / L [mm]	L_{min} [mm]	Article No.
HSC - SD - 12 / . . .	205	0060.500 ①
HSC - SD - 16 / . . .	215	0060.510 ①
HSC - SD - 20 / . . .	220	0060.520 ①
HSC - SD - 25 / . . .	275	0060.530 ①

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

HSC-HD double headed bar



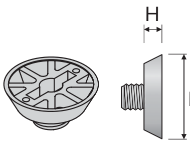
Material:
Concrete steel
B500B

Designation type bar diam. d_s / L [mm]	L_{min} [mm]	Article No.
HSC - HD - 12 / . . .	175	0060.200 ①
HSC - HD - 16 / . . .	175	0060.210 ①
HSC - HD - 20 / . . .	175	0060.220 ①
HSC - HD - 25 / . . .	175	0060.230 ①

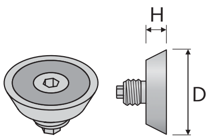
① please state required length when ordering, see bottom of page.

Formwork accessories

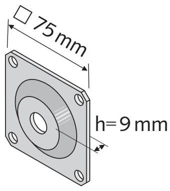
Nailing plate, plastic
3905



Magnetic plate
6365



Nailing plate, metal
3916



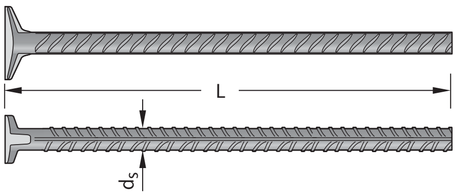
Designation	For bar diam. d_s [mm]	D [mm]	H [mm]	Article No.
3905 - 12	12	60	10	0725.020-00002
3905 - 16	16	60	10	0725.020-00004
3905 - 20	20	60	10	0725.020-00005
3916 - 25	25	75	9	0725.030-00001
6365 - 12	12	40	12	0741.180-00001
6365 - 16	16	40	12	0741.180-00002
6365 - 20	20	55	12	0741.180-00003

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.

Anchor dimensions				
d_s [mm]	12	16	20	25
f [mm]	30	35	44	55
g [mm]	35	53	66	83
L_3 [mm]	16,5	22,5	28,5	36,0

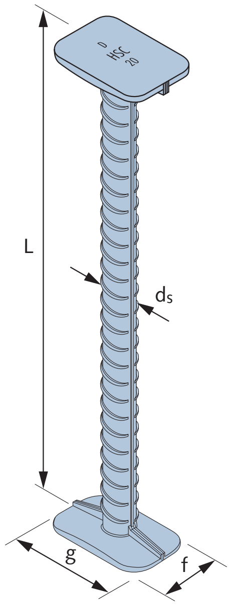
HSC-H single headed anchor bar



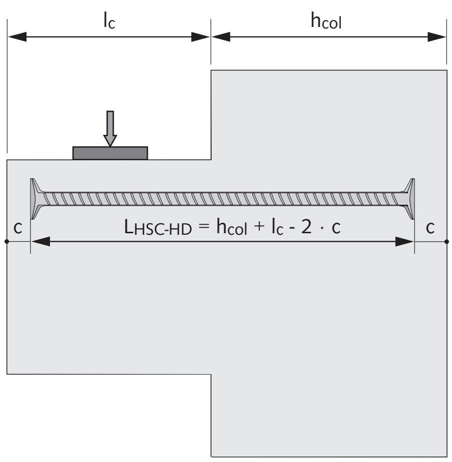
Material:
Concrete steel
B500B

Designation type bar diam. d_s / L [mm]	Article No.
HSC - H - 12 / . . .	0060.100 ①
HSC - H - 16 / . . .	0060.110 ①
HSC - H - 20 / . . .	0060.120 ①
HSC - H - 25 / . . .	0060.130 ①

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



Monolithic design, order length



HALFEN HSC STUD CONNECTOR

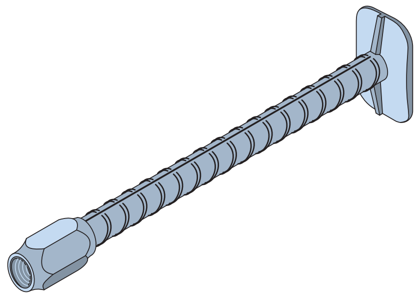
HSC Stud Connector

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 head, for connection and anchorage of reinforcement steel bars, with Building authority approval, for predominantly and non-predominantly static loads,

certified with the RAL quality mark RAL-GZ 996/2 issued by the Association for Anchorage and Reinforcement Technology (*Gütegemeinschaft Verankerungs- und Bewehrungstechnik* e.V.)



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,

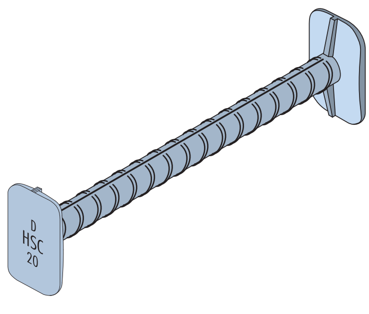
type HSC-S-16/L
16 = diameter [mm],
L = length ... [mm],

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 Building authority approval, for predominantly and non-predominantly static loads,

certified with the RAL quality mark RAL-GZ 996/2 issued by the Association for Anchorage and Reinforcement Technology (*Gütegemeinschaft Verankerungs- und Bewehrungstechnik* e.V.)



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.de

Order form

☐ Enquiry ☐ Order

(Please tick appropriate)

HALFEN Vertriebsgesellschaft mbH
Katzbergstraße 3 · D - 40764 Langenfeld
Fax: + 49-(0)2173/970-225

Organisation/facility

Address

Contact person

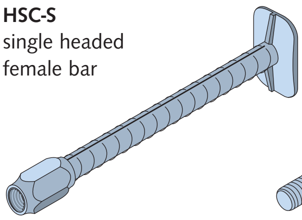
Phone

Fax

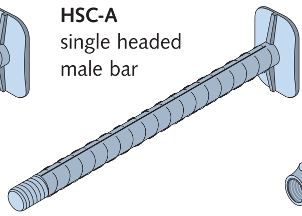
e-mail

Construction project

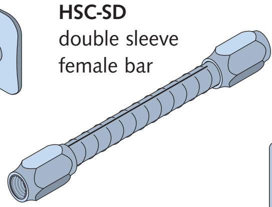
HSC-S
single headed
female bar



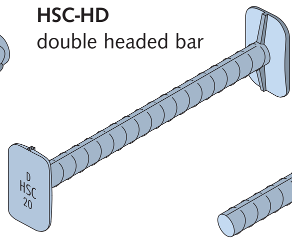
HSC-A
single headed
male bar



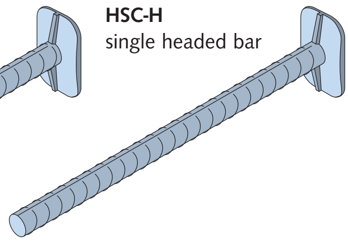
HSC-SD
double sleeve
female bar



HSC-HD
double headed bar

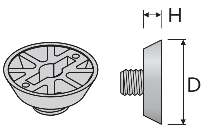


HSC-H
single headed bar

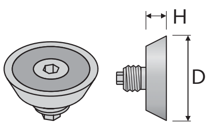


Formwork accessories

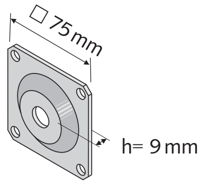
Nailing plate, plastic



Magnetic plate



Nailing plate, metal



Pos.	No. [pcs.]	Type	Bar diam. d_s [mm]	Length [mm]	Article no.	Price per unit [EUR]	Total price per pos. [EUR]

Amount
packaging and freight charges added — **EUR**

Delivery address
(only if different
from order address)

Date,
signature

CONTACT HALFEN WORLDWIDE

HALFEN is represented by subsidiaries in the following 14 countries, please contact us:

Austria	HALFEN Gesellschaft m.b.H. Leonard-Bernstein-Str. 10 1220 Wien	Phone: +43-1-259 6770 E-Mail: office@halfen.at Internet: www.halfen.at	Fax: +43-1-259-6770 99
Belgium / Luxembourg	HALFEN N.V. Borkelstraat 131 2900 Schoten	Phone: +32-3-658 07 20 E-Mail: info@halfen.be Internet: www.halfen.be	Fax: +32-3-658 15 33
China	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	Phone: +86-10 5907 3200 E-Mail: info@halfen.cn Internet: www.halfen.cn	Fax: +86-10 5907 3218
Czech Republic	HALFEN-DEHA s.r.o. Business Center Šafránkova Šafránkova 1238/1 155 00 Praha 5	Phone: +420 -311-690 060 E-Mail: info@halfen-deha.cz Internet: www.halfen-deha.cz	Fax: +420-235-314 308
France	HALFEN S.A.S. 18, rue Goubet 75019 Paris	Phone: +33-1- 445231 00 E-Mail: halfen@halfen.fr Internet: www.halfen.fr	Fax: +33-1-445231 52
Germany	HALFEN Vertriebsgesellschaft mbH Katzbergstrasse 3 40764 Langenfeld	Phone: +49-2173-970-0 E-Mail: info@halfen.de Internet: www.halfen.de	Fax: +49-2173-970 225
Italy	HALFEN S.r.l. Soc. Unipersonale Via F.lli Bronzetti N° 28 24124 Bergamo	Phone: +39-035-0760711 E-Mail: info@halfen.it Internet: www.halfen.it	Fax: +39-035-0760799
Netherlands	HALFEN b.v. Oostermaat 3 7623 CS Borne	Phone: +31-74-267 14 49 E-Mail: info@halfen.nl Internet: www.halfen.nl	Fax: +31-74-267 26 59
Norway	HALFEN AS Postboks 2080 4095 Stavanger	Phone: +47-51 82 34 00 E-Mail: post@halfen.no Internet: www.halfen.no	Fax: +47-51 82 34 01
Poland	HALFEN Sp. z o.o. Ul. Obornicka 287 60-691 Poznan	Phone: +48-61-622 14 14 E-Mail: info@halfen.pl Internet: www.halfen.pl	Fax: +48-61-622 14 15
Sweden	Halfen AB Box 150 435 23 Mölnlycke	Phone: +46-31-98 58 00 E-Mail: info@halfen.se Internet: www.halfen.se	Fax: +46-31-98 58 01
Switzerland	HALFEN Swiss AG Hertistrasse 25 8304 Wallisellen	Phone: +41-44-849 78 78 E-Mail: mail@halfen.ch Internet: www.halfen.ch	Fax: +41-44-849 78 79
United Kingdom / Ireland	HALFEN Ltd. Humphrys Road · Woodside Estate Dunstable LU5 4TP	Phone: +44 -1582- 47 03 00 E-Mail: info@halfen.co.uk Internet: www.halfen.co.uk	Fax: +44-1582-47 03 04
United States of America	HALFEN USA Inc. 8521 FM 1976 P.O. Box 547 Converse, TX 78109	Phone: +1 800.423.91 40 E-Mail: info@halfenusa.com Internet: www.halfenusa.com	Fax: +1 877.683.4910
For countries not listed HALFEN International	HALFEN International GmbH Liebigstr. 14 40764 Langenfeld / Germany	Phone: +49 -2173-970-0 E-Mail: info@halfen.com Internet: www.halfen.com	Fax: +49 -2173-970-849

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