HALFEN HSC STUD CONNECTOR

TECHNICAL PRODUCT INFORMATION

HALFEN HSC STUD CONNECTOR

CONCRETE

HSC 16-E

HALFEN

YOUR BEST CONNECTIONS

HALFEN HSC Stud Connector

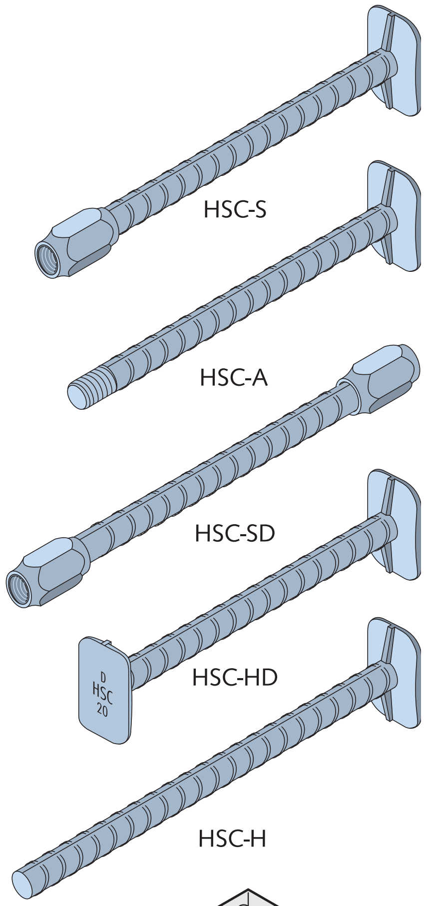
Highly effective reinforcement anchor

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.

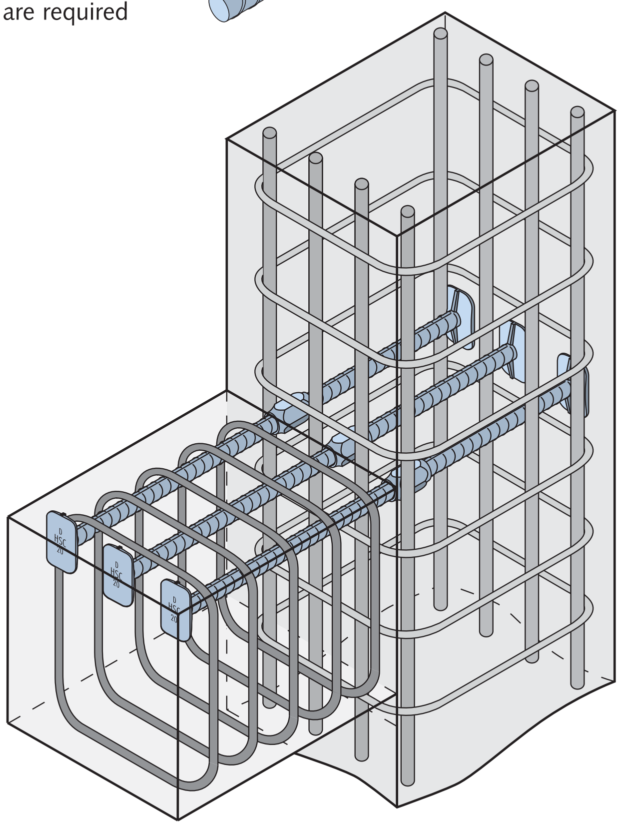
The HALFEN HSC Stud connector is especially suitable for use in highly reinforced areas such as corbels and beam to column connections.
The problems that occur in the layout of reinforcement and distribution of forces with conventional rebar solutions do not apply. The amount of reinforcement steel is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



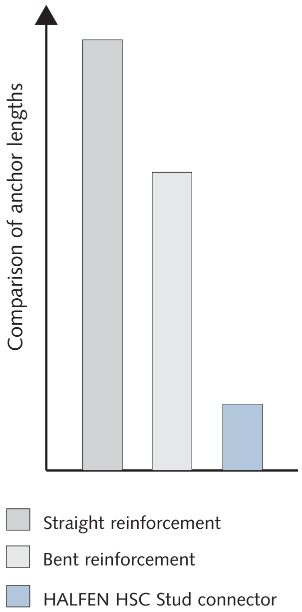
National Technical Approval Z-21.8-1973 for HALFEN HSC Stud connector
National Technical Approval Z-1.5-189 for HALFEN HBS-05 Screw connection



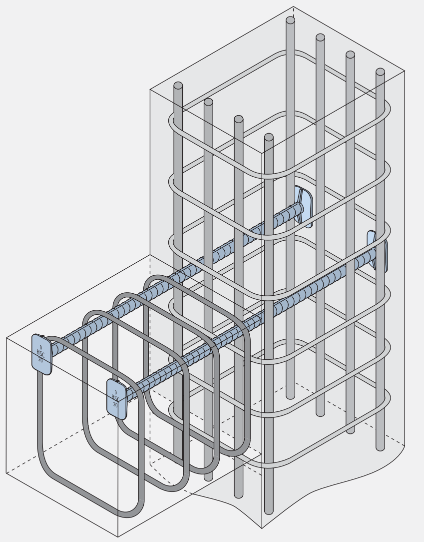
Corbel with HALFEN HSC Stud Connector

General

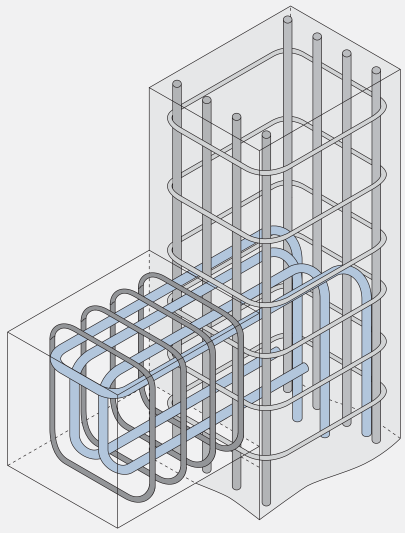
Extremely short anchorage lengths



Simple reinforcement layout

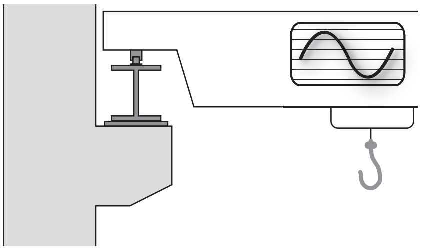


Corbel with HALFEN HSC Stud connector: secure anchorage, simple reinforcement layout



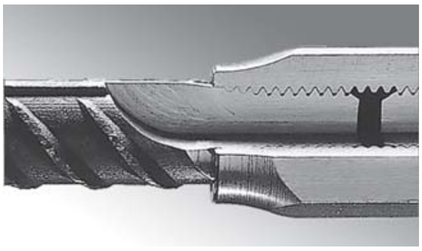
Conventional corbel reinforcement with large bending diameters, high steel usage and complicated reinforcement

Advantages in planning and design



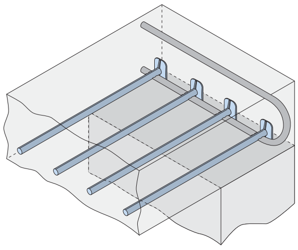
- approval for predominantly static and non-predominantly static loading cases
- HALFEN provides free easy-to-use corbel dimensioning software
- HALFEN provides a complimentary consultation service for customer's projects
- head to head and multiple-layered placement of anchor heads allow a high degree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

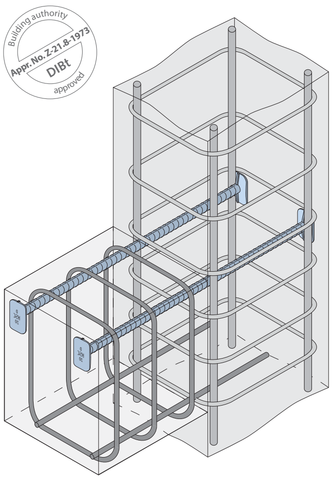
Wide application range



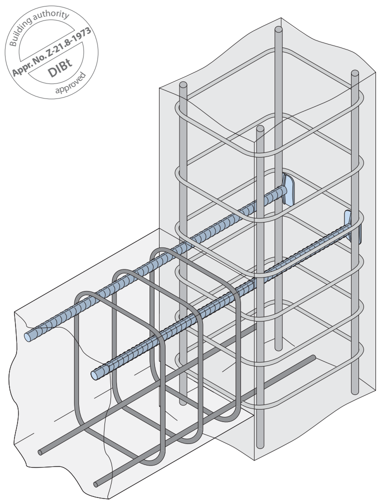
- corbels
- frame corners
- beam supports
- slab supports
- half joints

Application Examples

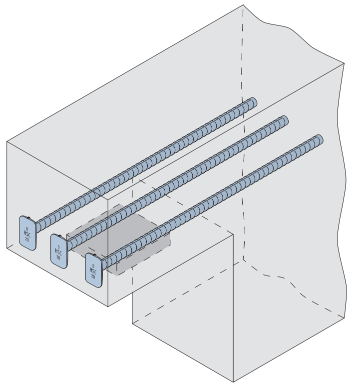
Corbels → page 7 - 10



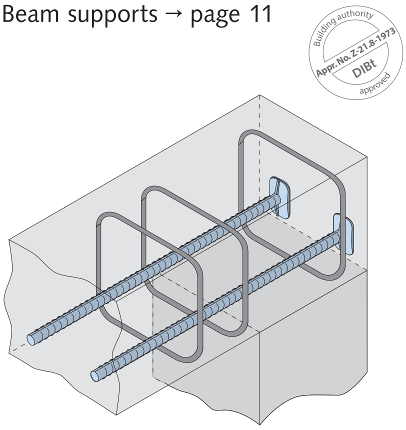
Frame corners → page 6



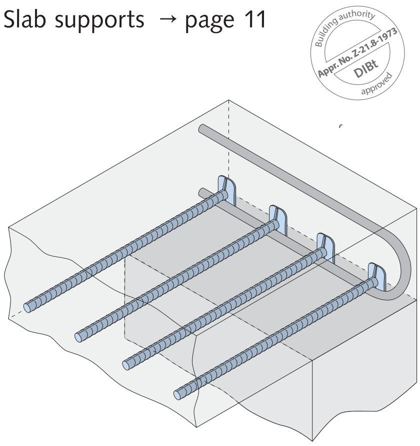
Half joints



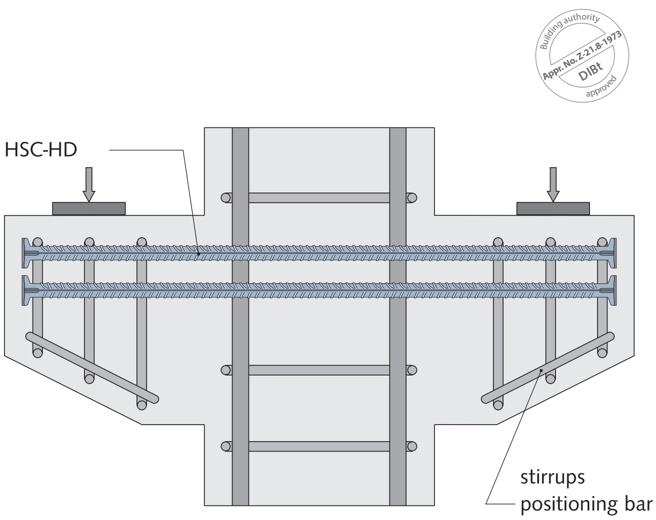
Beam supports → page 11



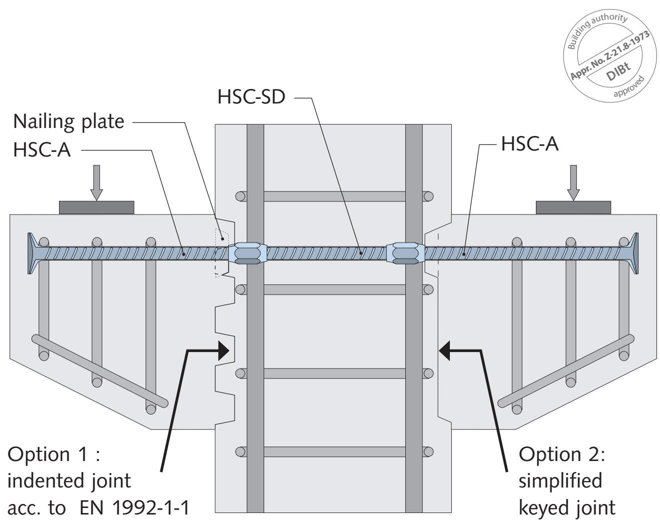
Slab supports → page 11



Examples of corbel application



Corbel with multilayer reinforcement in monolithic element → page 16



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

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 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 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

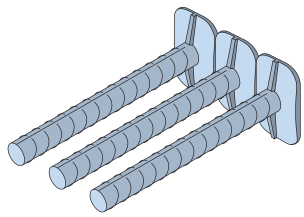
Placement of anchor heads

Anchor heads may be aligned vertically or horizontally as required.

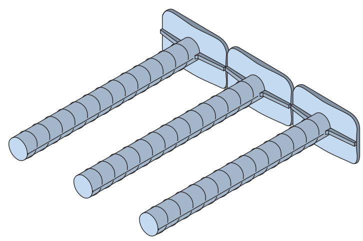
Spacing of bars

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.



Vertical anchor head layout

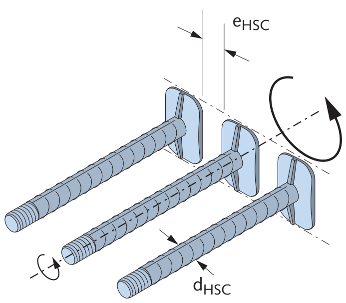


Horizontal anchor head layout

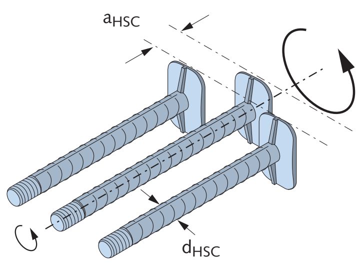
Minimum head spacings to ensure male bars can be installed and tightened (HSC connection bars)

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

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

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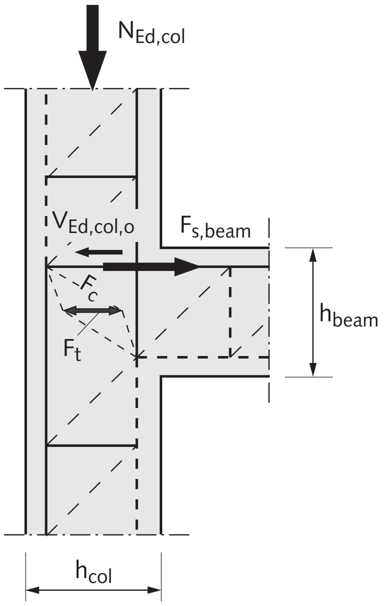
Frame corner according to approval Z-21.8-1973

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 National Technical Approval.

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:

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

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 " German Commitee 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_{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_{col} resp. 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: $1.0 \leq \frac{h_{beam}}{h_{col}} \leq 2.0$ $0.5\% \leq \rho_{col} \leq 2.0\%$

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

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:

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

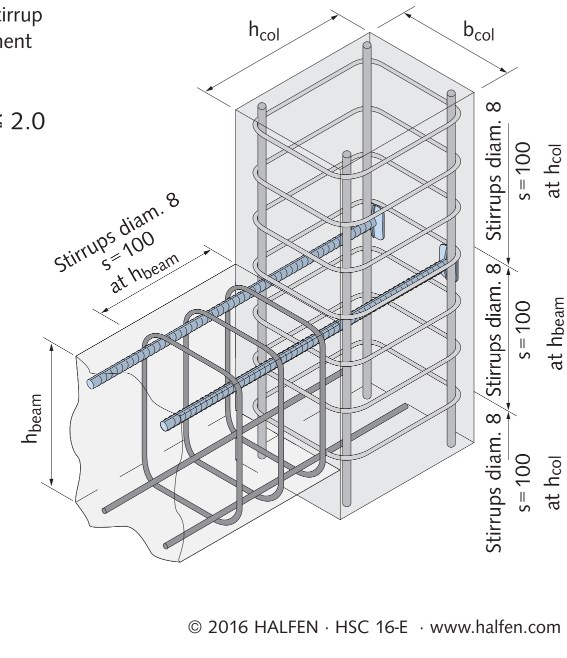
with: $A_{sj,eff}$ = effective shear reinforcement (aligned between upper edge joint and upper edge compression zone beam)

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 column dimensions acc. to Z-21.8-1973				
Anchor diameter	Concrete strength class	Column dimensions [mm]		Column longitudinal reinforcement [mm]
d_{HSC} [mm]		$b_{col,min}$	$h_{col,min}$	$d_{s,col,min}$
12	C20/25 - C70/85	240	240	12
16	C20/25 - C70/85	240	240	12
20	C20/25 - C35/45	300	300	16
	C40/50 - C70/85	240	240	
25	C20/25	300	400	20
	C25/30 - C30/37	300	350	
	C35/45 - C70/85	300	300	

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: $a_c / h_c \leq 0.5$

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 of the corbel according to the approval: see table "Constructional Specifications" 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 national technical requirements are observed; compare with figures and tables.

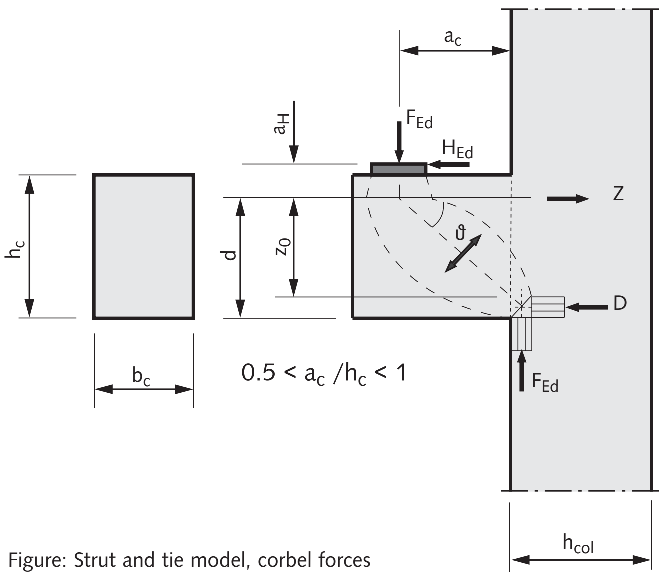


Figure: Strut and tie model, corbel forces

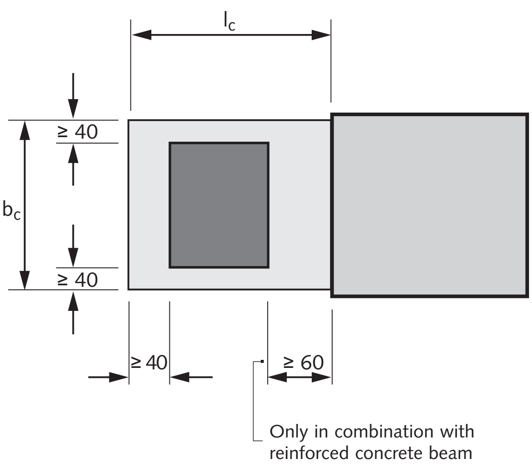


Figure: Bearing plate, top view [mm]

Corbels according to approval Z-21.8-1973

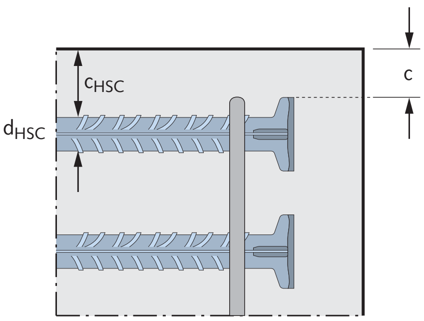
Deviating from the standard layout, HSC can be placed multilayered or staggered, corbel dimensions can also be below minimum given values. In these cases further calculations are required; see approval.

Further verifications and regulations

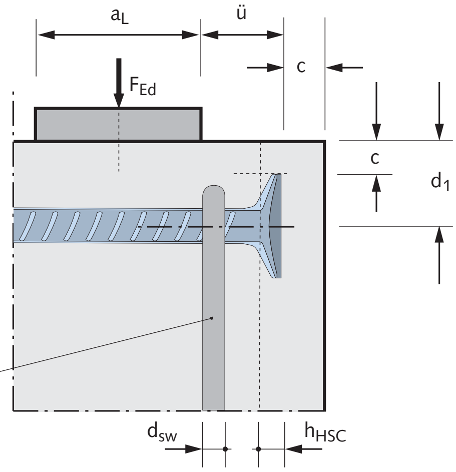
The transfer of forces to the column in single corbels can be verified using the same design rules as used for frame corners → page 6.

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.

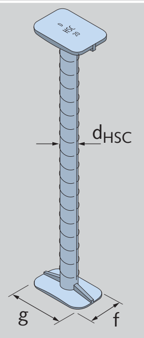
Horizontal cross section: anchor alignment, standard case (single layer, not staggered)



Vertical section



Constructional specifications



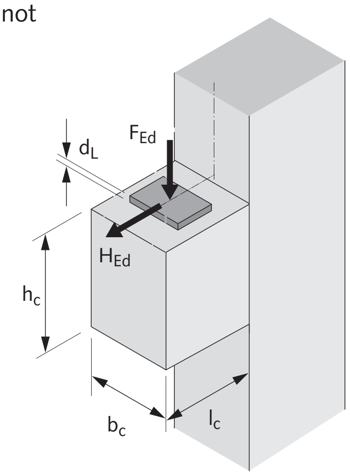
Anchor dimensions				Corbel dimensions		Concrete strength class	Stirrups	Concrete cover		Excess length
d_{HSC} [mm]	f [mm]	g [mm]	h_{HSC} [mm]	$b_{c,min}$ [mm]	$l_{c,min}$ [mm]	[-]	d_{sw} [mm]	c_{HSC} [mm]	c [mm]	ü [mm]
12	30	35	8	200	200	C20/25 ... C70/85	≥ 6	≥ 30	acc. to DIN EN 1992-1-1	$ü \geq \max \begin{cases} \frac{c}{2} + h_{HSC} \\ \frac{d_1}{2} + h_{HSC} - \frac{a_L}{2} \end{cases}$ (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 e.g. securing with tension belts are possible.

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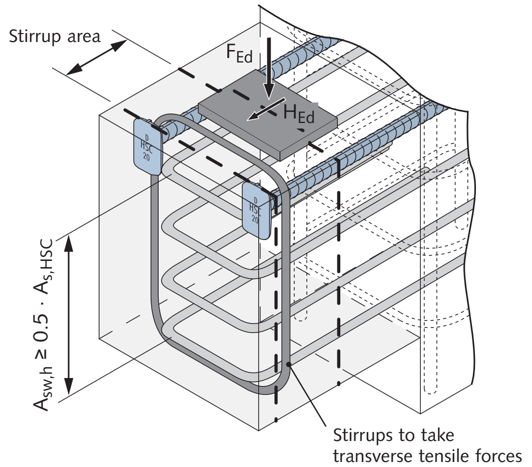
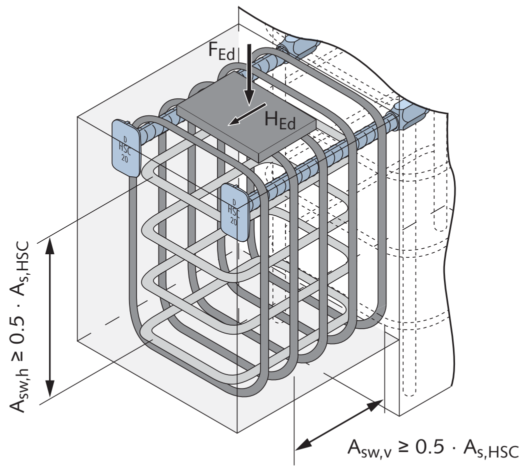
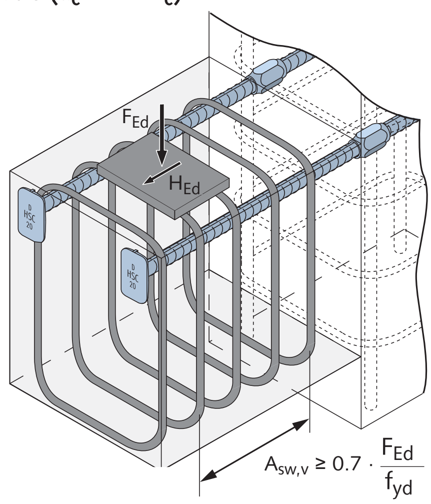
Short corbels ($a_c \leq 0.5\ h_c$)
Option 1: continuous tensile splitting reinforcement



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



Long corbels ($a_c > 0.5\ h_c$)



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

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

with:

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

x_j = h_c for indented 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 indented 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

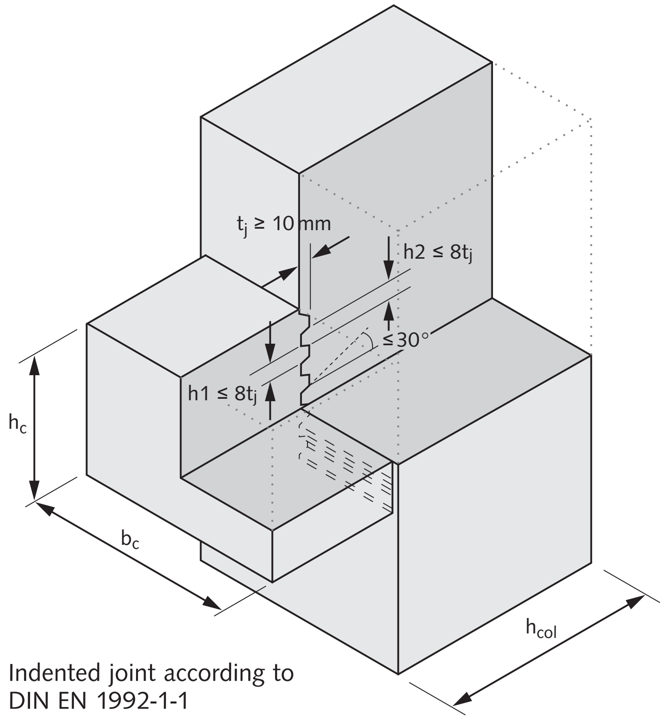
c_j, μ, ν_j, ... joint parameters according to table

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

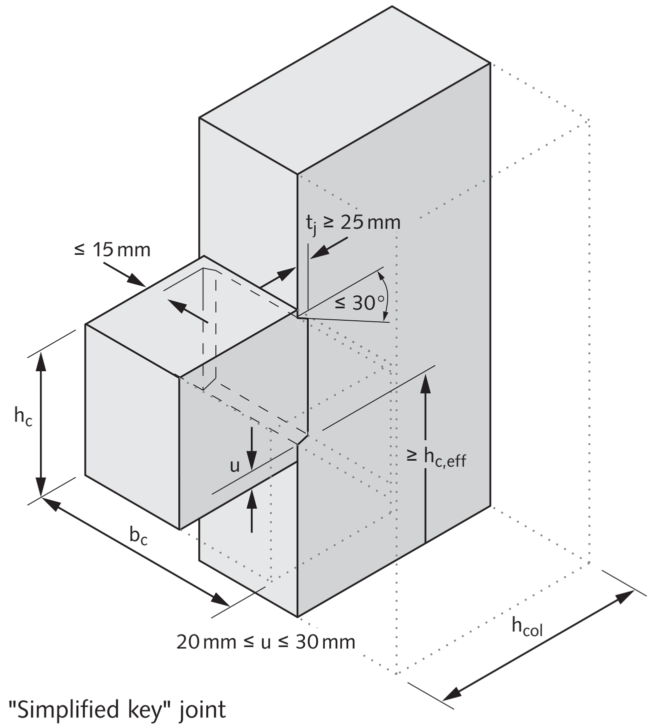
f_{ctd} = $f_{ctk;0.05} / \gamma_c$ ... design value of concrete tensile strength with $\gamma_c = 1.8$

Shear joints are usually designed with 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.

Coefficients of shear joints			
Joint design	c_j	μ	ν_j
Indented joint	0.5	0.9	0.7
Simplified key joint	0.4	0.7	0.5



Indented joint according to DIN EN 1992-1-1



"Simplified key" joint

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:

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

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} according to the table on page 8.

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

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

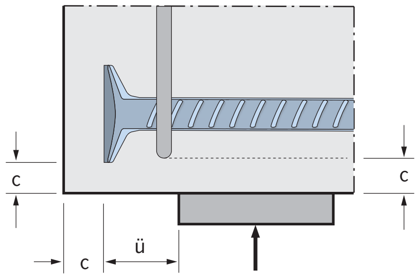
with: $$v = 0.7 - \frac{f_{ck}}{200\ N/mm^2} \geq 0.5$$

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

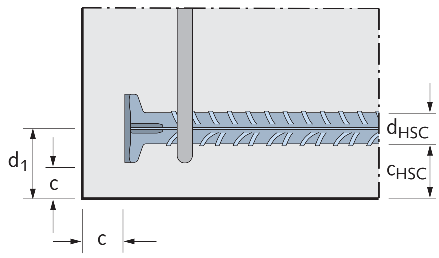
Solid slabs **requiring** statically shear reinforcement, beams: observing the minimum shear reinforcement in area l_{sw} = d from the leading edge of the support:

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

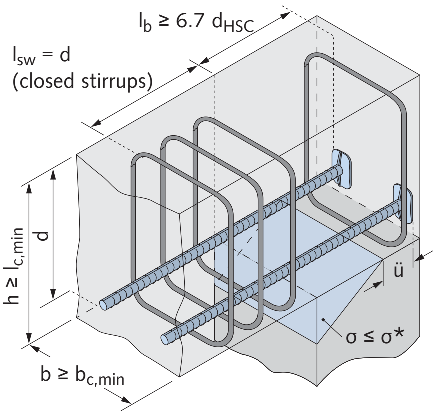
Slabs:
vertical reinforcement
Beams:
closed vertical stirrups



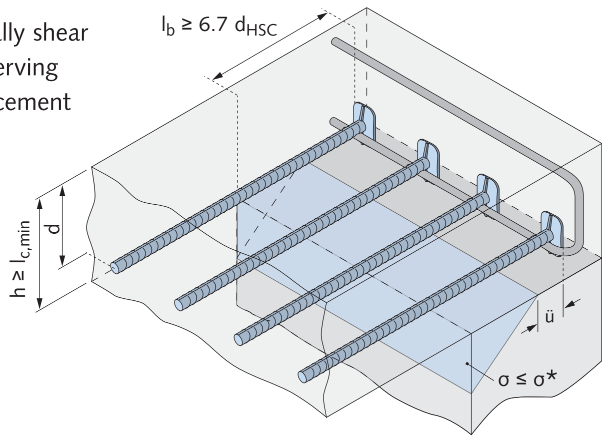
Concrete cover; head extension, vertical section



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

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

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

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

Shear resistance of the corbel

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

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

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

HSC reinforcement

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

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

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

chosen: 3 diam. 20: $A_{s,HSC,prov} = 9.42\,cm^2 > 7.02\,cm^2 = A_{s,HSC,req}$
(single layer layout sufficient)
Crack width proof necessary

Proof of HSC anchorage
(indirectly by observing building regulation)

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

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

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

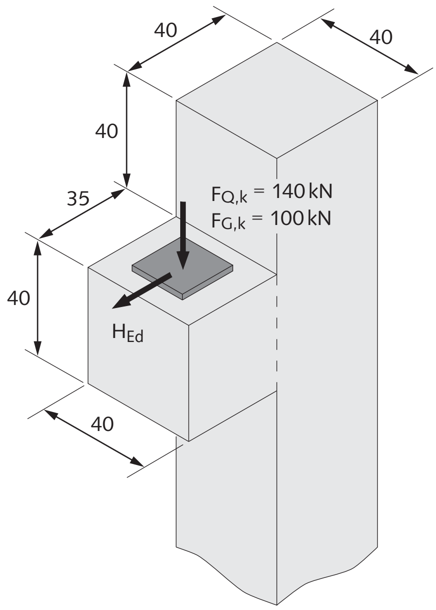
Specifications
- column, see figure below
- concrete C30/37
- $c_{nom} = 20\,mm$
- column reinforcement: each flank 4 diam. 20

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

$V_{Ed} = 1.35 \cdot 100\,kN + 1.5 \cdot 140\,kN = 345\,kN$

$H_{Ed} = 0.20 \cdot 345\,kN = 69\,kN$ (minimum value)



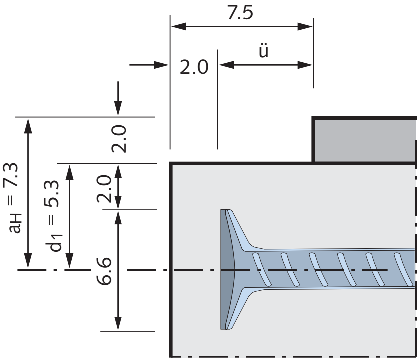
Dimensions in [cm]

TECHNICAL SUPPORT

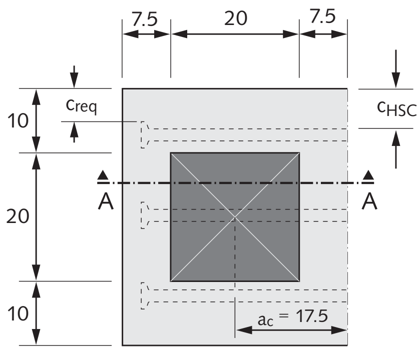
HALFEN Technical Support

Engineering services and technical support for your individual projects.
Contact information can be found at the back side of this catalogue.

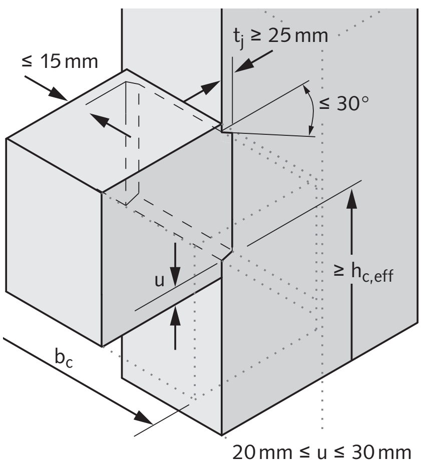
Calculation Example Corbel According to Approval Z-21.8-1973



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 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:

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

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

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

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

$= 490262\,\text{N} = 490.3\,\text{kN} > 409.7\,\text{kN} = V_{jh}$ ✓ → 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)

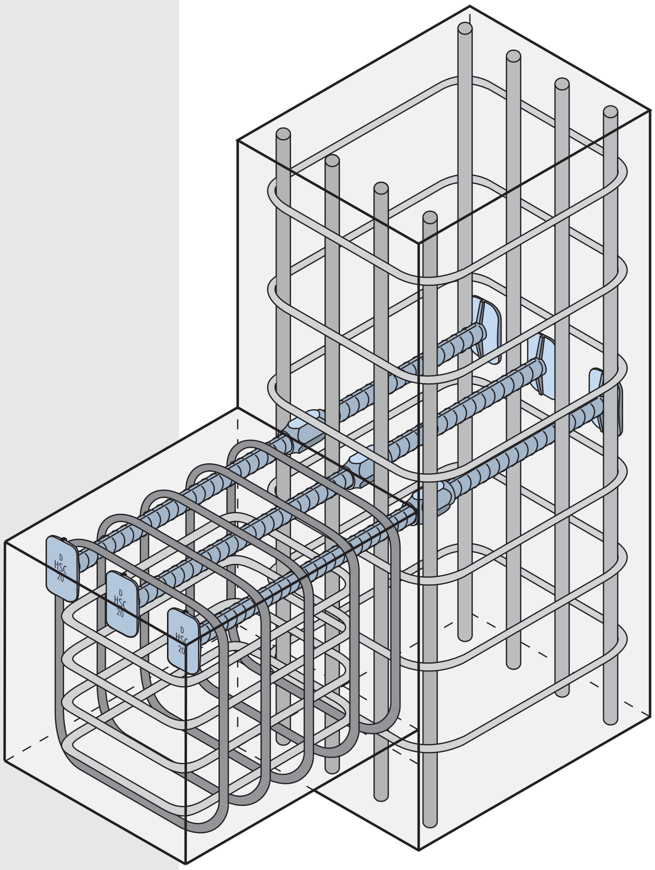
Longitudinal column reinforcement ratio:

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

Anchorage of longitudinal column reinforcement:

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

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.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

Organisation/plant ______________________

Contact person ______________________

Phone ______________ Fax ______________

E-mail ______________________

Construction project ______________________

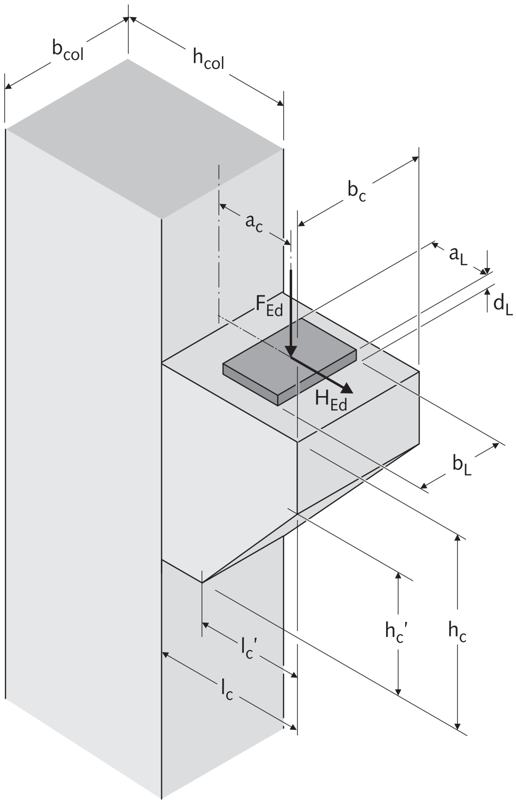
____

Site location ______________________

____

Item ______________________

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



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

Anchor diam. HSC	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

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

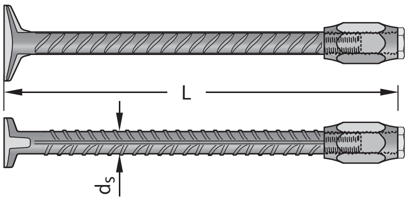
Vertical load	$N_{Ed,col,o}$		kN
Horizontal load	$V_{Ed,col,o}$		kN
Outer column reinforcement (longitudinal)	Number		pcs
	Diam.		mm

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 ②

Article name type bar diam. d_s / L [mm]	L_{min} [mm]	Article No.
HSC - S - 12 / . . .	155	0060.300 ①
HSC - S - 16 / . . .	180	0060.310 ①
HSC - S - 20 / . . .	200	0060.320 ①
HSC - S - 25 / . . .	230	0060.330 ①

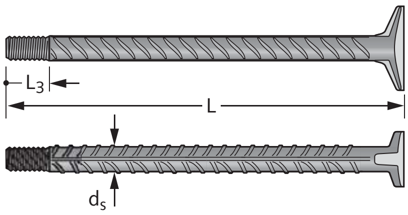
① required length, please indicate with your order, see page bottom.

HSC-S standard lengths

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

*) 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 ②

Article name type bar diam. d_s / L [mm]	L_{min} [mm]	Screw depth L_3 [mm]	Article No.
HSC - A - 12 / . . .	130	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

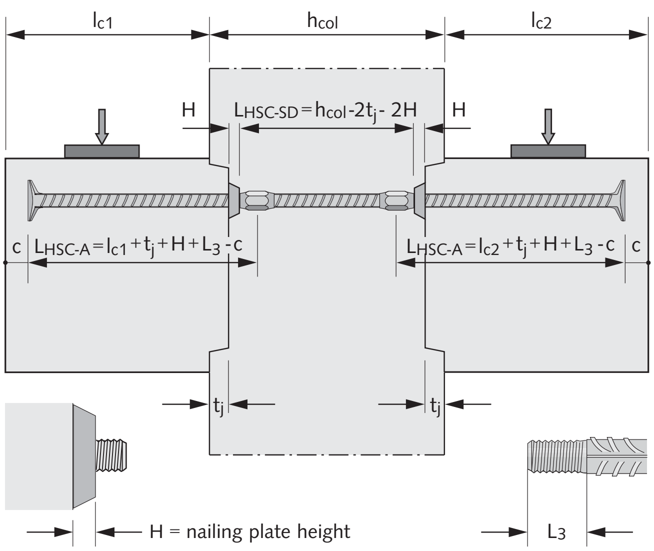
① please state required length when ordering, see bottom of page.

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

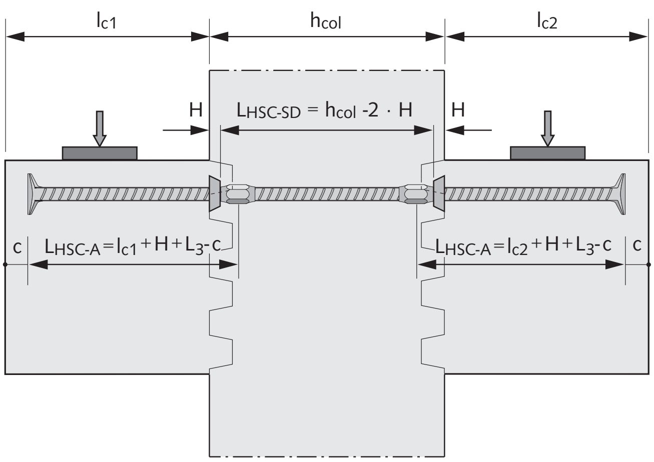
HSC-A standard lengths

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 indented joint, order length

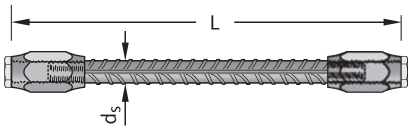


② B500NR stainless steel on request

HALFEN HSC STUD CONNECTOR

Product Range, References for Length Calculation

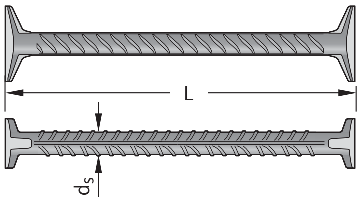
HSC-SD Double female bar



Material:
Concrete steel
B500B ②

Article name 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 / . . .	230	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

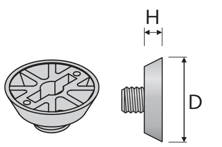


Material:
Concrete steel
B500B ②

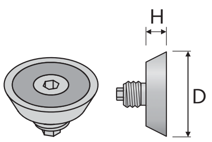
Article name type bar diam. d_s / L [mm]	L_{min} [mm]	Article No.
HSC - HD - 12 / . . .	175	0060.200 ①
HSC - HD - 16 / . . .	175	0060.210 ①
HSC - HD - 20 / . . .	175	0060.220 ①
HSC - HD - 25 / . . .	180	0060.230 ①
① please state required length when ordering		

Formwork accessories

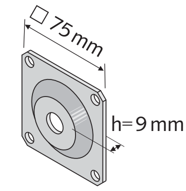
Nailing plate, plastic
3905



Magnetic plate
6365



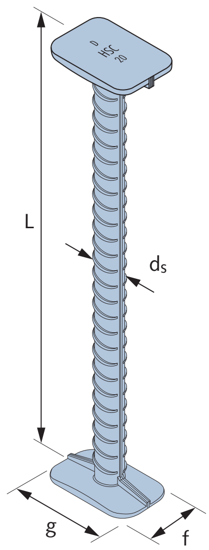
Nailing plate, metal
3916



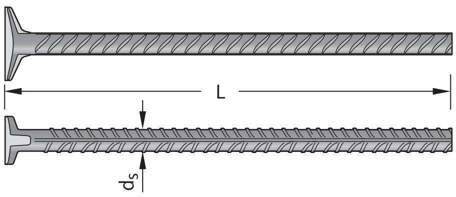
Article name	For bar diam. d_s [mm]	D [mm]	H [mm]	Article No.
3905 - 12	12	60	10	0725.020-00002
3905 - 16	16	60	10	0725.020-00004
3905 - 20	20	60	10	0725.020-00005
3916 - 25	25	75	9	0725.030-00001
6365 - 12	12	40	12	0741.180-00001
6365 - 16	16	40	12	0741.180-00002
6365 - 20	20	55	12	0741.180-00003

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.



HSC-H Single headed anchor bar



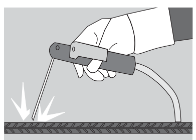
Material:
Concrete steel
B500B ②

Article name 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	

Dimensions HSC anchor head					
HSC - Typ		**12**	**16**	**20**	**25**
bar diameter $Ø_{ds}$	[mm]	12	16	20	25
anchor head width f	[mm]	30	35	44	55
anchor head length g	[mm]	35	53	66	83
contact-surface under-head A_{Kn}	[mm²]	906	1599	2504	3940

② B 500 NR stainless steel on request

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.

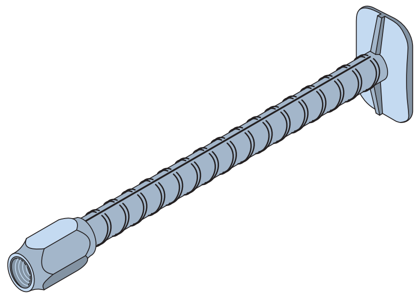
HSC Stud Connector

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,



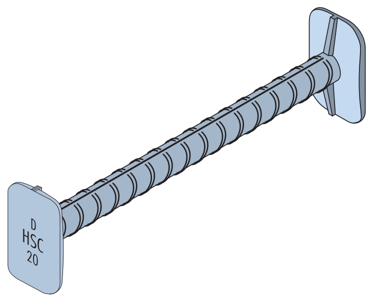
type HSC-S-16/L
16 = diameter [mm],
L = length ... [mm],

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

Order form

☐ **Enquiry** ☐ **Order**

(Please tick appropriate)

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.

Construction project

Organisation/facility

Address

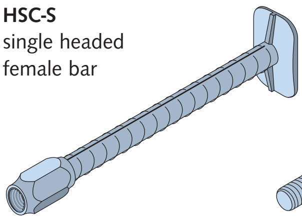
Contact person

Phone

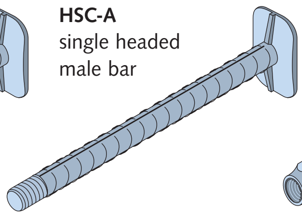
Fax

E-mail

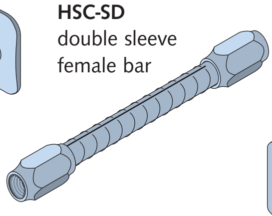
HSC-S
single headed female bar



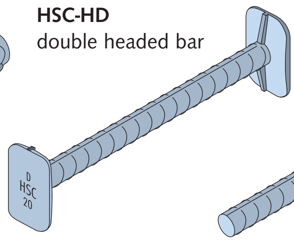
HSC-A
single headed male bar



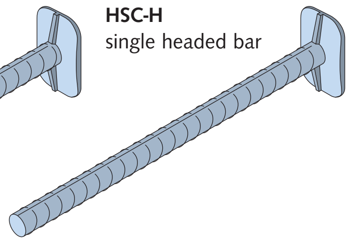
HSC-SD
double sleeve female bar



HSC-HD
double headed bar

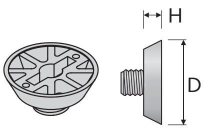


HSC-H
single headed bar

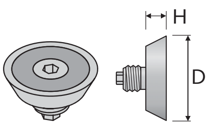


Formwork accessories

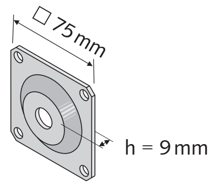
Nailing plate, plastic



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

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