Deutsches Institut für Bautechnik DIBt

Public-law institution jointly founded by the federal states and the Federation

Technical authority granting approvals and permits for construction products and construction techniques

National technical approval / General construction technique permit

Date: 29 Nov 2022
Reference number: I 24-1.21.8-12/22

Number:
Z-21.8-1973

Validity
from: **30 November 2022**
to: **30 November 2027**

Applicant:
Leviat GmbH
Liebigstraße 14
40764 Langenfeld, Germany

Subject of decision:
'HALFEN Stud Connector HSC' intended for the end anchorage of flexural tensile reinforcement in reinforced concrete members

The subject named above is herewith granted a national technical approval (*allgemeine bauaufsichtliche Zulassung*) / general construction technique permit (*allgemeine Bauartgenehmigung*). This decision contains seven pages and six annexes with a total of 19 pages.
The subject concerned was granted the first national technical approval under number Z-15.6-204 on 17 December 2002.

I GENERAL PROVISIONS

1 This decision confirms the fitness for use and application of the subject concerned within the meaning of the Building Codes of the federal states (*Landesbauordnungen*).

2 This decision does not replace the permits, approvals and certificates required by law for carrying out construction projects.

3 This decision is granted without prejudice to the rights of third parties, in particular private property rights.

4 Notwithstanding further provisions in the 'Special Provisions', copies of this decision shall be made available to the user and installer of the subject concerned. The user and installer of the subject concerned shall also be made aware that this decision must be made available at the place of use or place of application. Upon request, copies of the decision shall be provided to the authorities involved.

5 This decision shall be reproduced in full only. Partial publication requires the consent of DIBt. Texts and drawings in promotional material shall not contradict this decision. In the event of a discrepancy between the German original and this authorised translation, the German version shall prevail.

6 This decision may be revoked. The provisions contained therein may subsequently be supplemented and amended, in particular if this is required by new technical findings.

7 This decision is based on the information and documents provided by the applicant. Alterations to this basis are not covered by this decision and shall be notified to DIBt without delay.

II SPECIAL PROVISIONS

1 Subject concerned and field of use and application

The subject of approval is the 'HALFEN Stud Connector HSC', made of rebar B500B with a nominal diameter of 12, 14, 16, 20 or 25 mm, featuring single-ended or double-ended forged rectangular anchor heads. HSC anchors of nominal diameter 12 mm or 14 mm may also be made of stainless reinforcing steel B500 NR, material no. 1.4571 or 1.4362.

Application examples are provided in Annex 1.

The subject of the permit is the planning, design and execution of reinforced concrete members using the 'HALFEN Stud Connector HSC' for end anchoring of flexural tensile reinforcements with rectangular anchor heads, e.g. in exterior beam-column joints, corbels, beams and slabs in accordance with DIN EN 1992-1-1 in conjunction with DIN EN 1992-1-1/NA with a minimum concrete strength class of C20/25, a maximum concrete strength class of C70/85 and a density between 2,000 kg/m³ and 2,600 kg/m³ under static, quasi-static and fatigue loads.

2 Provisions for the construction product

2.1 Required properties

The starting material for the anchors shall have the properties of B500B in accordance with DIN 488-1 or B500 NR material no. 1.4571 or 1.4362 in accordance with the national technical approval.

The ultimate load of an anchor shall be at least:

$$P_u = f_t \cdot A_s$$

where: P_u = ultimate load in the anchor

f_t = minimum tensile strength of the reinforcing steel used (550 N/mm²)

A_s = actual cross-section of the anchor.

The load-bearing area of the anchor head shall be eight times the cross-sectional area of the anchor shaft.

The dimensions and permissible tolerances shall correspond to Annex 2 and the deposited data sheet.

2.2 Manufacture, packaging, transport, storage and marking

2.2.1 Manufacture

The anchor heads of the HSC anchors shall be forged in the manufacturing plant. The marking shall be impressed on the heads during this process.

Flash welding of the HSC anchors shall be carried out using the flash welding parameters deposited with DIBt. Manufacturing plants which weld the HSC anchors in accordance with this decision shall have provided evidence that they are competent to do so. This proof is deemed to have been provided if:

- welding processes and welding personnel are qualified in accordance with DIN EN 1090-2 and the manufacturer is in possession of a welding certificate of at least EXC 4 in accordance with DIN EN 1090-1 and

- the requirements in accordance with DIN EN ISO 17660-1 in conjunction with the DVS guideline DVS 1708 and the provisions of national technical approval Z-30.3-6 or DIN EN 1993-1-4 are met.

2.2.2 Packaging, transport and storage

The anchors shall be packaged, transported and stored in such a way that they are not damaged.

2.2.3 Marking

The delivery note for the anchors shall be marked by the manufacturer with the national conformity mark (*Ü-Zeichen*) in accordance with the Conformity Marking Ordinances (*Übereinstimmungszeichen-Verordnungen*) of the federal states and shall contain the anchor diameter. The mark shall only be applied if the requirements given in Section 2.3 are met. A marking in accordance with Annex 2 shall be impressed on each anchor head.

2.3 Confirmation of conformity

2.3.1 General

The manufacturer shall confirm for each manufacturing plant that the construction product complies with the provisions of this national technical approval by way of a declaration of conformity based on factory production control and a certificate of conformity issued by a certification body recognised for these purposes as well as on regular external surveillance carried out by a recognised inspection body in accordance with the following provisions: To issue the certificate of conformity and for external surveillance including the associated product testing, the manufacturer of the construction product shall use a certification body and an inspection body recognised for these purposes.

The declaration of conformity shall be submitted by the manufacturer through marking of the construction products with the national conformity mark, including statement of the intended use.

The certification body shall send a copy of the certificate of conformity issued by it to DIBt.

2.3.2 Factory production control

A factory production control system shall be set up and implemented in each manufacturing plant. Factory production control is understood to be continuous surveillance of production by the manufacturer to ensure that the construction products manufactured satisfy the provisions of this national technical approval. The factory production control shall at least include the following measures:

- Description and check of the starting material and the components:

  The manufacturer of the HSC anchors shall ensure that the properties required for the reinforcing steel B500B in accordance with DIN 488-1 or B500 NR in accordance with the national technical approval are verified through plant codes and national conformity marks.

- Verifications and tests to be carried out on the construction product:

  The ultimate load shall be determined in a test set-up as described in the deposited test plan.

  The dimensions specified in the deposited 'HSC anchor' data sheet shall be checked and the tolerances specified therein shall be observed.

The results of factory production control shall be recorded and evaluated in accordance with the test plan deposited with DIBt and the external surveillance body. The records shall at least include the following information:

- designation of the construction product,
- type of check or test,
- date of manufacture and testing of the construction product,
- result of the checks and tests and comparison with the requirements,
- signature of the person responsible for factory production control.

The records shall be kept for at least five years and submitted to the inspection body used for external surveillance. They shall be submitted to DIBt and the competent supreme building authority upon request.

If the test result is unsatisfactory, the manufacturer shall immediately take the necessary measures to resolve the defect. Construction products which do not meet the requirements shall be handled in such a way that they cannot be confused with compliant products. After the defect has been remedied, the relevant test shall be repeated immediately, where technically feasible and necessary to show that the defect has been eliminated.

2.3.3 External surveillance

The plant and the factory production control system shall be inspected regularly, i.e. at least once a year, by means of external surveillance at each manufacturing plant. Initial type-testing of the construction product shall be carried out within the scope of external surveillance. Samples for random testing shall also be taken. Sampling and testing shall be the responsibility of the recognised inspection body.

Within the framework of external surveillance of factory production control, samples shall be taken and tested in accordance with the deposited test plan and the test results shall be recorded and evaluated.

The results of certification and external surveillance shall be kept for at least five years. They shall be presented by the certification or inspection body to DIBt and the competent supreme building authority upon request.

3 Provisions for planning, design and execution

3.1 Planning and design

3.1.1 General

Unless otherwise specified below, DIN EN 1992-1-1 in conjunction with DIN EN 1992-1-1/NA or DIN EN 1992-2 in conjunction with DIN EN 1992-2/NA shall apply to the detailing and to determining the internal forces and moments as well as the flexural reinforcement of the reinforced concrete members.

3.1.2 Fatigue verification

Fatigue verification shall be carried out in accordance with DIN EN 1992-1-1 and DIN EN 1992-1-1/NA, Clause 6.8. The following characteristic fatigue strengths shall be assumed: for the diameter range 12 to 20 mm a stress range of $\Delta\sigma_{Rsk}$ = 80 N/mm² for N = $2 \cdot 10^6$ load cycles and for the diameter 25 mm a stress range of $\Delta\sigma_{Rsk}$ = 70 N/mm² for N = $2 \cdot 10^6$ load cycles (see DIN EN 1992-1-1, Figure 6.30). The stress exponents for the S-N curve shall be assumed to be k_1 = 3.5 to $2 \cdot 10^6$ load cycles, k_1 = 3 from $2 \cdot 10^6$ to 10^7 load cycles and k_2 = 5.

3.1.3 Exterior beam-column joints

The minimum dimensions of the members given in Annex 3, Table 2, shall be observed.

The eccentricity of the beam shear force shall not be greater than the width of the beam.

The beam height shall not exceed twice the column height.

Planning and design in accordance with DIN EN 1992-1-1 shall be carried out in accordance with Annex 3, based on DAfStb booklet 532.

3.1.4 Corbels

The minimum dimensions of the members given in Annex 4, Table 3, shall be observed.

Planning and design in accordance with DIN EN 1992-1-1 shall be carried out as set out in Annex 4 and the assumptions in DAfStb booklet 600, Appendix J.

3.1.5 Subsequently added cross-sections

For subsequently added cross-sections in exterior beam-column joints or corbels as given in Annex 5, the same compression strut resistance as that of monolithic cross-sections may be assumed if execution has been carried out properly. The tensile chord reinforcement shall be connected to the column with Halfen HBS-05 threaded coupler systems in accordance with ETA-21/0800.

3.1.6 Beams and slabs

The minimum dimensions of the members given in Annex 6, Table 6, shall be observed.

Planning and design in accordance with DIN EN 1992-1-1 shall be carried out as given in Annex 6.

3.2 Execution

In exterior beam-column joints, at least one bar of the column reinforcement shall be placed between the HSC anchor shaft and the lateral edge of the member as set out in Annex 3, Section 1.

If corbels or exterior beam-column joints are not monolithically designed, the provisions given in Annex 5 shall be observed.

The executing company shall provide a declaration of conformity in accordance with Section 16a(5) in conjunction with Section 21(2) of the Model Building Code to confirm conformity of the construction technique with the general construction technique permit included in this decision.

The following standards and references are referred to in this decision:

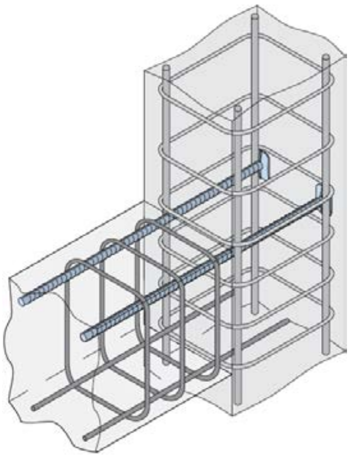
– DIN 488-1:2009-08	Reinforcing steels – Part 1: Grades, properties, marking
– DIN 488-2:2009-08	Reinforcing steels – Reinforcing steel bars
– DIN EN 1090-1:2012-02	Execution of steel structures and aluminium structures – Part 1: Requirements for conformity assessment of structural components; German version EN 1090-1:2009+A1:2011
– DIN EN 1090-2:2018-09	Execution of steel structures and aluminium structures – Part 2: Technical requirements for steel structures, German version EN 1090-2:2018
– DIN EN 1992-1-1:2011-01 + A1:2015-03	Eurocode 2: Design of concrete structures – Part 1-1: General rules and rules for buildings; German version EN 1992-1-1:2004 + AC:2010 + A1:2014 **and**
DIN EN 1992-1-1/NA:2013-04 + A1:2015-12	National Annex – Nationally determined parameters – Eurocode 2: Design of concrete structures – Part 1-1: General rules and rules for buildings + Amendment A1
– DIN EN 1992-2:2010-12	Eurocode 2: Design of concrete structures – Part 2: Concrete bridges - Design and detailing rules; German version EN 1992-2:2005 + AC:2008 **and**
DIN EN 1992-2/NA:2013-04	National Annex - Nationally determined parameters – Eurocode 2: Design of concrete structures – Part 2: Concrete bridges - Design and detailing rules
– DIN EN 1993-1-4:2015-10	Eurocode 3: Design of steel structures – Part 1-4: General rules – Supplementary rules for stainless steels; German version EN 1993-1-4:2006 + A1:2015

- DIN EN ISO 17660-1:2006-12 + Corr. 1:2007-08
  Welding – Welding of reinforcing steel – Part 1: Load-bearing welded joints (ISO 17660-1:2006); German version EN ISO 17660-1:2006, Corrigenda to DIN EN ISO 17660-1:2006-12
- DAfStb booklet 532:2002-08 — Design of frame nodes, basic principles and examples in accordance with DIN 1045-1, 1st edition 2002 (*Die Bemessung und Konstruktion von Rahmenknoten, Grundlagen und Beispiele gemäß DIN 1045-1, 1. Auflage 2002*)
- DAfStb booklet 600:2012-09 — Explanations regarding DIN EN 1992-1-1 and DIN EN 1992-1-1/NA (Eurocode 2) (*Erläuterungen zu DIN EN 1992-1-1 und DIN EN 1992-1-1/NA (Eurocode 2)*)
- DVS 1708:2009-09 — Prerequisites and procedure for granting constructor's qualifications for welding of reinforcing steel in accordance with DIN EN ISO 17660-1:2006-12 or in accordance with DIN EN ISO 17660-2:2006-12 (*Voraussetzungen und Verfahren für die Erteilung der Herstellerqualifikation zum Schweißen von Betonstahl nach DIN EN ISO 17660-1:2006-12 oder nach DIN EN ISO 17660-2:2006-12*)
- ETA-21/0800 — HALFEN HBS-05 threaded coupler system of 6 December 2021
- Z-30.3-6 — Products, structural components and fasteners made of stainless steels of 20 April 2022
- The data sheet is deposited with DIBt and the body used for external surveillance.
- The test plan is deposited with DIBt and the body used for external surveillance.

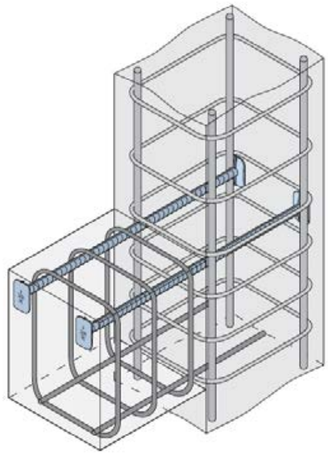
Dipl.-Ing. Beatrix Wittstock
Head of Section

Drawn up by
Kisan

HSC anchors in exterior beam-column joints

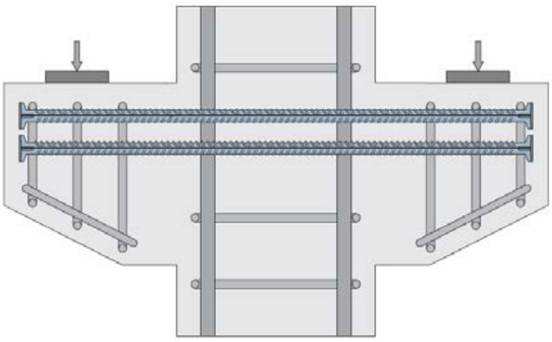


HSC anchors in corbels

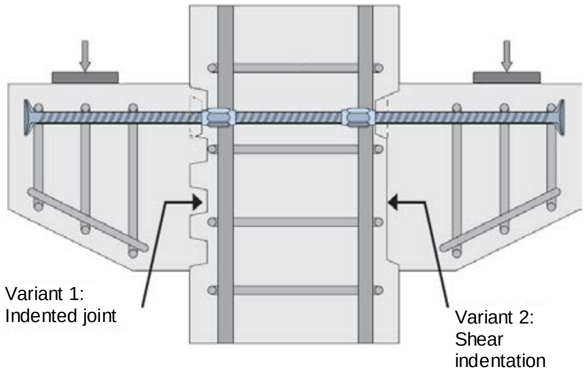


HSC anchors in corbels

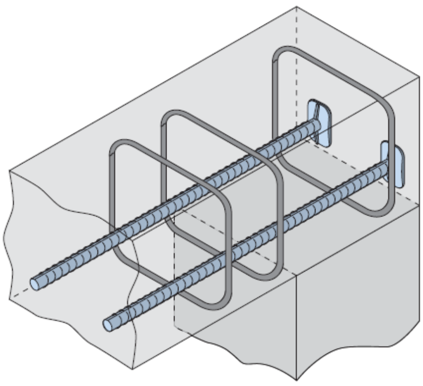
Corbels with multi-layer HSC anchors

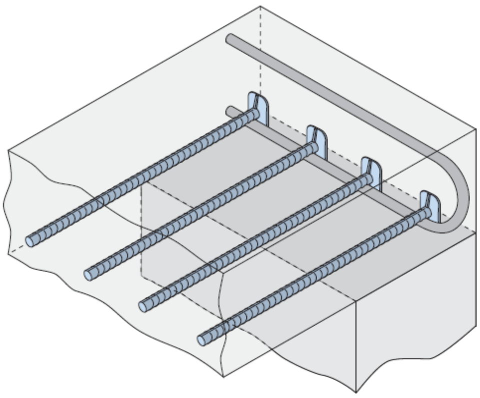


Concreting sections cast at different times with construction joint*



HSC anchors in beams and slabs



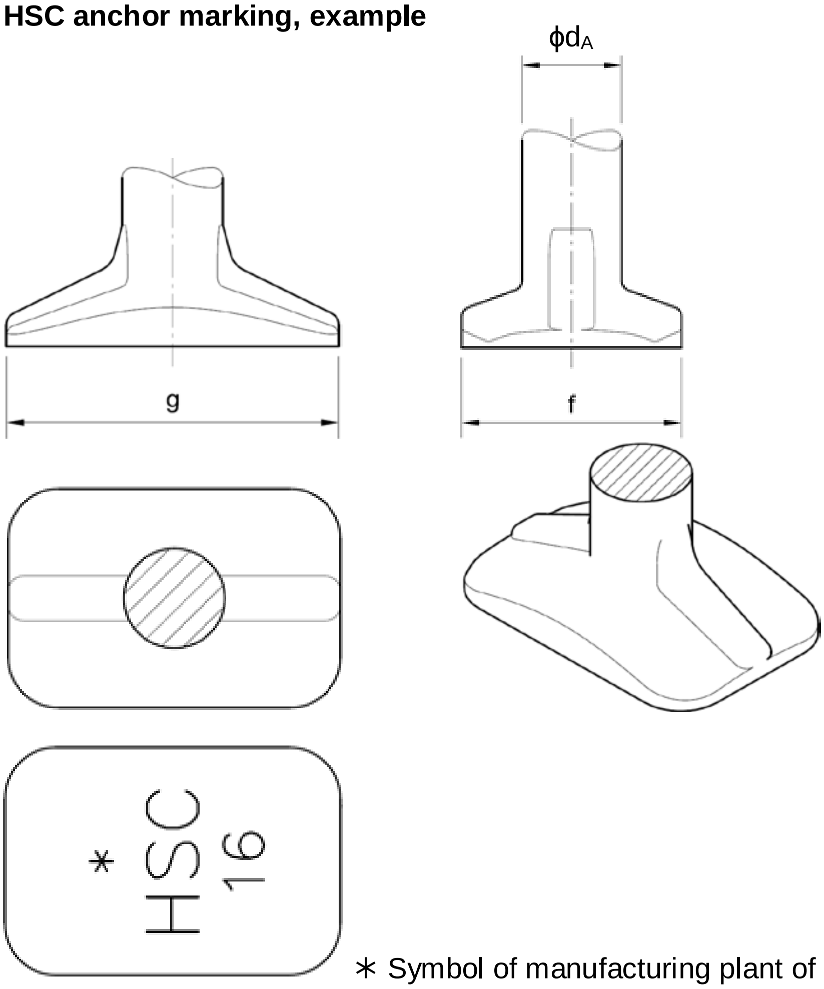


* Indented construction joint in accordance with DIN EN 1992-1-1, Clause 6.2.5, Figure 6.9, or shear indentation based on DIN EN 1992-1-1. HSC anchors are connected to the column using HALFEN HBS-05 threaded coupler systems in accordance with ETA-21/0800.

There are no restrictions on the number or arrangement of the HSC anchors as long as the requirements specified in Annexes 3, 4 and 6 are met.

HALFEN Stud Connector HSC	**Annex 1**
Layout of HSC anchors in exterior beam-column joints, corbels, beams and slabs	

HSC anchor marking, example



∗ Symbol of manufacturing plant of anchor

Material: Reinforcing steel B500B in accordance with DIN 488-1 for ϕd_A = 12 mm or 14 mm, alternatively stainless reinforcing steel B500 NR (material no. 1.4571 or 1.4362) in accordance with the national technical approval

Permissible welded joints at HSC anchor bars: butt joints in accordance with DIN EN ISO 17660-1, welding process 24 – flash welding in accordance with DIN EN ISO 4063

Table 1: Anchor dimensions

HSC	Shaft diameter ϕd_A	Head width f	Head length g	Head height h_{HSC}	Load-bearing area of anchor head $A_{K,n}$
	[mm]	[mm]	[mm]	[mm]	[mm²]
12	12	30	35	8	906
14	14	34	42	9	1,232
16	16	35	53	10	1,599
20	20	44	66	12	2,504
25	25	55	83	14	3,940

HALFEN Stud Connector HSC

Dimensions of the HSC anchors

Annex 2

Planning and design of exterior beam-column joints in accordance with DIN EN 1992-1-1

1. Geometry and designations, detailing rules

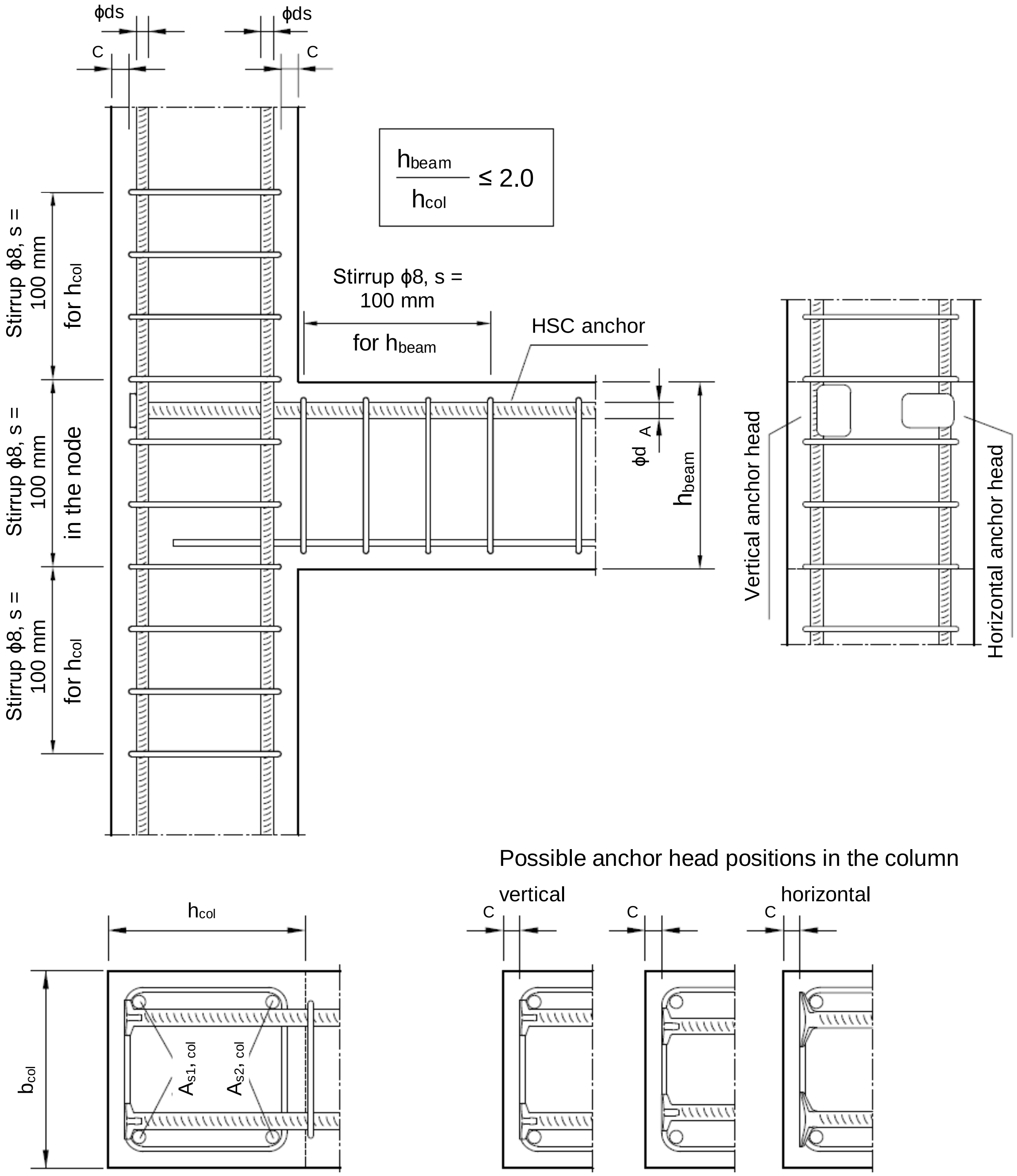


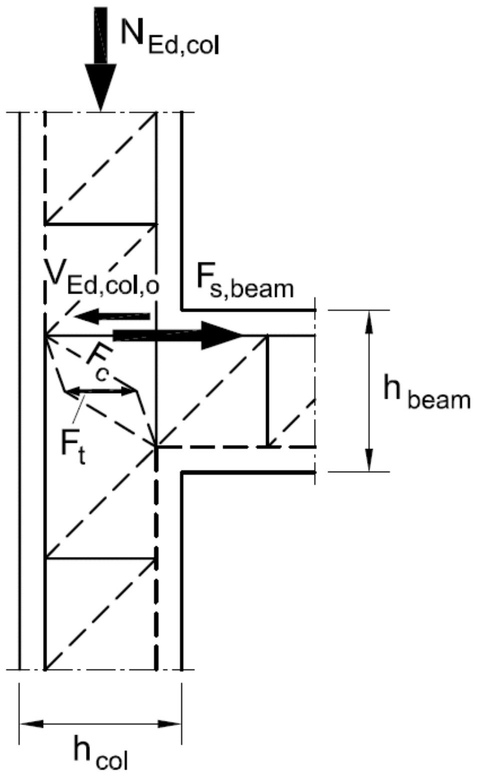
Figure 1: Reinforcement layout, example

HALFEN Stud Connector HSC	
Exterior beam-column joints in accordance with DIN EN 1992-1-1	**Annex 3** Page 1/5

The anchor heads may be installed vertically or horizontally. The minimum requirements for the member dimensions and column longitudinal reinforcement given in Table 2 shall be met. The concrete cover c shall be determined in accordance with DIN EN 1992-1-1.

Table 2: Minimum member dimensions and minimum diameters of column longitudinal reinforcements

HSC	**Column**			**Concrete strength class**
	$b_{col,min}$	$h_{col,min}$	$\phi d_{s,min}$	
	[mm]	[mm]	[mm]	[-]
12	240	240	12	C20/25 – C70/85
14	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



F_t = splitting force
F_c = compression strut force

Figure 2: Strut-and-tie model

HALFEN Stud Connector HSC

Exterior beam-column joints in accordance with DIN EN 1992-1-1

Annex 3
Page 2/5

2. Planning and design of the column

The column longitudinal reinforcement ratio for each column side $\rho_{s(..),col}$ shall be at least 0.5%.

$$\rho_{s(..),col} = \frac{A_{s(..),col}}{b_{col} \cdot h_{col}} \geq 0.5\% \quad (1)$$

where: $A_{s(..),col}$ = cross-sectional area of column longitudinal reinforcement in each column side

b_{col}, h_{col} = width and depth of the cross-section of the column

The column reinforcement shall run straight through the node.

It shall be verified that the sum of the tensile and compressive forces in the column longitudinal reinforcement can be anchored within the node:

$$l_b = \frac{|T|+|C_s|}{f_{bd} \cdot n \cdot U} \leq l_j \quad (2)$$

where: T = tensile force in the reinforcement

C_s = compressive force in the reinforcement

U = bond circumference of a reinforcement bar

n = number of bars in the respective column reinforcement

f_{bd} = bond stress in accordance with DIN EN 1992-1-1, Clause 8.4.2

l_j = node length along the reinforcement (= h_{beam})

l_b = anchorage length

The anchorage of the column reinforcement $A_{s(..),col}$ shall be verified for the least favourable moment-to-axial force ratio of possible combinations of actions.

For sway frame constructions, the column reinforcement at the node sections shall be increased by a flat rate of 1/3 in proportion to the bending design. This additional reinforcement shall be anchored outside the node.

Stirrups shall be designed and arranged as specified in Annex 3, Section 4.

3. Planning and design of the beam

The bending design of the beam shall be carried out at a distance of 0.3 h_{col} from the neutral axis of the column.

The beam tensile reinforcement with HSC anchors shall be anchored behind the outer column longitudinal reinforcement but within the stirrup reinforcement of the column. The required concrete cover shall be maintained.

At least one bar of the column longitudinal reinforcement shall be arranged between the shaft of the HSC anchor and the lateral edge of the member as shown in Annex 3, Section 1, Figure 1.

A beam compression reinforcement shall not be taken into account in the calculation.

The lower beam reinforcement shall run straight into the node and shall end straight, i.e. unbent, in front of the rear column reinforcement.

Stirrups shall be designed and arranged as specified in Annex 3, Section 4.

4. Stirrup reinforcement

Beams and columns shall be reinforced with stirrups over a length h_{col} as measured from the node sections with a maximum spacing of s ≤ 10 cm; cf. illustration in Annex 3, Section 1 Figure 1.

The horizontal stirrup reinforcement of the node shear field of the exterior beam-column joints shall be executed with U bars or closed stirrups in accordance with DIN EN 1992-1-1/NA Figure 8.5DE.

The U bars shall be anchored in the beam with a length of d_{beam} (effective depth of beam) and shall go around the outermost column longitudinal reinforcement.

The structurally required reinforcement ratio shall be calculated in accordance with Annex 3, Section 5, Equation (6).

5. Verification of shear resistance

A suitable structural system shall be selected for determining the span moment and for designing the beam as well as the upper and lower column.

The acting node shear force V_{jh} results from the tensile force in the beam tensile reinforcement $A_{s,HSC} \cdot f_{yd}$ and the shear force of the upper column $V_{Ed,col,o}$:

$$V_{jh} = A_{s,HSC} \cdot f_{yd} - V_{Ed,col,o} \tag{3}$$

It shall be verified that the acting node shear force V_{jh} is not greater than the node resistance with stirrups $V_{j,Rd}$ in accordance with Annex 3, Section 5, Equation (6), and that it does not exceed the upper limit of the node resistance $V_{j,Rd,max}$ as set out in Annex 3, Section 5, Equation (7).

$$V_{jh} \leq \begin{cases} V_{j,Rd} \\ V_{j,Rd,\,max} \end{cases} \tag{4}$$

Node resistance without stirrups:

$$V_{j,cd} = 1.55 \cdot \left(1.2 - 0.3 \cdot \frac{h_{beam}}{h_{col}}\right) \cdot \left(1 + \frac{\rho_{As1,col}{}^{-0.5}}{7.5}\right) \cdot b_{eff} \cdot h_{col} \cdot f_{cd}^{*\,1/4} \quad \text{in [N]} \tag{5}$$

where:

$\frac{h_{beam}}{h_{col}}$ = shear slenderness, $1.0 \leq \frac{h_{beam}}{h_{col}} \leq 2.0$

h_{beam} = cross-sectional height of the beam in [mm]

h_{col} = cross-sectional depth of the column in [mm]

b_{eff} = effective node width in [mm] $b_{eff} = \frac{b_{beam} + b_{col}}{2} \leq b_{col}$

$\rho_{As1,col}$ = column longitudinal reinforcement ratio for column reinforcement $A_{s1,col}$ in accordance with Annex 3, Section 2, Equation 1 in [%] $0.5\% \leq \rho_{As1,col} \leq 2.0\%$

$f_{cd}^{*} = \frac{f_{ck}}{\gamma_c}$ = design value of concrete compressive strength in [N/mm²]

Node resistance with stirrups:

$$V_{j,Rd} = V_{j,cd} + 0.475 \cdot A_{sj,eff} \cdot f_{yd} \leq V_{j,Rd,\,max} \tag{6}$$

where: $V_{j,cd}$ = node resistance without stirrups in accordance with Annex 3, Section 5, Equation (5)

$A_{sj,eff}$ = effective shear reinforcement (arranged above the beam compression zone; it can be considered up to the upper edge of the node)

$f_{yd} = \frac{f_{yk}}{\gamma_s}$ = design value of yield strength of the reinforcement

Maximum node resistance:

$$V_{j,Rd,\,max} = \gamma_N \cdot 0.3 \cdot f_{cd}^{*} \cdot b_{eff} \cdot h_{col} \leq 2 \cdot V_{j,cd} \tag{7}$$

where: γ_N = $\gamma_{N1} \cdot \gamma_{N2}$

γ_{N1} = effect of quasi-permanent column force

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

γ_{N2} = effect of shear slenderness

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

$N_{Ed,perm,col}$ = column force due to quasi-permanent action combination (permanent) (compression: negative, tension: positive)

$A_{c,col}$ = cross-sectional area of column $A_{c,col} = h_{col} \cdot b_{col}$

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

h_{beam}, b_{beam} = cross-sectional height and width of the beam

h_{col}, b_{col} = cross-sectional depth and width of the column

$f_{cd}^{*} = \frac{f_{ck}}{\gamma_c}$ = design value of concrete compressive strength

f_{ck} = characteristic value of concrete compressive strength

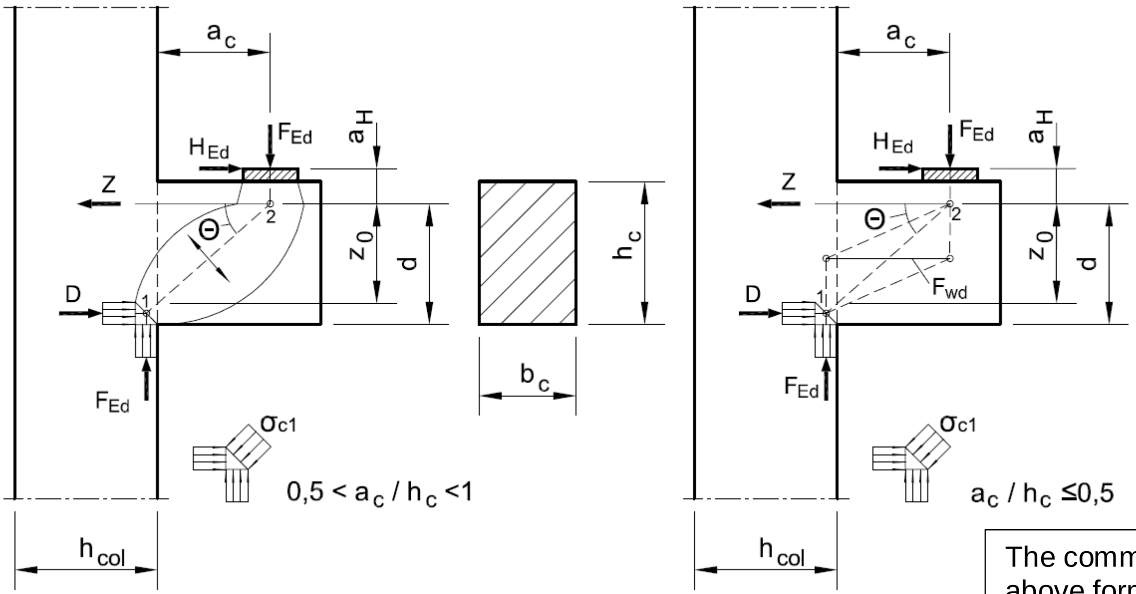
$V_{j,cd}$ = node resistance without stirrups in accordance with Annex 3, Section 5, Equation (5)

6. Verification of the shear joint

For concreting sections cast at different times, the joint shall be designed and verified in accordance with Annex 5.

Planning and design of reinforced concrete corbels in accordance with DIN EN 1992-1-1

1. Geometry and designations, detailing rules



The comma used in the above formulas stands for the decimal marker.

Figure 3: Strut-and-tie model in accordance with DAfStb booklet 600

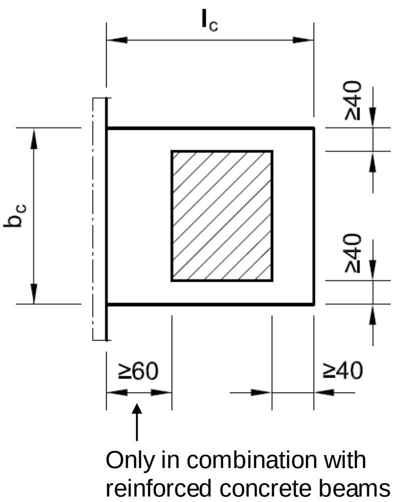


Figure 4: Arrangement of a loading plate, recommendation

The HSC anchors may be arranged in one layer or multiple layers, staggered or not staggered. The anchor heads may be installed vertically or horizontally. The concrete cover c, c_1 shall be determined in accordance with DIN EN 1992-1-1.

HALFEN Stud Connector HSC	
Corbels in accordance with DIN EN 1992-1-1	**Annex 4** Page 1/8

In general, the following detailing rules shall apply when HSC anchors are used in corbels:

a) The minimum dimensions of the corbels given in Annex 4, Section 1, Figure 3 and Table 3, shall be maintained

b) Edge distances and positions of the HSC anchors in the corbel as set out in Figure 5 and Annex 4, Section 1, Table 4

c) Placement of one closed vertical stirrup with ϕd_{sw} in accordance with Annex 4, Section 1, Table 4, for each row of HSC anchors between the middle of the loading plate and the anchor heads; see Annex 4, Section 9.

Table 3: Minimum dimensions of the corbel

HSC	**Corbel***		**Concrete strength class**
	$b_{c,min}$	$l_{c,min}$	
	[mm]	[mm]	[-]
12	200	200	C20/25 – C70/85
14	200	200	C20/25 – C70/85
16	200	200	C20/25 – C70/85
20	300	300	C20/25 – C25/30
	240	200	C30/37 – C35/45
	200	200	C40/50 – C70/85
25	300	400	C20/25
	300	350	C25/30 – C30/37
	300	300	C35/45 – C70/85

* The minimum dimensions of the corbel can be reduced if the anchorage of the HSC anchors can be verified as specified in Annex 4, Section 8.

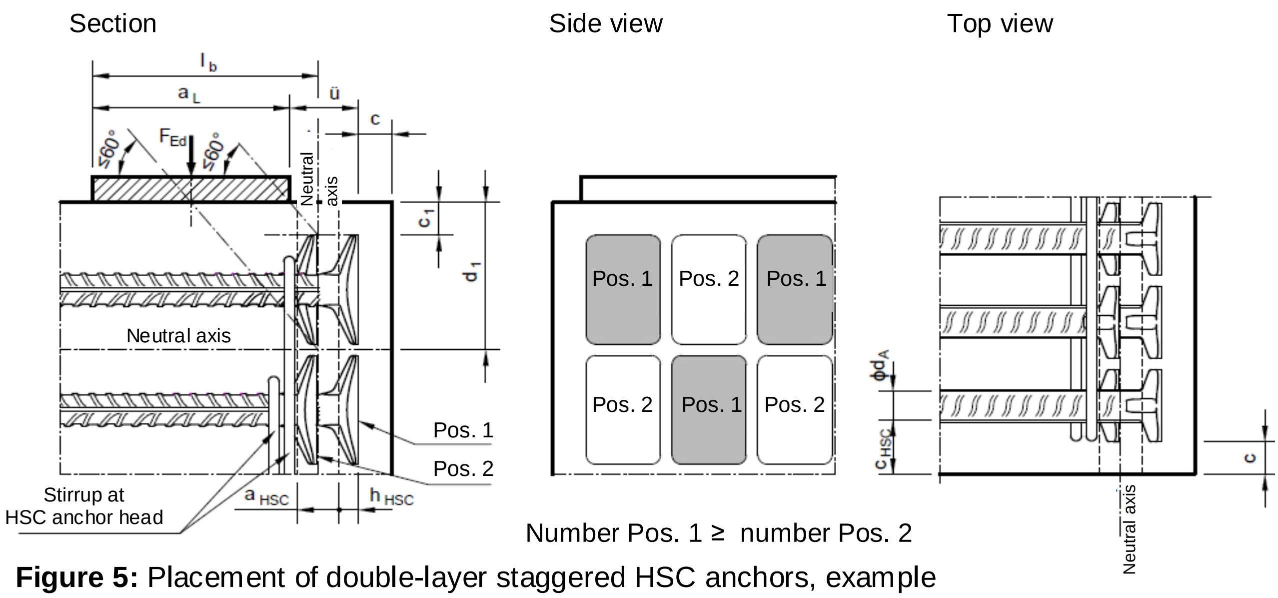


Figure 5: Placement of double-layer staggered HSC anchors, example

HALFEN Stud Connector HSC	
Corbels in accordance with DIN EN 1992-1-1	**Annex 4** Page 2/8

Table 4: Stirrups, concrete cover and head protrusion

HSC	Stirrup	Concrete cover		h_{HSC}	Head protrusion
	ϕd_{sw}	c_{HSC}	c, c_1		ü*
	[mm]	[mm]	[mm]	[mm]	[mm]
12	≥ 6	≥ 30	in accordance with DIN EN 1992-1-1	8	$ü \geq \max\begin{cases} a_{HSC}+h_{HSC} \\ \frac{c_1}{2}+\frac{a_{HSC}}{2}+h_{HSC} \\ \frac{d_1}{2}+\frac{a_{HSC}}{2}+h_{HSC}-\frac{a_L}{2} \end{cases}$
14	≥ 6	≥ 35		9	
16	≥ 6	≥ 40		10	
20	≥ 8	≥ 50		12	
25	≥ 10	≥ 60		14	

* a_{HSC} = 0 mm for non-staggered reinforcement placement

2. Actions

Design value of acting vertical load:

$$V_{Ed} = F_{Ed} \tag{8}$$

If friction forces in the supports as a result of restrained deformations cannot be excluded, a horizontal force of

$$H_{Ed} \geq 0.2 \cdot F_{Ed} \tag{9}$$

shall be applied.

3. Verification of shear resistance of corbel

$$V_{Ed} \leq V_{Rd,max} = 0.5 \cdot v \cdot b_c \cdot z \cdot \frac{f_{ck}}{\gamma_c} \tag{10}$$

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

f_{ck} = characteristic concrete compressive strength

z = lever arm of internal forces to determine shear resistance

$z = 0.9 \cdot d$

d = effective depth

4. Determination of tensile chord force

$$Z_{Ed} = F_{Ed} \cdot \frac{a_c}{z_0} + H_{Ed} \cdot \frac{a_H + z_0}{z_0} \tag{11}$$

where: $\frac{a_c}{z_0}$ ≥ 0.4

a_c = lever arm of external forces, distance from corbel edge to vertical force F_{Ed}

a_H = distance from neutral axis of tensile chord reinforcement to horizontal force H_{Ed}

z_0 = lever arm of internal forces to determine tensile chord force

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

d = effective depth

5. Determination of required amount of reinforcement for HSC anchors

$$A_{s,HSC} = \frac{Z_{Ed}}{f_{yd}} \qquad (12)$$

where: f_{yd} = design value of yield strength of HSC anchors

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

6. Verification of the shear joint

For column and corbel sections cast at different times, the joint shall be designed and verified as specified in Annex 5.

7. Verification of concrete compression under the loading plate

Verification of concrete compression under the loading plate shall be carried out in accordance with DIN EN 1992-1-1. The design distribution area A_{c1} shall be determined as specified in Figure 6.

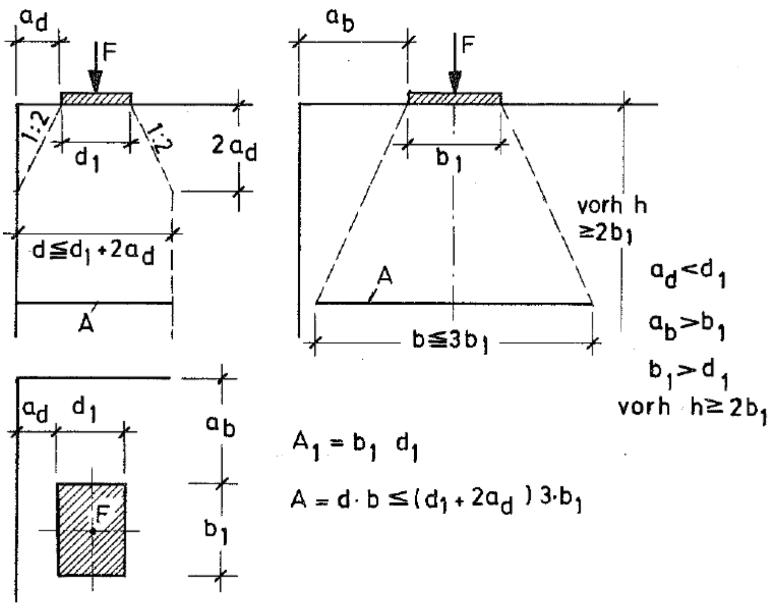


Figure 6: Determination of the design distribution area A_{c1} (= A) according to Leonhardt (lecture on solid construction – Part 2: Special design cases in reinforced concrete construction)

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Corbels in accordance with DIN EN 1992-1-1	**Annex 4** Page 4/8

8. Verification of the anchorage of HSC anchors in the corbel

The anchorage of a **single-layer** of HSC anchors in the corbel shall be deemed verified when the detailing rules a) to c) specified in Annex 4, Section 1, have been observed.

The anchorage of **multi-layer** HSC anchors in the corbel or if the **minimum dimensions** of the corbel **are not met** shall be deemed verified when the detailing rules b) and c) and the following anchorage verification have been observed:

$$Z_{Ed} \leq n_{HSC} \cdot \pi \cdot d_A \cdot l_b \cdot f_{bd} + A_{c0} \cdot \bar{f}_{cd} \quad (13)$$

where: n_{HSC} = number of HSC anchors

d_A = shaft diameter of HSC anchors

l_b = anchorage length from the inner face of the loading plate to vertical neutral axis of all anchor heads; see Annex 4, Section 1, Figure 5

f_{bd} = bond stress in accordance with DIN EN 1992-1-1, Clause 8.4.2

$\bar{f}_{cd}$ = $f_{cd} \cdot \sqrt{\frac{A_{c1}}{A_{c0}}} \leq 3.0 \cdot f_{cd}$

(In compression nodes without ties, f_{cd} may be increased by 10% in accordance with DIN EN 1992-1-1, Clause 6.5.4(4a), and DIN EN 1992-1-1/NA NDP re 6.5.4(4).)

f_{cd} = design value of concrete compressive strength in accordance with DIN EN 1992-1-1

A_{c0} = loaded concrete area of all HSC anchors with load-bearing area $A_{K,n}$ for each HSC anchor in accordance with Annex 2, Table 1

A_{c1} = design distribution area as given in Figure 7

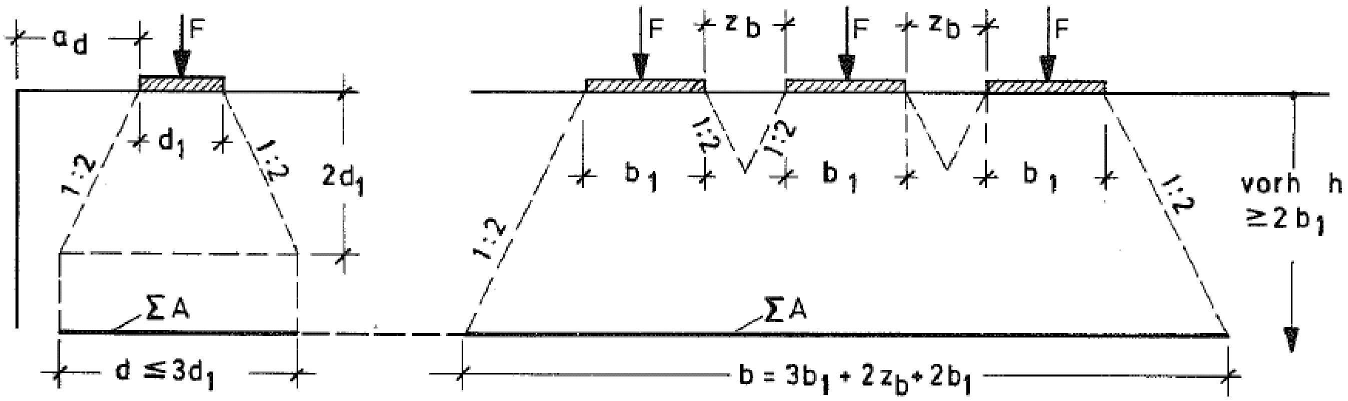


Figure 7: Determination of the design distribution area A_{c1} (= A) according to Leonhardt (lecture on solid construction – Part 2: Special design cases in reinforced concrete construction)

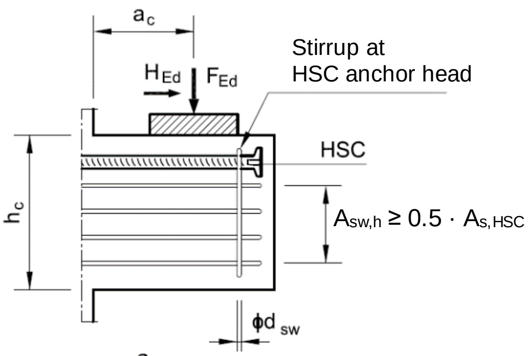
The effect of transverse compressive stress on the anchorage may be taken into account in accordance with DIN EN 1992-1-1, Clause 8.4.4, Table 8.2, and DIN EN 1992-1-1/NA NCI re 8.4.4(2), Table 8.2.

9. Arrangement of stirrups

To secure the concrete cover under transverse stress in the region of the loading point, at least one closed vertical stirrup with ϕd_{sw} in accordance with Annex 4, Section 1, Table 4, shall be required for each HSC anchor layer. It shall be arranged between the middle of the loading plate and the HSC anchor heads (see Annex 4, Section 1, Figure 5).

The lateral concrete cover shall be selected in accordance with DIN EN 1992-1-1 (see Annex 4, Section 1, Table 4).

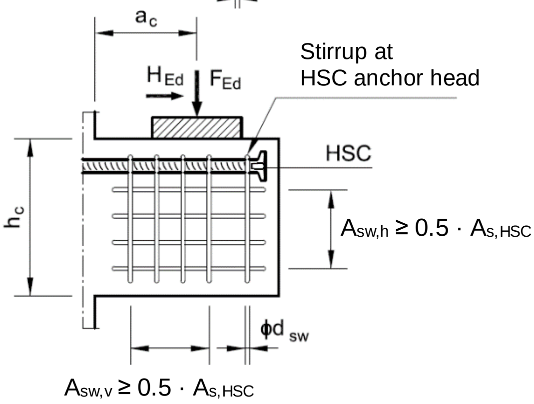
Stirrups for taking up splitting forces:



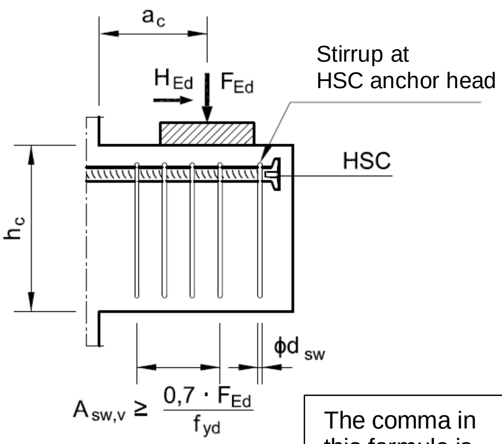
For $a_c \leq 0.5 \cdot h_c$ and $V_{Ed} > 0.3 \cdot V_{Rd,max}$ ($V_{Rd,max}$ as given in eq. (10)

- Closed horizontal or inclined stirrups with a total cross-section of at least 50% of the chord reinforcement $A_{s,HSC}$ shall be placed with the stirrups encompassing both the corbel and the column.

or



- Closed horizontal and vertical stirrups each with a total cross-section of at least 50% of the chord reinforcement $A_{s,HSC}$ shall be placed in the corbel with the corbel and the column being separately reinforced with stirrups.



For $a_c > 0.5 \cdot h_c$ and $V_{Ed} > V_{Rd,c}$ ($V_{Rd,c}$ nach DIN EN 1992-1-1, Clause 6.2.2 (1) and DIN EN 1992-1-1/NA, NDP re 6.2.1(1))

- Closed vertical stirrups shall be placed for stirrup forces of $F_{wd} = 0.7 \cdot F_{Ed}$ in total.

The comma in this formula is used as the decimal marker.

10. Verification of anchorage of HSC anchors in the supporting column

The anchorage of HSC anchors in the supporting column shall be deemed verified when the following detailing rules have been observed:

a) Minimum dimensions of column in accordance with Annex 3, Section 1, Figure 1 and Table 2
b) Minimum bar diameter of column longitudinal reinforcement in accordance with Annex 3, Section 1, Figure 1 and Table 2
c) Positioning of HSC anchor heads behind the outermost column longitudinal reinforcement and within the column stirrup reinforcement with the required concrete cover in accordance with Annex 3, Section 1, Figure 1 being maintained
d) Placement of at least one bar of the column longitudinal reinforcement between the shaft of the HSC anchor and the lateral edge of the member in accordance with Annex 3, Section 1, Figure 1
e) Stirrup reinforcements with closed stirrups shall be placed in the column along the corbel height h_c with a spacing of s ≤ 10 cm; cf. illustration in Figure 8.

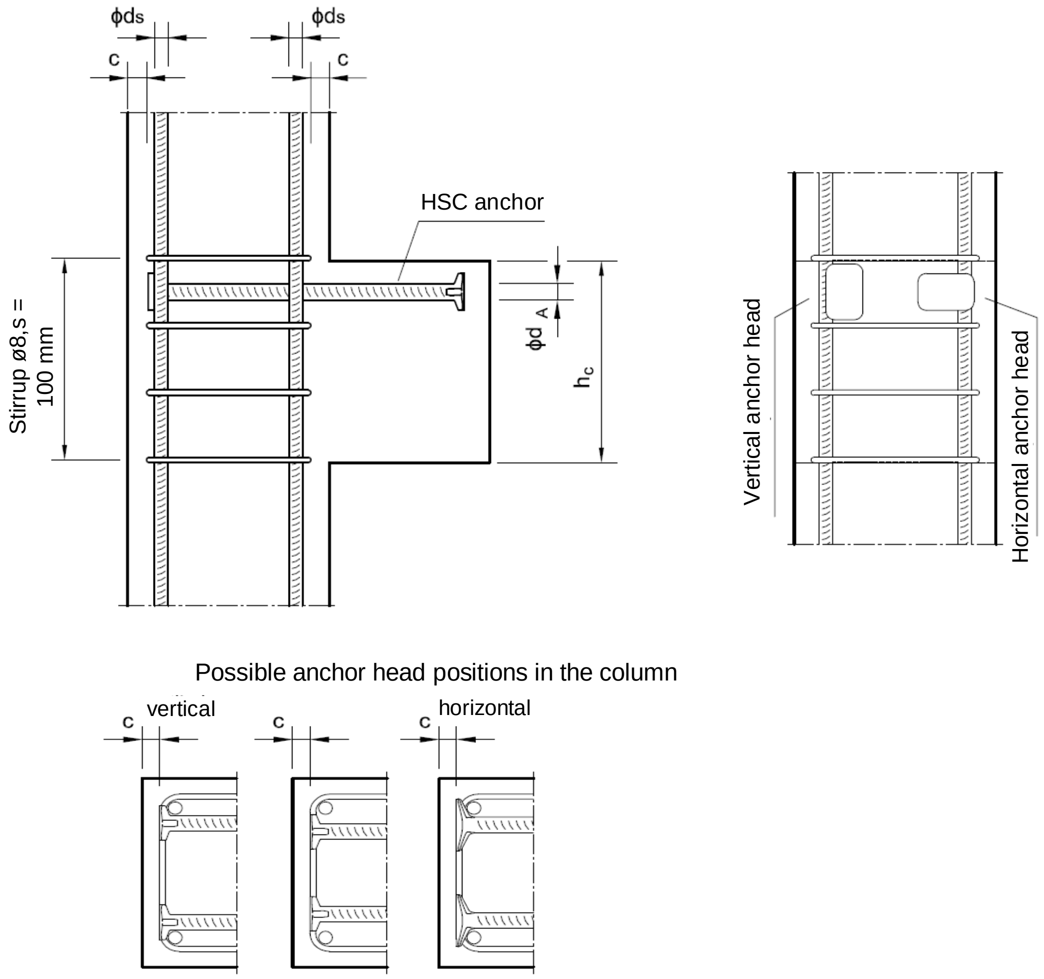


Figure 8: Reinforcement layout in the column, examples

11. Verification of anchorage of HSC anchors bent downwards in the supporting column

The anchorage of HSC anchors bent downwards by 90° in the supporting column through overlapping with the flexural tensile reinforcement in the column shall be deemed verified when the following detailing rules have been observed:

a) Minimum mandrel diameter of the HSC anchors $D \geq 10\ \phi d_A$; cf. illustration in Figure 9

b) Minimum bar diameter of column longitudinal reinforcement in accordance with Annex 3, Section 1, Figure 1 and Table 2

c) HSC anchors outside bent bar regions shall be lapped with the column longitudinal reinforcement with a lap length of l_0

d) Placement of at least one bar of the column longitudinal reinforcement between the shaft of the HSC anchor and the lateral edge of the member in accordance with Annex 3, Section 1, Figure 1

e) Stirrup reinforcements with closed stirrups shall be placed in the column along the corbel height h_c with a spacing of $s \leq 10$ cm; cf. illustration in Figure 9.

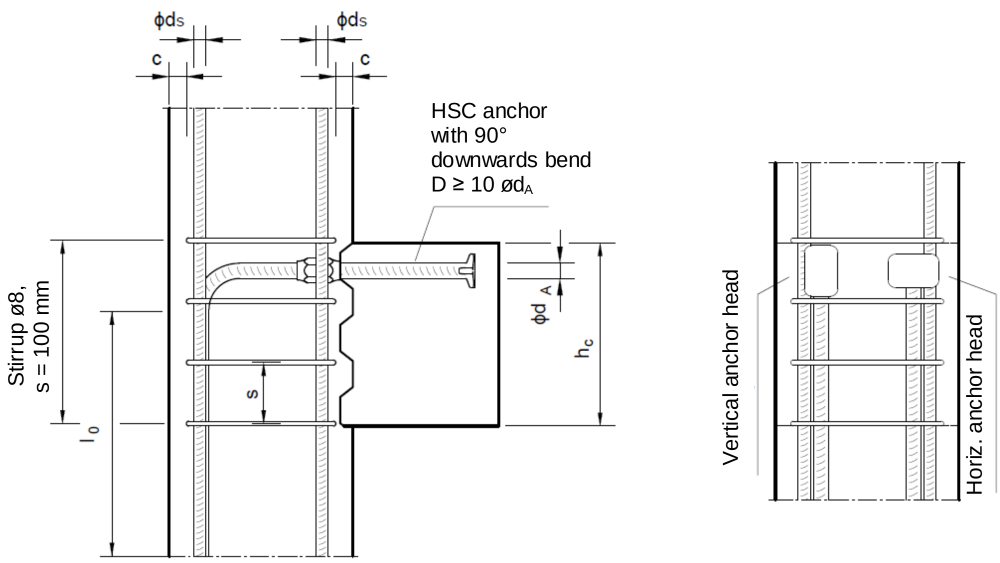


Figure 9: Reinforcement in the column for HSC anchors bent 90° downwards, example

Planning and design of shear joint

The shear joint shall be designed as an indented joint or as a shear indentation in accordance with Figure 10 with the indent spacing not being less than the maximum aggregate size in the concrete mix. The resistance of the shear joint shall be verified as follows:

$$V_{Ed} \leq V_{Rdi} = c \cdot f_{ctd} \cdot b_i \cdot x_i + 1.2 \cdot \mu \cdot A_s \cdot f_{yd} \leq V_{Rdi,max} \qquad (14)$$

where: $V_{Rdi,max} = 0.5 \cdot \nu \cdot f_{cd} \cdot b_i \cdot h_{c,eff}$

x_i = $h_{c,eff}$ for indented joint or for shear indentation without longitudinal tensile force ($H_{Ed} \leq 0$)

= $x_c - u \leq 500$ mm for shear indentation with longitudinal tensile force ($H_{Ed} > 0$)

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

= $h_c - u \leq 500$ mm for shear indentation

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

u = distance from lower edge of shear indentation to lower corbel edge 20mm≤u≤30mm

b_i, h_c = width and height of joint

f_{ctd} = design value of concrete tensile strength $f_{ctd} = \frac{f_{ctk;0.05}}{\gamma_c}$ where $\gamma_c = 1.8$

f_{cd} = design value of concrete compressive strength in accordance with DIN EN 1992-1-1

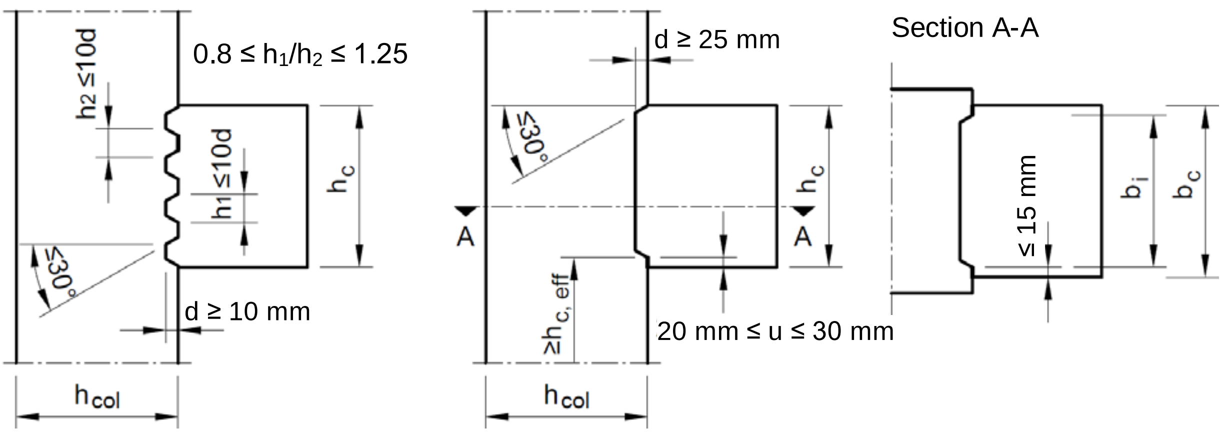
A_s = total cross-section of reinforcement lying in the tension zone and crossing the joint at 90°

f_{yd} = design value of yield strength of reinforcement in accordance with DIN EN 1992-1-1

c, μ, ν = design factors as given in Table 5

Table 5: Shear joint design factors

Construction joint	c	μ	ν
Indented joint	0.5	0.9	0.7
Shear indentation	0.4	0.7	0.5



a) Indented joint b) Shear indentation

Figure 10: Shear joint design

Beams and slabs in accordance with DIN EN 1992-1-1

1. Geometry and designations, detailing rules

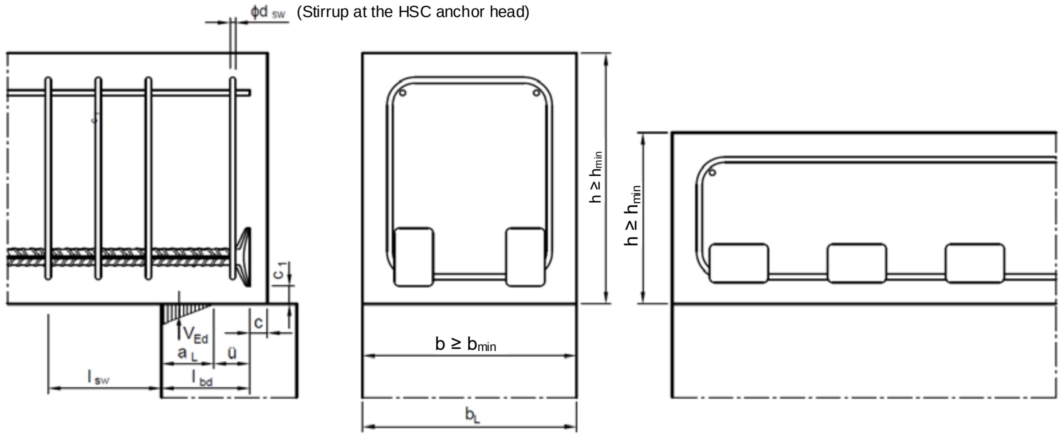


Figure 11: Layout of HSC anchors with triangular bearing stress, example

The HSC anchors may be arranged in one layer or multiple layers, staggered or not staggered. The anchor heads may be installed vertically or horizontally.

In general, the following detailing rules shall be observed when installing HSC anchors in beams and slabs:

a) Minimum dimensions of beams and slabs in accordance with Figure 11 and Table 6
b) Edge distances and positions of the HSC anchors in beams and slabs in accordance with Annex 6, Section 1, Figure 12 and Table 7
c) Placement of one closed vertical stirrup for beams or one vertical U bar for slabs with ϕd_{sw} in accordance with Annex 6, Section 1, Table 7, per HSC anchor layer in the region of the anchor heads; see Annex 6, Section 1, Figure 12.
d) Arrangement of a transverse reinforcement in the support region of at least 20% of the flexural tensile reinforcement for slabs

Table 6: Minimum dimensions of beams and slabs

HSC	Beams*, slabs*		Concrete strength class
	b_{min}	h_{min}	
	[mm]	[mm]	[-]
12	200	200	C20/25 – C70/85
14	200	200	C20/25 – C70/85
16	200	200	C20/25 – C70/85
20	300	300	C20/25 – C25/30
	240	200	C30/37 – C35/45
	200	200	C40/50 – C70/85
25	300	400	C20/25
	300	350	C25/30 – C30/37
	300	300	C35/45 – C70/85

* The minimum dimensions of the beams and slabs may be reduced if the anchorage of the HSC anchors can be verified in accordance with Annex 6, Section 2.

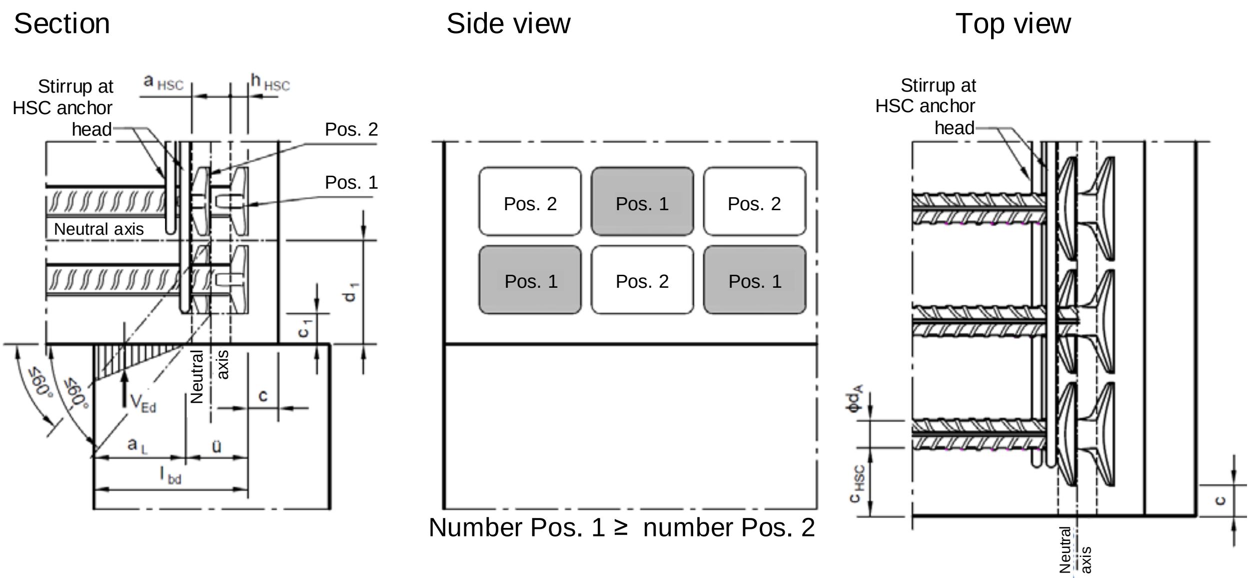


Figure 12: Arrangement of two-layer staggered HSC anchors with triangular bearing stress, example

Table 7: Stirrups and concrete cover

HSC	Stirrup	Concrete cover		h_{HSC}	Head protrusion
	ϕd_{sw}	c_{HSC}	c, c_1		ü
	[mm]	[mm]	[mm]	[mm]	[mm]
12	≥ 6	≥ 30	in accordance with DIN EN 1992-1-1	8	in accordance with Annex 6, Section 2
14	≥ 6	≥ 35		9	
16	≥ 6	≥ 40		10	
20	≥ 8	≥ 50		12	
25	≥ 10	≥ 60		14	

2. Verification of anchorage of HSC anchors in beams and slabs

The anchorage of HSC anchors in beams and slabs for a **single-layer** HSC anchor arrangement shall be deemed verified when the detailing rules a) to d) in accordance with Annex 6, Section 1, have been observed and when the required anchorage length at the end support has been determined in accordance with Annex 6, Section 2, Equation (15).

The anchorage of HSC anchors in beams and slabs for **multi-layer** HSC anchor arrangements or if beam and slab **dimensions do not meet the minimum dimensions** shall be deemed verified when the detailing rules b) to d) have been observed and when the required anchorage length at the end support has been determined in accordance with Annex 6, Section 2, Equation (15). The anchorage verification in accordance with Annex 4, Section 8, Equation (13), shall additionally be provided.

For a **specified anchorage length** at the end support of $l_{bd} \geq 6.7 \cdot \phi d_A$, the anchored tensile force may be determined in accordance with Annex 4, Section 8, Equation (13). For verification of the anchorage of HSC anchors in beams and slabs, the detailing rules b) to d) in accordance with Annex 6, Section 1, shall be satisfied.

The required anchorage length at the end support l_{bd} for a fully loaded reinforcement is as follows:

$$l_{bd} = a_L + ü \geq 6.7 d_A \tag{15}$$

For direct support without loading plates or support bearings, a *triangular* bearing stress may be assumed. In this case, Equations (16) and (17) shall apply for a_L and ü:

$$a_L = \frac{2 \cdot V_{Ed}}{\sigma \cdot b_L} \tag{16}$$

where: V_{Ed} = shear force at support
σ = maximum value of calculated support pressure
b_L = support width

$$ü \geq \max \begin{cases} a_{HSC} + h_{HSC} \\ \frac{c_1}{2} + \frac{a_{HSC}}{2} + h_{HSC} \\ \frac{d_1}{2} + \frac{a_{HSC}}{2} + h_{HSC} - \frac{4 \cdot V_{Ed}}{3 \cdot \sigma \cdot b_L} \end{cases} \tag{17}$$

For a *uniformly distributed* bearing stress, Equations (18) and (19) shall apply for a_L and ü:

$$a_L = \frac{V_{Ed}}{\sigma \cdot b_L} \tag{18}$$

and

$$ü \geq \max \begin{cases} a_{HSC} + h_{HSC} \\ \frac{c_1}{2} + \frac{a_{HSC}}{2} + h_{HSC} \\ \frac{d_1}{2} + \frac{a_{HSC}}{2} + h_{HSC} - \frac{a_L}{2} \end{cases} \tag{19}$$

For non-staggered reinforcement, a_{HSC} = 0 mm.

3. Shear resistance

The shear resistance shall be verified in accordance with DIN EN 1992-1-1. The following regulations shall also be observed:

$V_{Rd,max}$ shall be restricted for beams and slabs in accordance with Annex 4, Section 3, Equation (10).

For solid slabs with structurally required shear reinforcement and for beams, a minimum shear reinforcement in accordance with equation (20) shall be placed in the region of l_{sw} = d starting at the front edge of the support:

$$A_{sw} \geq 0.7 \cdot \frac{V_{Ed}}{f_{yw,d}} \tag{20}$$