HALFEN HSC STUD CONNECTOR

APPROVAL NO. Z-21.8-1973

HALFEN HSC STUD CONNECTOR

Z_HSC 03/18-E

CONCRETE

HALFEN

YOUR BEST CONNECTIONS

General note

Use of third-party products

This approval only applies to original HALFEN products manufactured by HALFEN. The specifications in this approval are not transferable to other products.
Users are fully liable for personel injuries and material damage caused by third-party products used instead of HALFEN products.

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Deutsches Institut für Bautechnik (DIBt)
(German Centre of Competence for Construction)
National and Federal State approved statutory public body
Member of the EOTA, UEAtc and WFTAO

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Notification of amendment to the national technical approval dated 21st November 2017

Date	Ref no.:
1st March 2018	**I 24-1.21.8-4/18**

Approval number:
Z-21.8-1973

Period of validity:

Valid from: **1st March 2018**

Expires on: **30th November 2022**

Applicant:
HALFEN GmbH
Liebigstraße 14
40764 Langenfeld

Approved product: **HALFEN HSC Stud connector**

This notice amends the general building authority approval no. Z-21.8-1973 dated 21st November 2017.
This general building authority approval comprises three pages and one annex.
This amendment is only valid in connection with the general building authority approval mentioned above and may only be used in combination thereof.

Note: This translation of the original German version has not been verified by the Deutsches Institut für Bautechnik.

Ref. I. GENERAL PROVISIONS

The general provisions of the general building authority no. Z-21.8-1973 have been replaced by the following:

1. This national technical approval verifies the usability and applicability of the aforementioned construction product in accordance with the Landesbauordnungen (Regional Building Codes of the German Federal States).

2. The national technical approval does not replace any permits, approvals and certificates legally required for the execution of building projects.

3. The granting of this national technical approval does not affect the legal rights of any third party; in particular those pertaining to private protection laws.

4. The manufacturer and distributor of the aforementioned construction product must make copies of the national technical approval available to the purchaser i.e. the end-user irrespective of further regulations as stated in the “Specific Provisions”, and must give notice that the national technical approval for the product must be available at the point of application. Copies of the national technical approval must be made available to the respective authorities on request.

5. Reproductions or copies of this national technical approval must always be in full. Reproduction in extracts requires the consent of the Deutsches Institut für Bautechnik. Text and drawings used in advertising material must not contradict the national technical approval. Translations of the national technical approval must include a disclaimer as follows "This translation of the original German version is not authorized by the Deutsches Institut für Bautechnik'" (Vom Deutschen Institut für Bautechnik nicht geprüfte Übersetzung der deutschen Originalfassung).

6. This national technical approval can be revoked at any time. The provisions of this national technical approval may be subsequently amended or modified, especially if technical progress makes this necessary.

7. This approval also includes a general building authority approval. The general type approval provided by this certificate may also be regarded as a general building authority design approval certificate.

8. This approval is based on the specifications and documents submitted by the applicant. Any change to these basic specifications are to be made available to the the Deutsches Institut für Bautechnik without delay.

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Ref. II. SPECIAL PROVISIONS

The special provisions of the technical approval have been changed as follows:

Section 2.3.3, first paragraph is replaced by the following:

2.3.3 Third party controls

In each manufacturing plant, factory quality control must be reviewed at regular intervals, at least once a year, by an independent-body. Independent inspection must include an initial test of the construction product and samples taken for random inspections. The respective approved inspection body is responsible for taking samples and testing

Annex 6 of the national technical approval has been replaced by the amended annex 6Ä of this notification.

Beams and slabs according to DIN EN 1992·1·11

1. Dimensions and descriptions, detailing rules

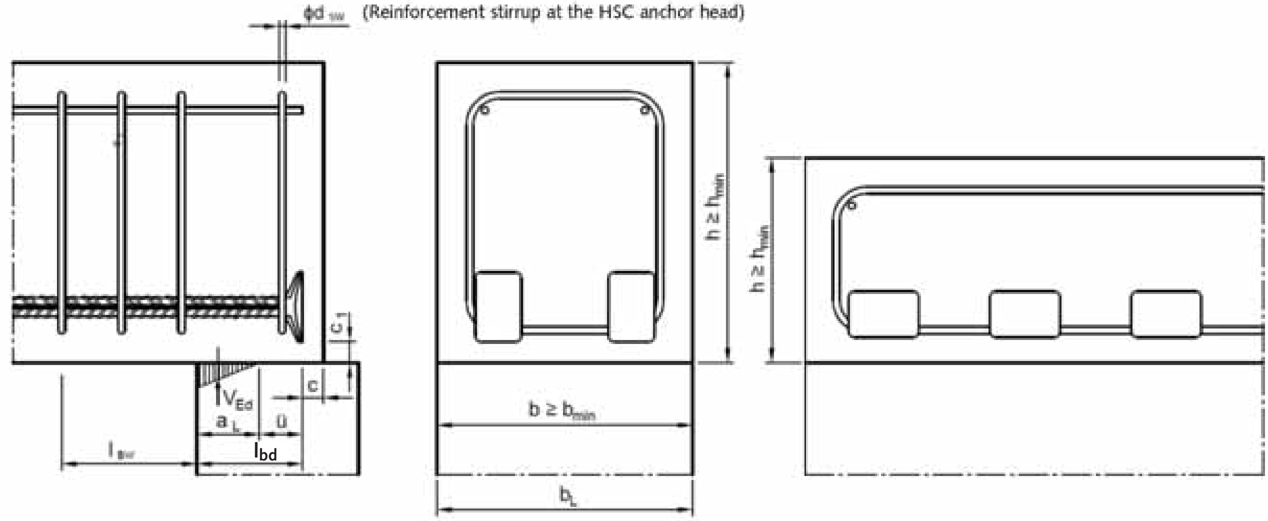

Figure 11: HSC Anchors layout with triangular support stress, example.

The HSC Anchors can be arranged in a single row or multi rows, either staggered or non-staggered.
The anchor heads can be oriented either vertically or horizontally.

In general the following detailing rules must be observed when using HSC Anchors in slab or beam elements.

a) The minimum component dimensions according to figure 11 and table 6.

b) The edge spacing and the position of the HSC Anchor according to annex 6Ä, section 1, figure 12 and table 7.

c) One closed stirrup reinforcement must be used in beams or one vertical U-stirrup in slabs with ϕd_{sw} according to annex 6Ä, section 1 table 7, for each layer of HSC anchor reinforcement at the anchor heads, see annex 6Ä section 1, figure 12.

d) Installation of lateral reinforcement in the support area of at least 20% of the bending tensile reinforcement for slabs.

Table 6. Minimal dimensions of beams and slabs

HSC	Beam*, slab*		Strength classes for concrete
d_A	b_{min}	h_{min}	
[mm]	[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

*Minimum dimensions for the component can be reduced if the anchorage of the HSC Anchor can be verified according to annex 6Ä, section 2.

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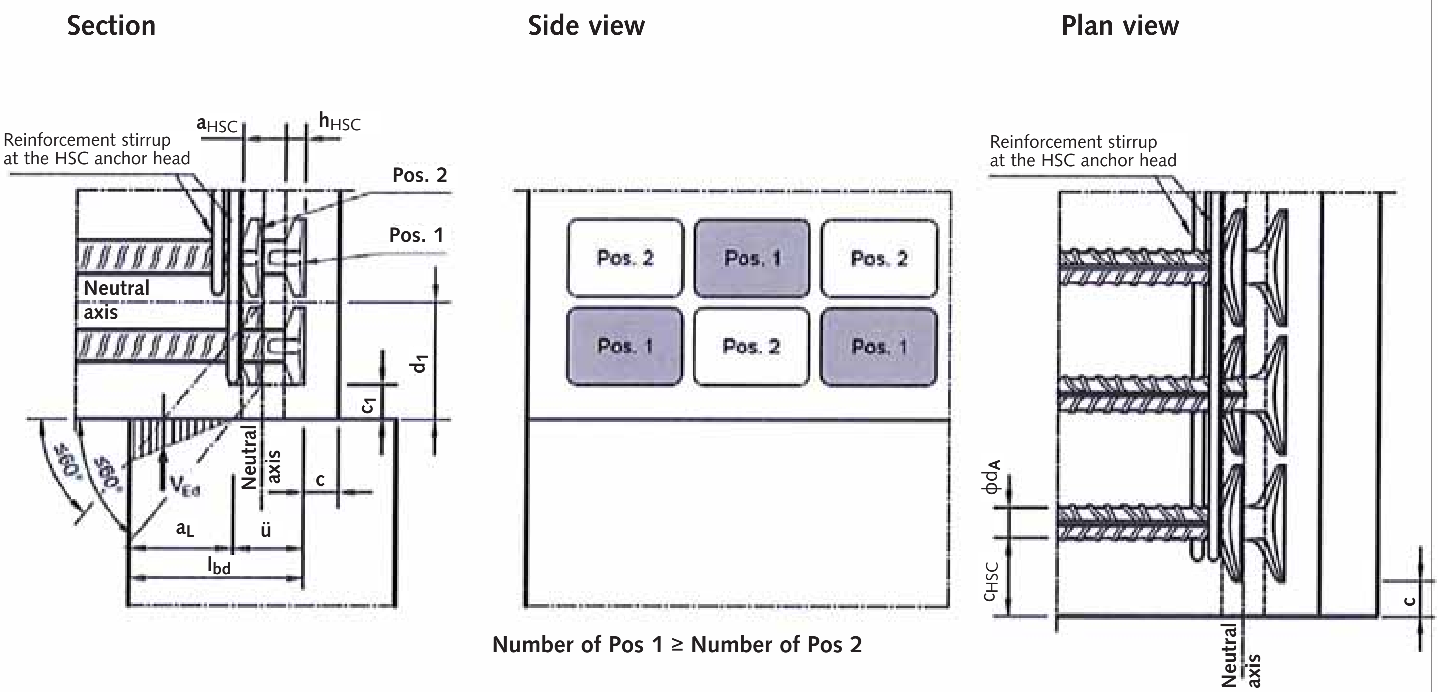

Figure 12: Arrangement of two-layer staggered HSC Anchors with triangular support stress; example

Table 7. Stirrup and concrete cover

HSC	Stirrup	Concrete cover		h_{HSC}	Head protrusion
	ϕd_{sw}	c_{HSC}	c, c_1		ü
[mm]	[mm]	[mm]	[mm]	[mm]	[mm]
12	≥ 6	≥ 30	acc. to DIN EN 1992-1-1	8	acc. annex 6Ä, section 2
14	≥ 6	≥ 35		9	
16	≥ 6	≥ 40		10	
20	≥ 8	≥ 50		12	
25	≥ 10	≥ 60		14	

2. Anchorage of the reinforcement

Verification of the anchorage for a **single row** of HSC Anchor tension reinforcement, in beams or slabs, is fulfilled if the detailing rules a) to d) according to annex 6Ä, section1 have been observed and the anchorage lengths of the end support have been verified according to annex 6Ä, section 2, equation (15).

When verifying the anchorage in **multi rows** of HSC Anchor tension reinforcement or if the **minimal dimensions of the construction element** have been reduced, the detailing rules b) to d) have been observed and the anchorage lengths of the end support was verified according to annex 6Ä, section 2, equation (15). In addition the anchorage must be verified according to annex 4, section 8, equation (13).

With the **predefined length** of the end support $l_{bd} \geq 6.7\ \phi d_A$ the anchored tension load can be calculated according to annex 4, section 8 equation (13). To verify the anchorage of HSC anchors in beams and slabs, the detailing rules b) to d) according to annex 6Ä, section 1 must be observed.

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The required anchorage length of the end support l_{bd} with fully stressed reinforcement is equal to:

$$l_{bd} = a_L + ü \geq 6.7\ d_A \qquad (15)$$

A triangular stress distribution can be assumed for direct support without a base plate or positioning plate. In this case a_L and ü apply for equations (16) and (17).

$$a_L = \frac{2 \cdot V_{Ed}}{\sigma \cdot b_L} \qquad (16)$$

with V_{Ed} = Shear load at the support
σ = Maximal value of the calculated support pressure
b_L = Width of support

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

The equations (18) and (19) apply for a_L and ü with uniformly distributed support stress.

$$a_L = \frac{V_{Ed}}{\sigma \cdot b_L} \qquad (18)$$

and

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

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

3. Shear load capacity

Verification of shear load capacity must be in accordance with DIN EN 1992-1-1.
In addition the following must be observed.

$V_{Rd,max}$ for beams and slabs must be limited in accordance to annex 4, section 3, equation (10).

A minimal shear reinforcement according to equation (20) is required for solid slabs with statically required shear reinforcement and beams at l_{sw} = d from the front edge of the support.

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

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National Technical Approval

Date
21st November 2017

Ref no.:
I 24-1.21.8-5/17

Approval number:
Z-21.8-1973

Applicant:
HALFEN GmbH
Liebigstraße 14
40764 Langenfeld

Period of validity:

Valid from: **30th November 2017**

Expires on: **30th November 2022**

Approved product: **HALFEN HSC Stud connector**

The aforementioned construction product is herewith granted a general building authority approval.
This general building authority approval comprises six pages and six annexes.
The product was first issued with a general building authority approval on the 17th December 2002 with the approval number Z-15.6-204.

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II. SPECIAL PROVISIONS

1. Object of approval and intended use

The object of this national technical approval is the HALFEN HSC Stud connector with reinforcing steel B500B, nominal diameter 12, 14, 16, 20 or 25 mm, with single or double-ended forged rectangular heads. Alternatively stainless reinforcing steel B500 NR with nominal diameter 12 or 14 mm, material classification no. 1.4571 or 1.4362 may be used for the HSC Stud connector.
HALFEN HSC Stud connectors are used for anchorage in frame-end nodes, corbels and beams or slabs in reinforced concrete elements, which are designed and constructed according to DIN EN 1992-1-1:2010-01.
Application examples are provided in annex 1. HALFEN Stud connectors may only be used in normal strength concrete. The concrete strength must be at least C20/25 but not more than C70/85.
HALFEN HSC Anchors may be used for static, quasi-static and fatigue stress loads.

2. Provisions for the construction product

2.1.1 Material characteristics

The raw material used for socket bars must have the characteristics of ribbed reinforcing steel B500B according to DIN 488-1 or B500 NR (Material no. 1.4571 or 1.4362) in accordance with the national technical approval.
The ultimate load of each anchor is at least

$$P_u = f_t \cdot A_s$$

With P_u = ultimate load in the anchor
f_t = minimum tensile strength of the reinforcing steel (550 N/mm^2)
A_s =actual cross section of the anchor

The remaining available area under the anchor head must be at least eight times the cross section of the anchor shaft. The dimensions and allowable tolerances must comply with annex 2 and the submitted data sheets.

2.2 Manufacturing, packaging, shipment, storage and identification

2.2.1 Manufacturing

The anchor heads for the HSC Stud connectors are forged at the production plant. The identification marks are stamped into the head during this process.

2.2.2 Packaging, transport and storage

The stud connectors must be packed, transported and stored appropriately to ensure they are protected against damage.

2.2.3 Marking

The shipping documents for the stud connector must be marked by the manufacturer with the conformity mark (Ü-mark) in accordance with the conformity mark regulations of the Federal states; this must include the anchor diameter. The marking may only be used if the conditions in accordance with section 2.3 are met. Each head of the stud connector must be marked with the identification details as illustrated in annex 2.

2.3 Verification of conformity

2.3.1 General information

To confirm conformity of the construction product with the provisions of this national technical approval, a certificate of conformity must be issued for each manufacturing location based on a quality control plan and on a regular third-party inspection including an initial test of the construction product in accordance with the following provisions.

The manufacturer of the construction product must contract an approved certification body for independent inspection and to issue a certificate of conformity as well as an approved inspection body for relevant product testing.

The manufacturer is required to mark the construction product with a conformity mark (Ü-mark) including a declaration of the intended use to which a certificate of conformity has been awarded.

A copy of the certificate of conformity issued by the certification body must be submitted to the Deutsches Institut für Bautechnik.

2.3.2 Factory quality controls

Each manufacturing plant must set up and implement an in-house, quality control plan. This is understood as the continuous internal monitoring of the production process, implemented by the manufacturer, to ensure the construction products manufactured by them are in conformity with the provisions of this national technical approval.

The factory quality control plan shall include at minimum the following measures:

- Specification and testing of raw materials and their components:

  The manufacturer of HSC Stud connectors must ensure that the reinforcement steel B500B in accordance with DIN 488-1 or B500 NR are compliant with the required characteristics of the general building authority approval, and are appropriately marked with the manufacture-identification number and the Ü-mark.

- required verification and testing of the construction product:

  The ultimate load must be verified in a test situation in accordance with the set test specifications. The dimensions specified in the data sheet for HSC Stud connectors must be checked; the specified tolerances therein are mandatory.

The results of the factory quality control plan are to be documented and evaluated In accordance with the check-list deposited with the independent inspection body and the Deutsches Institut für Bautechnik.

The documentation must include at least the following:

- Identification of the construction product
- method of test or inspection
- production date, test date of the construction product, raw material or components
- results of the inspection and tests, and evaluation against the requirements
- signature of the person responsible for factory quality control plan

The documents must be held for at least five years and be submitted to the inspection body responsible for third-party inspection. On request, these records must be made available to the Deutsches Institut für Bautechnik and to the responsible building authority (obersten Bauaufsichtsbehörde).

In case of unsatisfactory test results the manufacturer must take immediate action to resolve the deficiency. Construction products which do not comply with the requirements must be handled in a manner to ensure they cannot be mistaken for products complying with the requirements. After a problem has been resolved, the respective test must be repeated immediately; as far as this is technically feasible and necessary to verify that the deficiency has been rectified.

2.3.3 Third-party controls

In each manufacturing plant, factory quality control must be reviewed at regular intervals, at least twice a year, by an independent-body. Independent inspection must include an initial test of the construction product and samples taken for random inspections. The respective approved inspection body is responsible for taking samples and testing.

During the assessment of factory quality control, all samples must be taken and evaluated as specified in the documented quality control plan. A record of the results must be kept and evaluated.
The results of the certification and third-party control must be kept for at least five years. On request, they must be made available by the appointed certification or inspection body to the Deutsches Institut für Bautechnik and to the responsible building authority (obersten Bauaufsichtsbehörde).

3 Provision for design and dimensioning

3.1 Planning and dimensioning

3.1.1 Introduction

DIN EN 1992-1-1 together with DIN EN 1992-1-1/NA apply for planning, detailing the structural design and calculating internal forces unless defined otherwise in the following.

3.1.2 Verification against fatique

Verification of fatigue loading must be according to DIN EN 1992-1-1 and DIN EN 1992-1-1/NA, section 6.8. As reference value for fatigue strength, for nominal diameters 12 to 20 mm a stress variation range $\Delta\sigma_{Rsk}$ = 80 N/mm² for N=$2 \cdot 10^6$ load cycles and for 25 mm diameter a stress variation range $\Delta\sigma_{Rsk}$ = 70 N/mm² for N=$2 \cdot 10^6$ load cycles is to be assumed (see DIN EN 1992-1-1, figure 6.30). The tension stress exponents of the Wöhler line are to be assumed as 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 Frame-end-nodes

The minimum dimensions of the components according to Annex 3, table 2 must be observed.

Eccentricity in the beam shear load should not be greater than the width of the beam. The beam height should not exceed twice the column width. Design and calculation is according to DIN EN 1992-1-1 based on Annex 3 and based on DAfStb (German Committee for Structural Concrete), publication issue no. 532.

3.1.4 Corbels

The minimum dimensions of the components according to annex 4, table 3 must be observed.
Design and calculation is according to DIN EN 1992-1-1 based on Annex 4 and DAfStb publication, issue no. 600, annex J.

3.1.5 Subsequently added cross-sections

When correctly executed, the same compression strut capability as in monolithic cross-sections may be assumed for subsequent, cross-sections at frame-end-nodes or corbels as in Annex 5.
Connection of the tension-reinforcement to the column is with HALFEN HBS-05-Screw connections according to approval no. Z-1.5-189.

3.1.6 Beams and slabs

The minimum dimension as in Annex 6 table 6 must be observed. Design and calculation is according to DIN EN 1992-1-1 based on Annex 6.

3.2 Application instructions

According to Annex 3, section 1, for frame-end-nodes, at least one bar of the column reinforcement must be placed between the HSC Anchor shaft and the edge of the construction element.
The regulations according to Annex 5 must be observed if corbels or frame nodes are not designed as a monolithic element.

Following standards and references are referred to in this national technical approval

- DIN 488-1 : 2009-08	Reinforcement steel – Section 1: Steel types, characteristics, identification.
- DIN 488-2 : 2009-08	Reinforcement steel - Reinforcement bar steel.
- DIN EN 1992-1-1:2011-01	Eurocode 2: Design and construction of reinforced and prestressed concrete structures. Part 1-1: general rules and rules for buildings; German version EN 1992-1-1: 2004 + AC: 2010.
- DIN EN 1992-1-1/NA:2013-04	National Annex, National determined parameters. Eurocode 2: Design and construction of reinforced and prestressed concrete structures. Part 1-1: general rules and rules for buildings
- DAfStb-Issue 532:2002-08	The design and construction of frame nodes, basics and examples according to DIN 1045-1,1, 2002 issue.
- DAfStb-Issue 600:2012-09	Supplementary notes for DIN EN 1992-1-1 and DIN EN 1992-1-1/NA (Eurocode 2).
- Approval no. Z-1.5-189	Mechanical connection and anchoring of steel bars Type "HBS-05 Screw connections" from 13th February 2017.

- A data sheet is deposited at the Deutsches Institut für Bautechnik and the inspection body responsible for third-party control.
- A quality control plan is deposited at the Deutsches Institut für Bautechnik and the inspection body responsible for third-party control.

Beatrix Wittstock
Referatsleiter (Head of Division)

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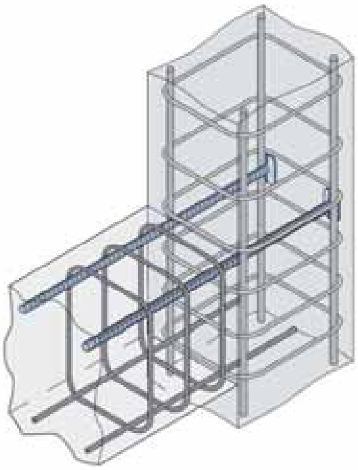
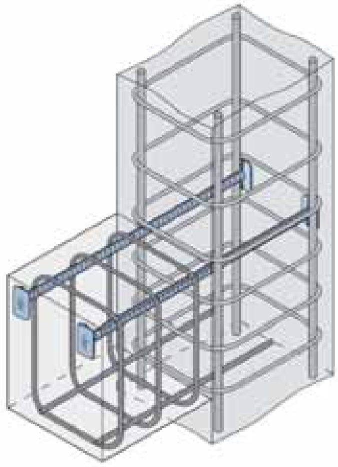
HSC Anchors in frame-end nodes

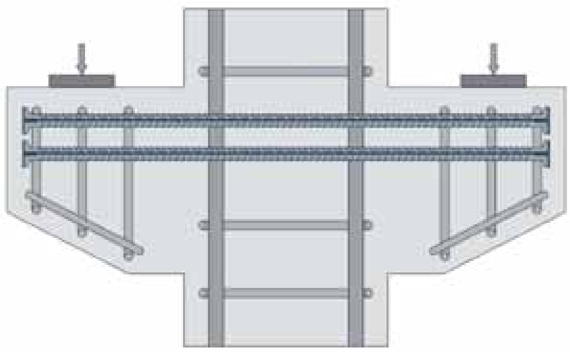


HSC Anchors in corbels

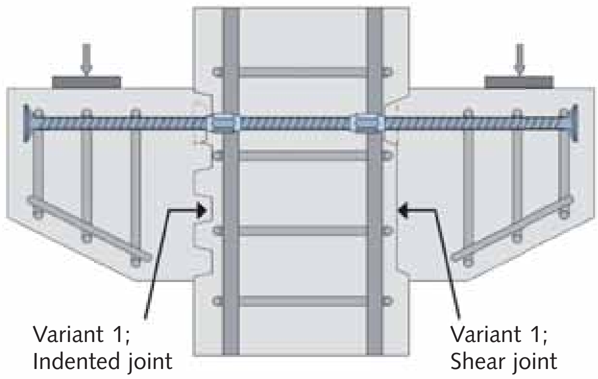


HSC Anchors in corbels

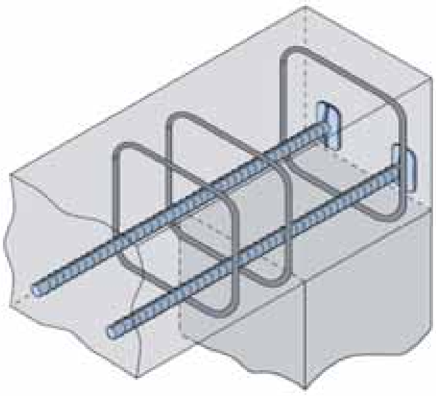
Corbel with multilayer HSC Anchors

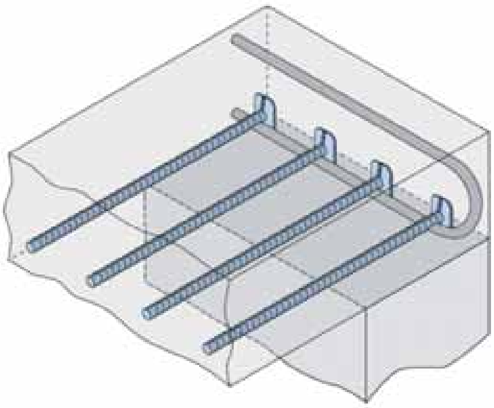


Corbels subsequently concreted in sections with concrete joint



HSC Anchors in beams and slabs



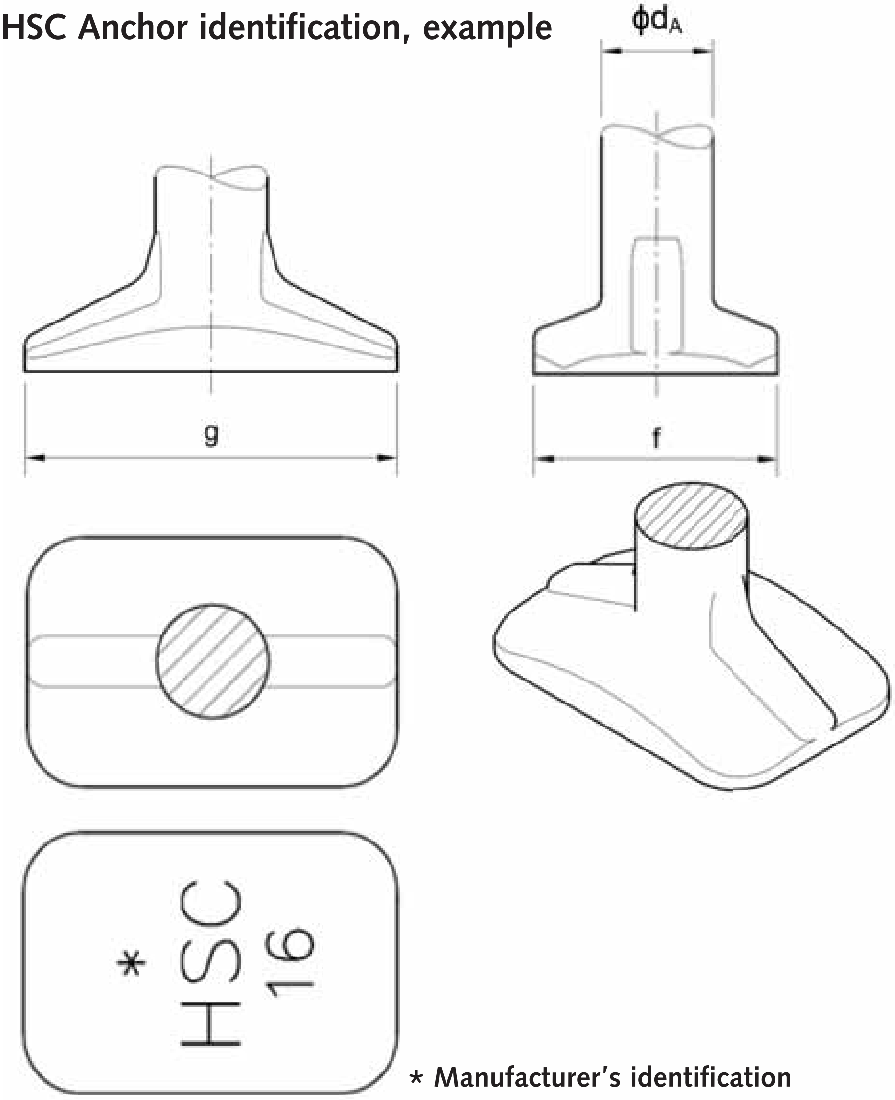


* Indented construction joint based on DIN EN 1992-1-1, section 6.2.5, figure 6.9 or construction joint with shear indentation in accordance with DIN EN 1992-1-1. HSC Anchors are connected to the column with HALFEN HBS-05 Screw connections according to approval no. Z-1.5-189.

According to Annex 3, 4 and 6, the number and layout of required HSC Anchors is optional as long as all requirements have been met.

HALFEN YOUR BEST CONNECTIONS	Annex 1 **HALFEN HSC Stud connector** Layout of the HSC in frame-end-nodes, corbels, beams and slabs	HALFEN GmbH Liebigstr. 14 D - 40764 Langenfeld Phone: +49-2173-970-0 Fax: +49-2173-970-123

HSC Anchor identification, example



* Manufacturer's identification

Material: Reinforcement steel B500B in accordance with DIN 488-1 ϕd_A 12 or 14 mm, alternatively made of stainless reinforcement steel B500 NR (material no. 1.4571 or 1.4362) in accordance with the general building authority approval.

Allowable welds HSC Stud connectors: butt joint welds according to DIN EN ISO 17660-1, welding process 24 flash butt welding according to DIN EN ISO 4063

Table 1: Anchor dimensions

HSC	Anchor diameter ϕd_A	Head width f	Head length g	Head height h_{HSC}	Underside surface of the anchor head $A_{K,n}$
	[mm]	[mm]	[mm]	[mm]	[mm²]
12	12	30	35	8	906
14	14	34	42	9	1232
16	16	35	53	10	1608
20	20	44	66	12	2514
25	25	55	83	14	3927

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Design and calculation of frame-end-nodes according to DIN EN 1992-1-1

1. Geometry and description, construction regulations

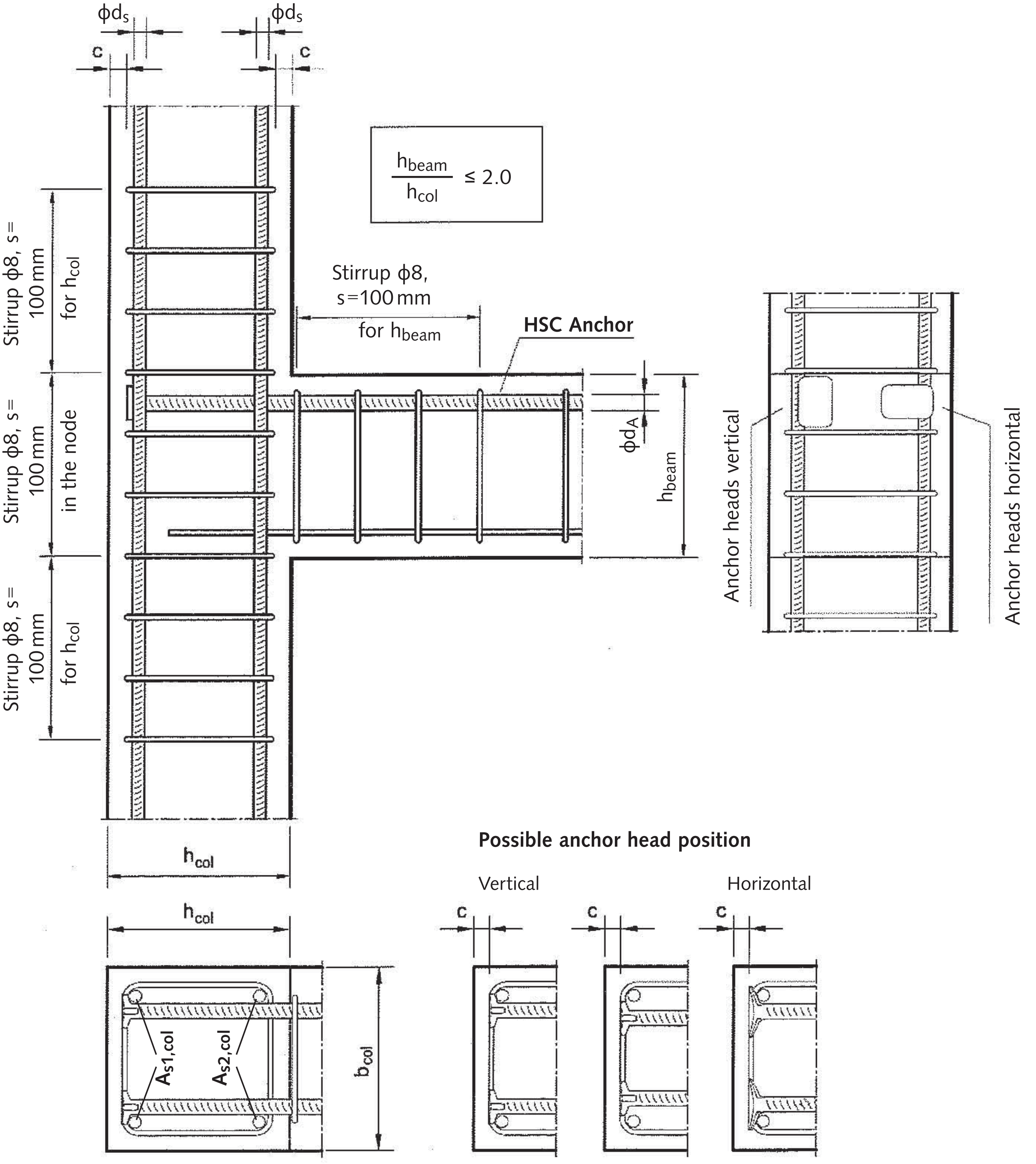

Figure 1: Reinforcement layout, example

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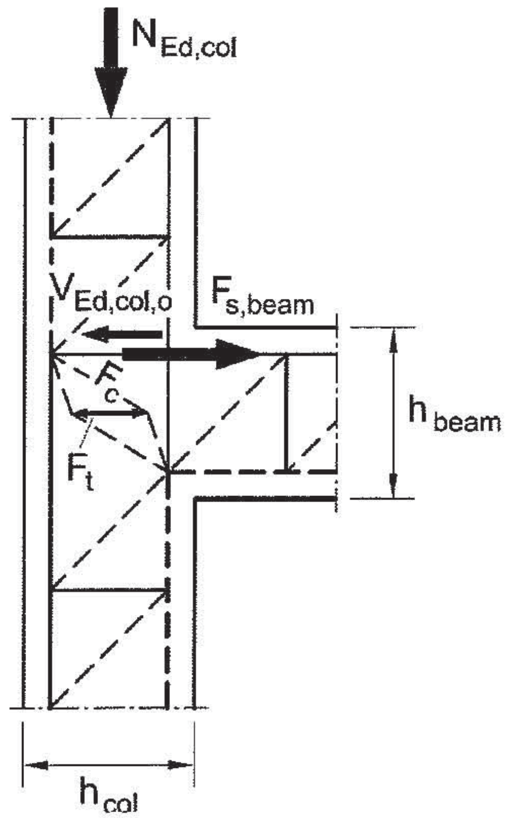
The anchor heads can be installed vertically or horizontally. The specifications for minimum dimensions and diameter of the column longitudinal reinforcement bars in Table 2 must be observed. Concrete cover c must be designed according to DIN EN 1992-1-1.

Table 2: Minimal dimensions for the building element and the minimal diameter for longitudinal reinforcement in the column

HSC	Column			Concrete compressive strength
	$b_{col,min}$	$h_{col,min}$	$\phi d_{s,min}$	
[mm]	[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: Tensile splitting load
F_c: Compression strut load

Figure 2: Strut and tie model

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2. Design and dimensioning the column

The ratio of longitudinal reinforcement in the column section for each column side $p_{s(..),col}$ must be at least 0.5%.

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

with $A_{s(..)col}$ = cross-section of the column longitudinal reinforcement

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

The column reinforcement in the node must be installed using only straight rebars.
It must be verified that the sum of the tensile and compressive forces of longitudinal reinforcement can be anchored within the node:

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

with
- T = Tensile load in the reinforcement
- C_s = Compression load in the reinforcement
- U = Bond circumference of a reinforcement bar
- n = Number of reinforcement bars
- f_{bd} = Bond stress according to DIN EN 1992-1-1, section 8.4.2
- l_j = Node length at the reinforcement (= h_{beam})
- l_b = Anchorage length

Anchorage of the column reinforcement $A_{s(..),col}$ must be calculated for the least favourable moment-normal force ratio of possible combinations of actions.

In sway frame constructions the column reinforcement at nodes connections must be increased in by a flat rate of ⅓ in proportion to the bending calculation. This additional reinforcement must be anchored outside the node.

Stirrup reinforcement must be calculated and designed according to annex 3, section 4.

3. Design and dimensioning the beam

The bending calculation for the beam assumes a distance of 0.3 h_{col} from the neutral axis of the column.

The HSC Anchor used as beam tie reinforcement must be anchored behind the columns outer longitudinal reinforcement but inside the transverse reinforcement or stirrup reinforcement of the column; correct concrete cover must be observed.

According to annex 3, section 1, figure 1, at least one rebar of the column longitudinal reinforcement must be installed between the HSC anchor shaft and the longitudinal column edge.

Calculative method for consideration of reinforcement in the compression flange is not permitted.

The lower beam reinforcement must run straight into the node and must terminate unbent in front of the rear reinforcement in the column.

Stirrup reinforcement must be calculated and designed according to annex 3, section 4.

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4. Stirrup reinforcement

Stirrups must be planned with a maximum spacing of **s** ≤10 cm measured at a distance of h_{col} from the node sections of beams and columns. (Compare with annex 3,section 1, figure 1).

Horizontal stirrups in frame-end-nodes must be designed as u-bars or closed stirrups according to DIN EN 1992-1-1/NA, figure 8.5DE.

U-bars must be anchored in the beam with a length of d_{beam} (effective static height of the beam) and enclose the outermost longitudinal column reinforcement.

The static required ratio of reinforcement must be calculated according to annex 3, section 5, equation (6).

5. Verification of the shear load capacity

Select a suitable static system to determine the span moment and to design the beam and the upper and lower column.
The effective shear load in the node V_{jh} results from the tension load of the beam tie reinforcement $A_{s,HSC} \cdot f_{yd}$ and the shear load of the upper column $V_{Ed,col,o}$:

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

It must be verified that the resulting shear load in the node V_{jh} does not exceed the node load capacity with stirrups $V_{j,Rd}$ according to annex 3, section 5, equation (6) and that the upper limit of the node load capacity $V_{j,Rd,max}$ according to annex 3, section 5, equation (7) is not exceeded.

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

Node load capacity with no stirrups:

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

with: $\frac{h_{beam}}{h_{col}}$ = Shear slenderness ratio, $1.0 \leq \frac{h_{beam}}{h_{col}} \leq 2.0$

h_{beam} = Cross section height of the beam in [mm]

h_{col} = Cross section height of the column in [mm]

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

$\rho_{As1,col}$ = Ratio of longitudinal reinforcement for the column reinforcement $A_{s1,col}$ according to annex 3, section2, equation (1) in [%] $0.5\% \leq \rho_{As1,col} \leq 2.0\%$

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

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Node load capacity with stirrups:

$$V_{j,Rd} = V_{j,cd} + 0{,}475 \cdot A_{sj,eff} \cdot f_{yd} \leq V_{j,Rd,max} \qquad (6)$$

with $V_{j,cd}$ = Node load capacity without stirrups according to annex 3, section 5 , equation (5)

$A_{sj,eff}$ = effective shear reinforcement (placed above the beam pressure zone and can be considered up to the upper edge of the node)

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

Maximal node load capacity:

$$V_{j,Rd,max} = \gamma_n \cdot 0.3 \cdot f_{cd}^{\cdot} \cdot b_{eff} \cdot h_{col} \leq 2 \cdot V_{j,cd} \qquad (7)$$

with γ_n = $\gamma_{N1} \cdot \gamma_{N2}$

γ_{N1} = Effect of the quasi-permanent column load

$$\gamma_{N1} = 1.5 \cdot \left[1 + 0{,}8 \frac{N_{Ed,col}}{A_{c,col} \cdot f_{ck}}\right] \leq 1.0$$

γ_{N2} = Effect of the shear slenderness ratio

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

$N_{Ed,col}$ = quasi-permanent column load (Compression: negative, tension: positive)

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

$A_{c,col}$ = Cross section surface of the 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 section height and width of the beam

h_{col}, b_{col} = Cross section height and width of the column

$f_{cd}^{\cdot} = \frac{f_{ck}}{\gamma_c}$ = Design value of the concrete compressive strength

f_{ck} = Characteristic value of the concrete compressive strength

$V_{j,cd}$ = Node load capacity without stirrups according annex 3, section 5, equation (5)

6. Verification of the shear joint

The joint between concrete elements cast at different times must be designed and verified according to annex 5.

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Design and calculation of reinforced concrete corbels in accordance with DIN EN 1992-1-1

1. Dimensions and discriptions, detailing rules

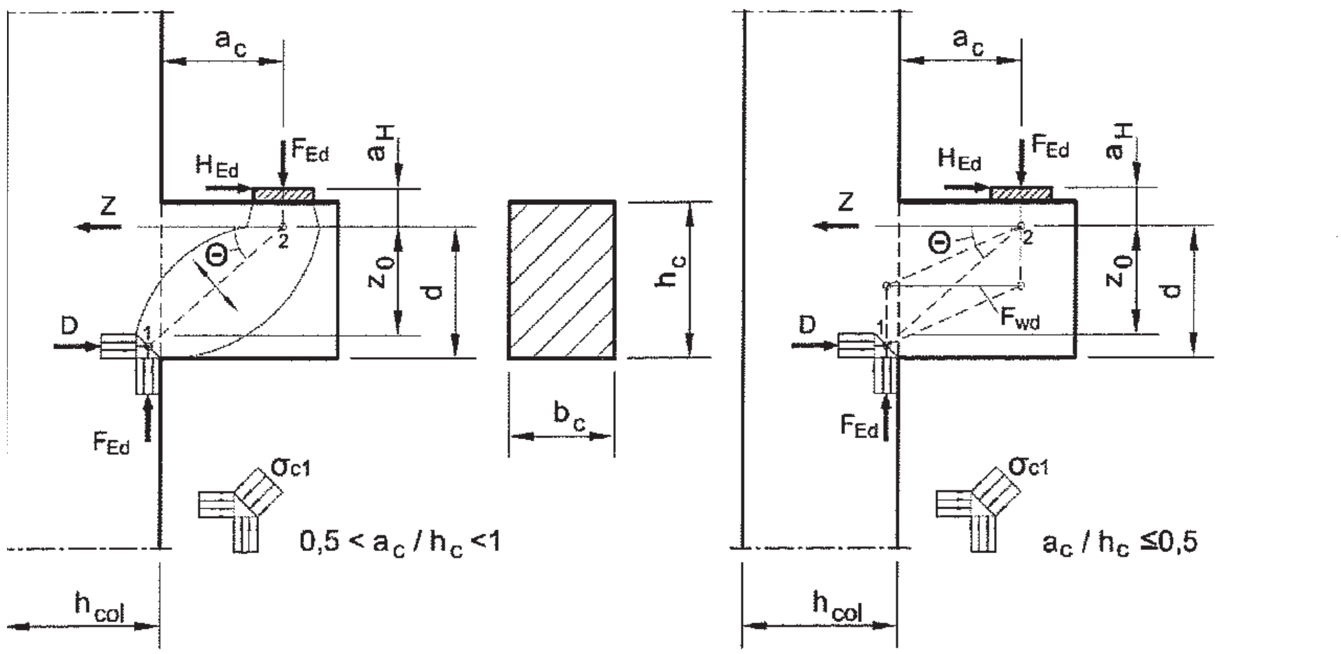

Figure 3: Tie and strut model based on DAfStb, publication no. 600

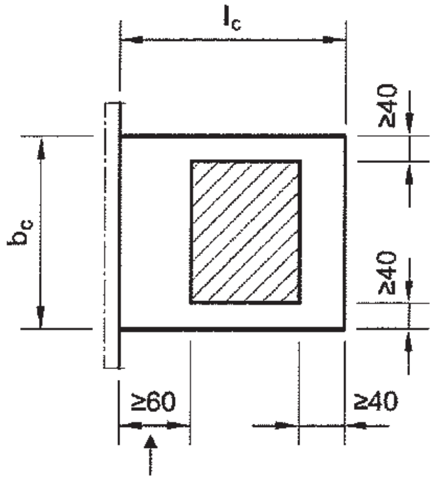

Figure 4: Arrangement of the base plate; recommendation.

The HSC Anchors can be installed in one or more layers; staggered or non-staggered. The anchor heads can be aligned vertically or horizontally. The concrete cover c, c_1 must be verified in accordance with DIN EN 1992-1-1.

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In general the following detailing rules apply when using HSC Anchors as anchorage elements in corbels:

a) The minimal dimensions of the corbel must be according to annex 4, section 1, figure 3 and table 3.
b) The edge distances and position of the HSC Anchors in the corbel must be according to figure 5 and annex 4, section 1, table 4.
c) One vertical closed stirrup reinforcement bar with ϕd_{sw} according to annex 4, section 1, table 4, is required for each row of HSC Anchors between the middle of the base plate and the anchor heads, see annex 4, section 9.

Table 3: Minimal dimensions of the corbel

HSC Anchor	Corbel*		Concrete strength class
	$b_{c,min}$	$l_{c,min}$	
[mm]	[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 minimal dimensions of the corbel can be reduced if the anchorage of the HSC Anchor can be verified in accordance with annex 4, section 8.

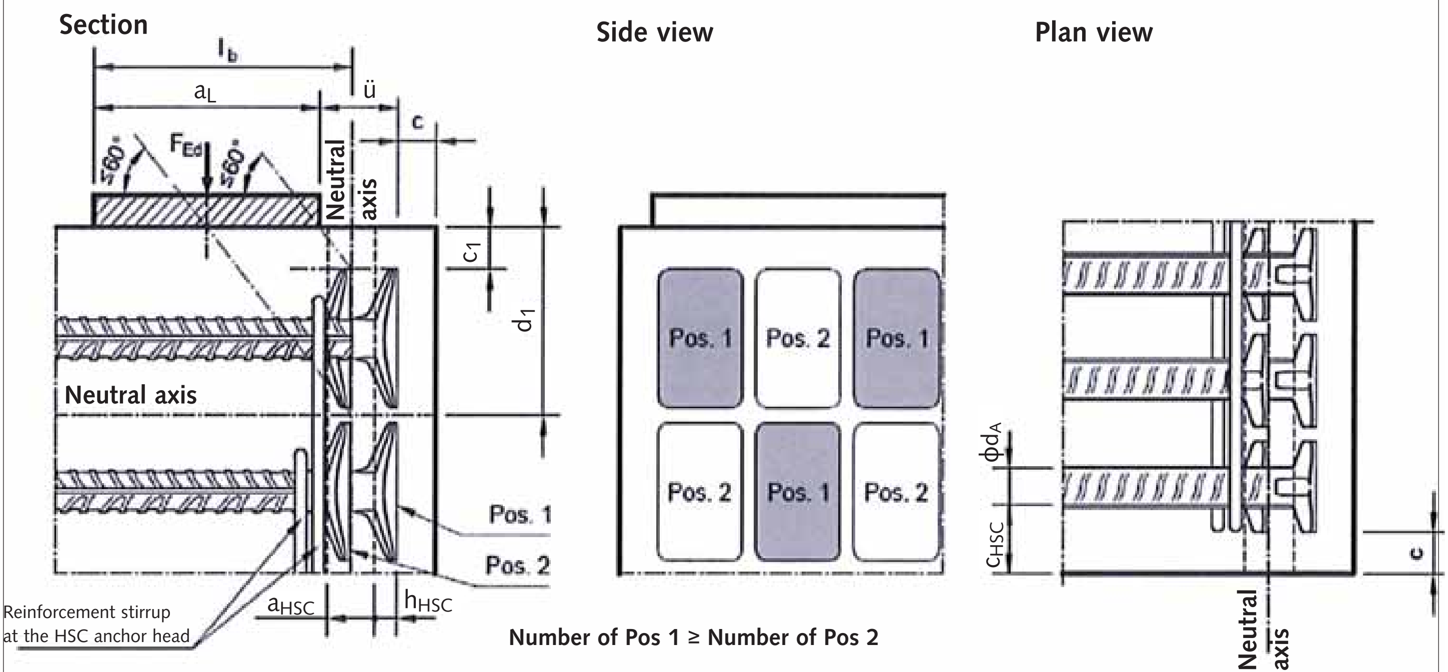

Figure 5: Layout of double-layer staggered HSC Anchors; example

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Note: This translation of the original German version has not been verified by the Deutsches Institut für Bautechnik.

Table 4 Stirrups, concrete cover and head protusion

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

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

2. Load actions,
Design value of the effective vertical load.

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

If friction in the support caused by constrainted deformation cannot be excluded a horizontal force must be assumed

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

3. Verification of shear load capacity in the corbel

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

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

f_{ck} = characteristic concrete compressive strength

z = inner cantilever to determine the shear load capacity $z = 0.9 \cdot d$

d = effective static height

4. Verifying the tension flange load

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

with $\frac{a_c}{z_0}$ ≥ 0.4

a_c = outer cantilever, distance from the corbel edge to the vertical load F_{Ed}

a_H = distance from the neutral axis of the tension flange reinforcement to the horizontal force H_{Ed}

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z_0 = inner cantilever to determine the tension flange load capacity

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

d = effective static height

5. Verifying the required amount of reinforcement for the HALFEN HSC Anchor

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

with f_{yd} = Design value of yield strength for the HALFEN HSC Anchor

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

6. Verification of the shear joint

If columns and corbels are cast in different sections the joint must be designed and dimensioned in accordance with annex 5.

7. Verifying the concrete compression under the base plate

Verifying the concrete compression under the base plate is according to DIN EN 1992-1-1, whereby the calculated distribution surface A_{c1} is determined as shown in figure 6.

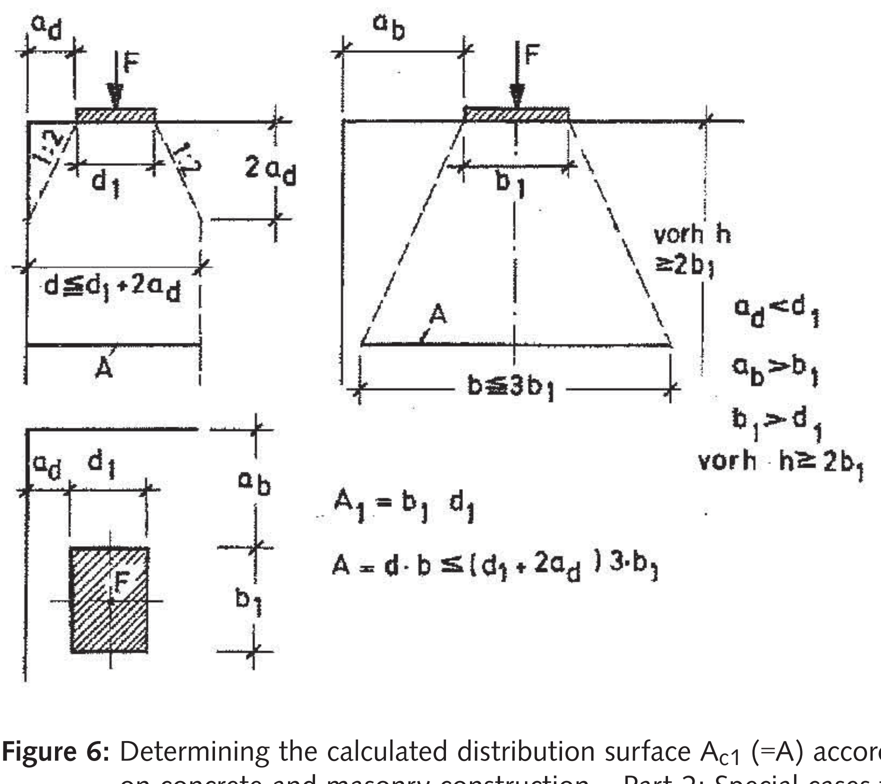

Figure 6: Determining the calculated distribution surface A_{c1} (=A) according to Leonhardt (Lecture on concrete and masonry construction – Part 2: Special cases for calculation of reinforced concrete constructions).

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8. Verifying the anchorage of the HSC Anchor in the corbel

The anchorage of a **single layer** of HSC Anchors in the corbel is considered verified if detailing rules a) - c) according to annex 4, section1 have been observed.

The anchorage is considered verified for multi-layer HSC Anchors in the corbel, or if the dimensions of the corbel fall below the minimal requirements, if detailing rules b) - c) and the following anchorage analysis has been observed.

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

with: n_{HSC} = Number of HSC Anchors

d_a = Shaft diameter of the HSC Anchor

l_b = Anchorage length; from the front edge of the base plate to the vertical neutral axis of all anchor heads, see annex 4, section 1, figure 5

f_{bd} = Bond stress according to DIN EN 1992-1-1, section 8.4.2

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

According to DIN EN 1992-1-1, section 6.5.4 (4a) and DIN EN 1992-1-1/NA, NDP 6.5.4 (4), fcd can be increased by 10% in compression nodes without anchorage of tension struts.

f_{cd} = Design value of the concrete compressive strength according to DIN EN 1992-1-1

A_{c0} = Underhead surface area of all HSC Anchors with underhead surface area $A_{K,n}$ for each HSC Anchor according to annex 2, table 1

A_{c1} = calculated distribution surface according to figure 7

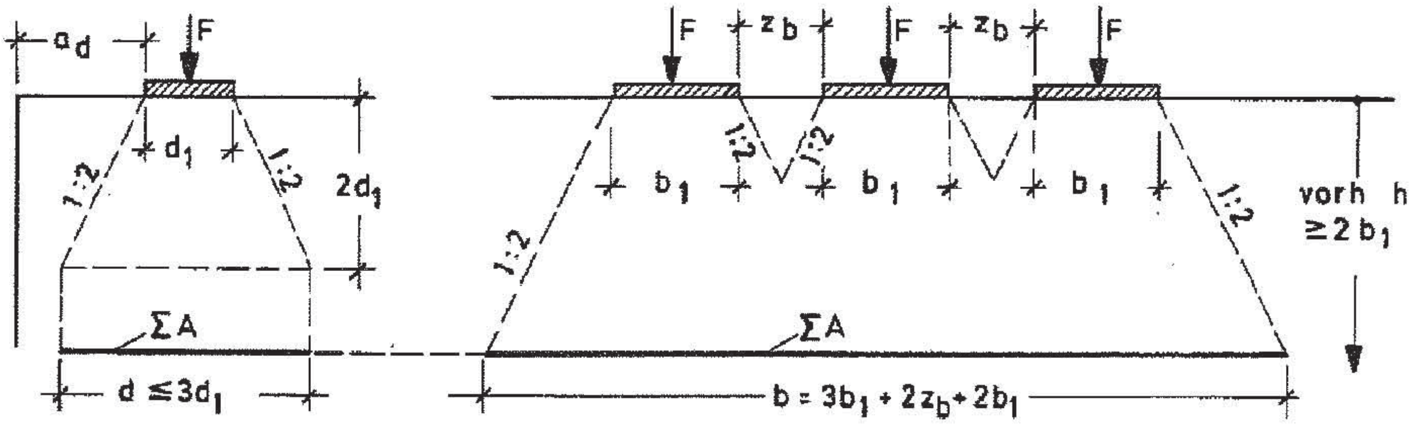

Figure 7: Determining the calculated distribution surface A_{c1} (=A) according to Leonhardt (Lecture on concrete and masonry construction – Part 2: Special cases for calculation of reinforced concrete constructions).

Allowance can be made for the effect of transverse shear pressure on the anchors in accordance to DIN EN 1992-1-1, section 8.4.4, table 8.2 and DIN EN 1992-1-1/NA, NCI 8.4.4 (2) table 8.2.

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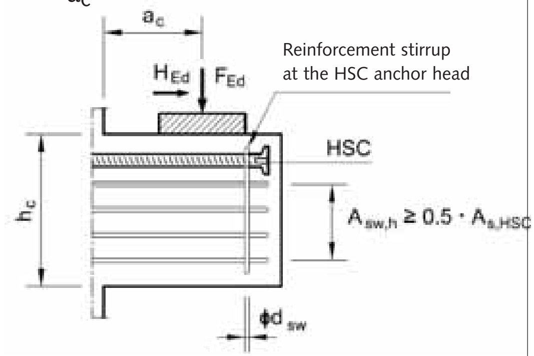
9. Stirrup layout

To account for tensile splitting in the concrete cover , at least one closed vertical stirrup with ϕd_{sw} according to annex 4, section 1, table 4 is required for each HSC anchor layer; the stirrup is placed between the middle of the base plate and the anchor heads (see annex 4, section 1, figure 5).
The lateral concrete cover must be dimensioned as specified in DIN EN 1992-1-1 (see annex 4, section 1, table 4).

Stirrups to prevent tensile splitting:

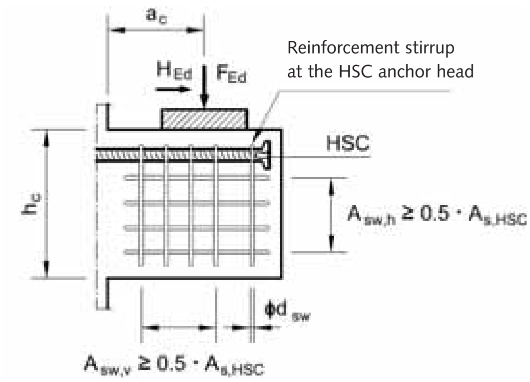
a_c



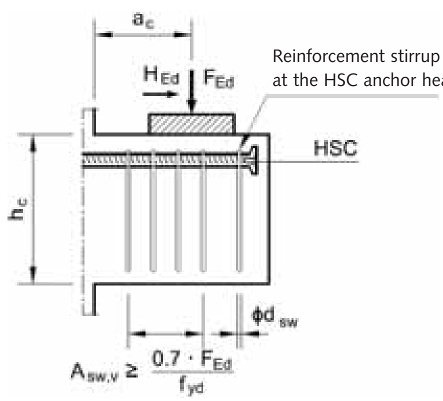
For $a_c \leq 0{,}5 \cdot h_c$ and $V_{Ed} > 0{,}3 \cdot V_{Rd,max}$ ($V_{Rd,max}$ acc. to Gl. 10)

- Closed horizontal or diagonal stirrups with a total cross-section of at least 50% of the flange reinforcement $A_{s,HSC}$ is required; the stirrups must enclose the corbel as well as the column.

or



- Closed horizontal and closed vertical stirrups each with a **total** cross-section of at least 50% of the flange reinforcement $A_{s,HSC}$ is required in the corbel; the corbel and the column must be reinforced separately.



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

- Closed vertical stirrups for stirrup reinforcement loads of total $F_{Wd} = 0.7 \cdot F_{Ed}$ are required.

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10. Verification of the anchorage of the HSC Anchors in the adjoining column

Verification of the anchorage of the HSC Anchors in the adjoining column may be considered as met if the following detailing rules have been observed.

a) Minimum dimensions of the column cross section according to annex 3, section 1, figure 1 and table 2

b) Minimum rod diameter of the column longitudinal reinforcement according to annex 3, section 1, figure 1 and table 2

c) Position of the HSC anchor heads behind the outermost longitudinal column reinforcement and within the column stirrup reinforcement while observing the required concrete cover in accordance with annex 3, section 1, figure 1.

d) Placement of at least one bar of longitudinal column reinforcement between the HSC Anchor and the lateral edge of the concrete element, according to annex 3, section 1, figure 1.

e) Closed stirrups with spacing of s ≤ 10 cm are distributed in the column over the height of the corbel h_c. Compare with the illustration in figure 8.

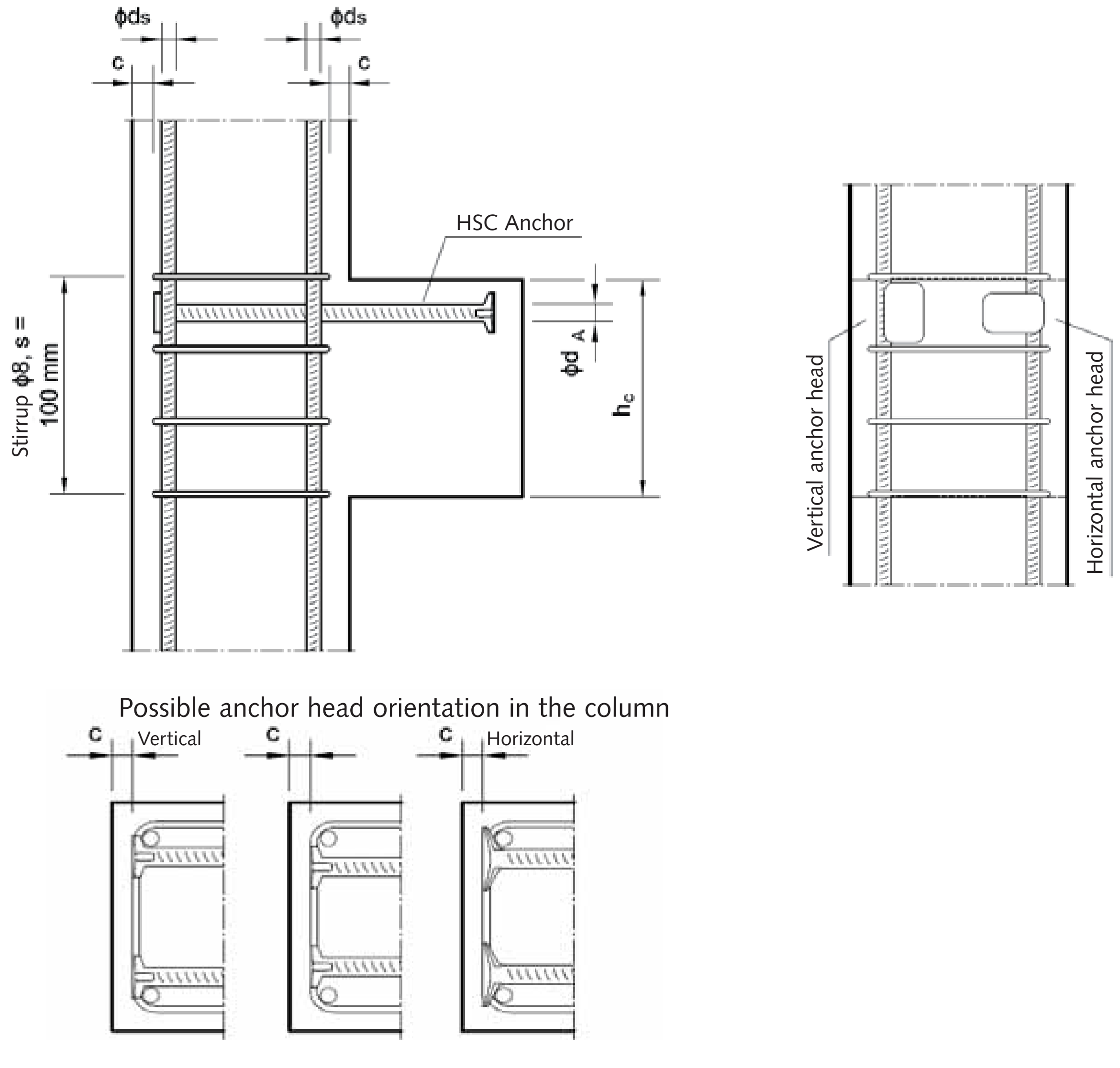

Figure 8: Reinforcement layout in the column, examples

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11. Anchorage verification for the bent HSC anchors in the adjoining column.

The anchorage verification for the downwards bent 90° HSC Anchors in the adjoining column with overlap with the tensile bending reinforcement is verified if the following detailing rules have been observed:

a) Minimum mandrel diameter for the HSC Anchor $D \geq 10\ \phi d_A$; compare with illustration in figure 9

b) Minimum rod diameter for the column longitudinal reinforcement according to annex 3, section 1, figure 1 and table 2

c) HSC Anchors are overlapped with the column longitudinal reinforcement with the overlap length l_0. This does not apply to overlapping with curved rebar.

d) At least one longitudinal reinforcement bar must be placed between the shaft of the HSC Anchor and the lateral edge of the construction element in accordance with annex 3, section 1, figure 1 column.

e) Closed stirrup reinforcement is required in the column, distributed over the corbel height h_c, with spacing $s \leq 10$ cm. Compare with the illustration in figure 9.

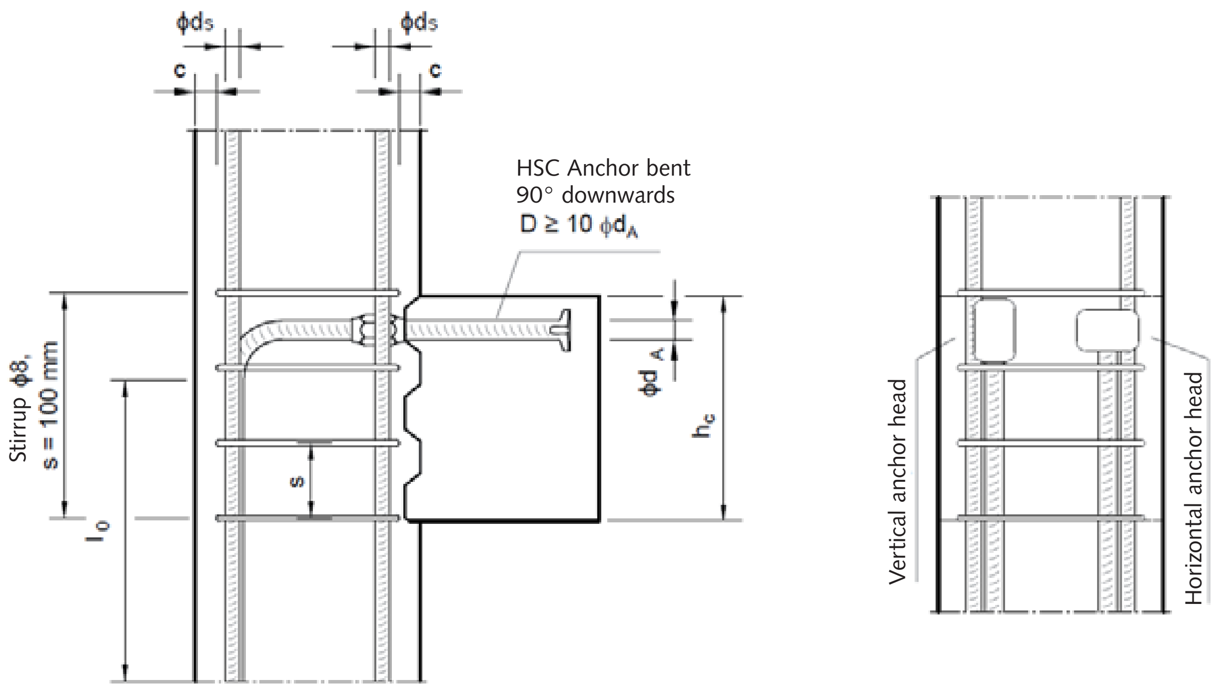

Figure 9: HSC Anchors reinforcement in the column, bent 90° downwards, example

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Shear joint design and calculation

The shear joint must be designed as an indented joint or as a joint with shear indentation as shown in figure 10. The size of the indent must not be designed smaller than the maximum aggregate size in the concrete.
The load capacity of the shear joint is verified as follows:

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

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

x_i	$= h_{c,eff}$	with indented joint or joint with shear indentation with no longitudinal tension load ($H_{Ed} \leq 0$)
	$= x_c - u \leq 500\,mm$	joint with shear indentation with longitudinal tension load ($H_{Ed} > 0$)
$h_{c,eff}$	$= h_c$ $= h_c - u \leq 500\,mm$	with indented joint joint with shear indentation

x_c = Height of the bending compression zone $x_c = 2 \cdot (d - z_o)$

u = Distance between lower edge of shear indentation and lower edge of the corbel $20m \leq u \leq 30\,mm$

b_i, h_c = Joint width and joint height

f_{ctd} = Design value of the concrete tension strength $f_{ctd} = \frac{f_{ctk;0.05}}{\gamma_c}$ with $\gamma_c = 1.8$

f_{cd} = Calculation value of the concrete compression strength acc. to DIN EN 1992-1-1

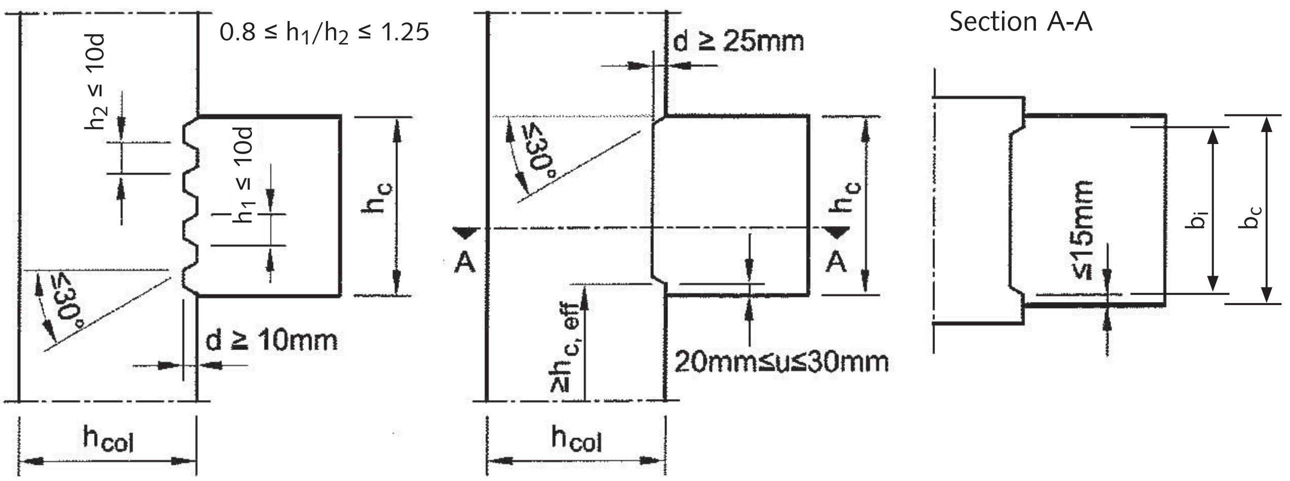
A_s = Total cross-section of the reinforcement in the tension zone and the 90°· cross-wise reinforcement in the joint

f_{yd} = Design yield strength of the reinforcing steel according to DIN EN 1992-1-1

c, μ, ν = design factors according to table 5

Table 5: Shear joint design factors

Joint design	c	u	v
indented joint	0.5	0.9	0.7
shear joint	0.4	0.7	0.5



a) indented joint b) joint with shear indentation

Figure 10: Design of the shear joint

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Beams and slabs according to DIN EN 1992-1-11

1. Dimensions and descriptions, detailing rules

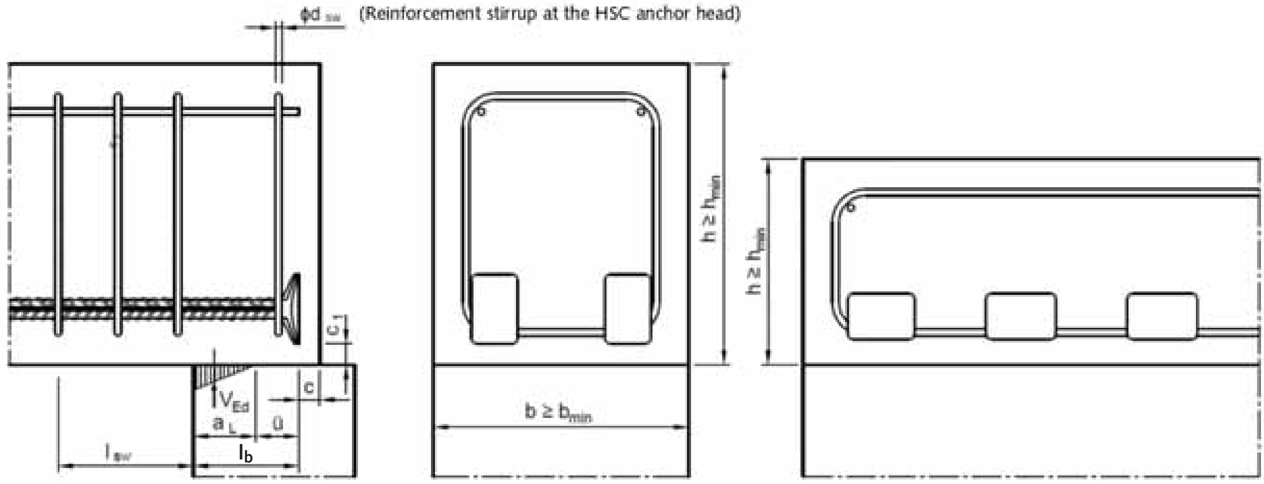

Figure 11: HSC Anchors layout with triangular support stress, example

The HSC Anchors can be arranged in a single row or multi rows, either staggered or non-staggered.
The anchor heads can be oriented either vertically or horizontally.

In general the following detailing rules must be observed when using HSC Anchors in slab or beam elements.

a) The minimum component dimensions according to figure 11 and table 6.

b) The edge spacing and the position of the HSC Anchor according to annex 6, section 1, figure 12 and table 7.

c) One closed stirrup reinforcement must be used in beams or one vertical U-stirrup in slabs with ϕd_{sw} according to annex 6, section 1 table 7, for each layer of HSC anchor reinforcement at the anchor heads, see annex 6 section 1, figure 12.

d) Installation of lateral reinforcement in the support area of at least 20% of the bending tensile reinforcement for slabs.

Table 6. Minimal dimensions of beams and slabs

HSC	Beam*, slab*		Strength classes for concrete
d_A	b_{min}	h_{min}	
[mm]	[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

*Minimum dimensions for the component can be reduced if the anchorage of the HSC Anchor can be verified according to annex 6, section 2.

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Section **Side view** **Plan view**

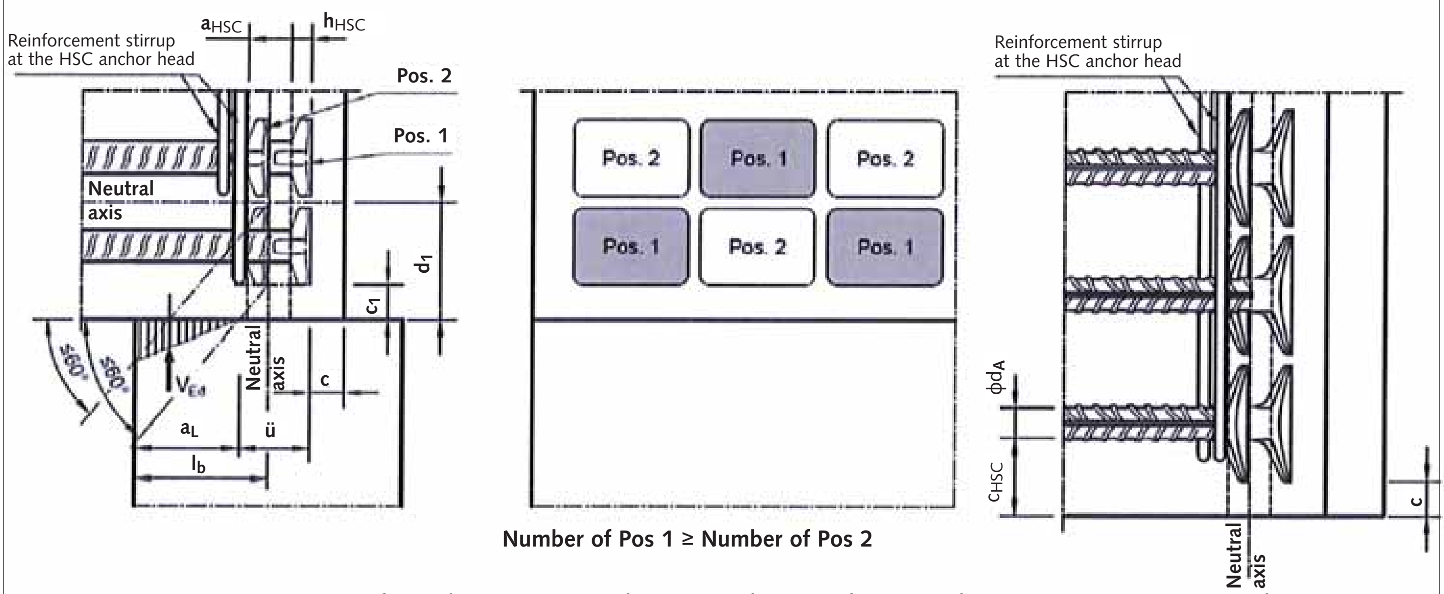

Figure 12: Arrangement of two-layer staggered HSC Anchors with triangular support stress; example

Table 7. Stirrup and concrete cover

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

2. Anchorage of the reinforcement

Verification of the anchorage for a **single row** of HSC Anchor tension reinforcement, in beams or slabs, is fulfilled if the detailing rules a) to d) according to annex 6, section1 have been observed and the anchorage lengths have been verified according to annex 6, section 2, equation (15).

When verifying the anchorage in **multi rows** of HSC Anchor tension reinforcement or if the **minimal dimensions of the construction element** have been reduced, the detailing rules b) to d) have been observed and the anchorage lengths was verified according to annex 6, section 2, equation (15).
In addition the anchorage must be verified according to annex 4, section 8, equation (13).

With the **predefined length** of $l_b \geq 6.7\ \phi d_A$ the anchored tension load can be calculated according to annex 4, section 8 equation (13). To verify the anchorage of HSC Anchors in beams and slabs, the detailing rules b) to d) according to annex 6, section 1 must be observed.

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The required anchorage length l_b with fully stressed reinforcement is equal to:

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

A triangular stress distribution can be assumed for direct support without a base plate or positioning plate. In this case a_L and ü apply for equations (16) and (17).

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

with V_{Ed} = Shear load at the support
σ = Maximal value of the calculated support pressure
b = Width of support

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

The equations (18) and (19) apply for a_L and ü with uniformly distributed support stress.

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

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 load capacity

Verification of shear load capacity must be in accordance with DIN EN 1992-1-1.
In addition the following must be observed.

$V_{Rd,max}$ for beams and slabs must be limited in accordance to annex 4, section 3, equation (10).

A minimal shear reinforcement according to equation (20) is required for solid slabs with statically required shear reinforcement and beams at l_{sw} = d from the front edge of the support.

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

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