Deutsches Institut für Bautechnik
Zulassungsstelle für Bauprodukte und Bauarten
Bautechnisches Prüfamt
Eine vom Bund und den Ländern
gemeinsam getragene Anstalt des
öffentlichen Rechts

Kolonnenstraße 30 B
D-10829 Berlin
Tel.: +49 30 78730-0
Fax: +49 30 78730-320
E-Mail: dibt@dibt.de
www.dibt.de

Authorised and notified according to Article 10 of the Council Directive of 21 December 1988 on the approximation of laws, regulations and administrative provisions of Member States relating to construction products (89/106/EEC)

Deutsches Institut für Bautechnik
DIBt

Mitglied der EOTA
Member of EOTA

European Technical Approval ETA-12/0454

English translation prepared by DIBt - Original version in German language

Handelsbezeichnung *Trade name*	HALFEN HDB Dübelleiste *HALFEN HDB shear rail*
Zulassungsinhaber *Holder of approval*	HALFEN GmbH Liebigstraße 14 40764 Langenfeld DEUTSCHLAND
Zulassungsgegenstand und Verwendungszweck *Generic type and use of construction product*	Doppelkopfanker als Durchstanzbewehrung *Double headed studs as punching reinforcement*
Geltungsdauer: *Validity:* vom *from*	18 December 2012
bis *to*	18 December 2017
Herstellwerke *Manufacturing plants*	HALFEN GmbH Otto-Brünner-Straße 3 06556 Artern DEUTSCHLAND Halfen-Produkcja Sp. zo.o. ul. Kolejowa 18a 63-460 Nowe Skalmierzyce POLEN

Diese Zulassung umfasst *This Approval contains*	31 Seiten einschließlich 17 Anhänge *31 pages including 17 annexes*

I LEGAL BASES AND GENERAL CONDITIONS

1 This European technical approval is issued by Deutsches Institut für Bautechnik in accordance with:

- Council Directive 89/106/EEC of 21 December 1988 on the approximation of laws, regulations and administrative provisions of Member States relating to construction products[1], modified by Council Directive 93/68/EEC[2] and Regulation (EC) N° 1882/2003 of the European Parliament and of the Council[3];
- *Gesetz über das In-Verkehr-Bringen von und den freien Warenverkehr mit Bauprodukten zur Umsetzung der Richtlinie 89/106/EWG des Rates vom 21. Dezember 1988 zur Angleichung der Rechts- und Verwaltungsvorschriften der Mitgliedstaaten über Bauprodukte und anderer Rechtsakte der Europäischen Gemeinschaften (Bauproduktengesetz - BauPG) vom 28. April 1998*[4]*, as amended by Article 2 of the law of 8 November 2011*[5]*;*
- Common Procedural Rules for Requesting, Preparing and the Granting of European technical approvals set out in the Annex to Commission Decision 94/23/EC[6].

2 Deutsches Institut für Bautechnik is authorized to check whether the provisions of this European technical approval are met. Checking may take place in the manufacturing plant. Nevertheless, the responsibility for the conformity of the products to the European technical approval and for their fitness for the intended use remains with the holder of the European technical approval.

3 This European technical approval is not to be transferred to manufacturers or agents of manufacturers other than those indicated on page 1, or manufacturing plants other than those indicated on page 1 of this European technical approval.

4 This European technical approval may be withdrawn by Deutsches Institut für Bautechnik, in particular pursuant to information by the Commission according to Article 5(1) of Council Directive 89/106/EEC.

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6 The European technical approval is issued by the approval body in its official language. This version corresponds fully to the version circulated within EOTA. Translations into other languages have to be designated as such.

[1] Official Journal of the European Communities L 40, 11 February 1989, p. 12
[2] Official Journal of the European Communities L 220, 30 August 1993, p. 1
[3] Official Journal of the European Union L 284, 31 October 2003, p. 25
[4] *Bundesgesetzblatt Teil I 1998*, p. 812
[5] *Bundesgesetzblatt Teil I 2011*, p. 2178
[6] Official Journal of the European Communities L 17, 20 January 1994, p. 34

II SPECIFIC CONDITIONS OF THE EUROPEAN TECHNICAL APPROVAL

1 Definition of the Halfen HDB and HDB-G double headed studs and intended use

1.1 Definition of the construction product

The Halfen HDB double headed studs with ribbed shafts are made of weldable ribbed reinforcement bars with a nominal characteristic yield strength of 500 MPa, the Halfen HDB-G double headed studs with smooth shafts are made of weldable, structural steel with a nominal characteristic yield strength of 500 MPa. The mechanical properties of the steel for fill the requirement according to EN 1992-1-1, Annex C.

They have a head at both ends with a diameter of three times the shaft diameter.

The diameters of the shafts are 10, 12, 14, 16, 18 and 20 mm for studs with smooth shafts and 10, 12, 14, 16, 20 and 25 mm for studs with ribbed bars.

The studs are assembled to form reinforcement elements comprising at least two studs (see figure 1). The studs are tack welded or clamped at one end to a non-structural steel rail or reinforcing bars for securing the position of the double headed studs when pouring the concrete. All studs of one of those reinforcement element shall have the same diameter.

To secure the position of the stud's during casting, bars of weldable reinforcing steel d_s = 6 mm to d_s = 10 mm or rails made of structural steel with a nominal characteristic yield strength of 235 MPa (S235JR acc. to EN 10025-2) or non-corrosive steel (No. 1.4401, 1.4404, 1.4571 acc. to EN 10088-5) are used.

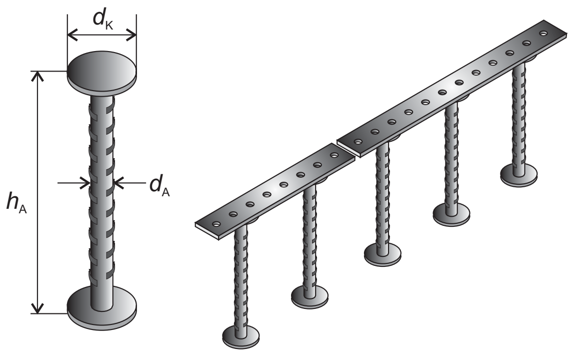


Figure 1: Double headed stud with steel rails welded to the heads

1.2 Intended use

The studs are installed as shear reinforcement in reinforced concrete flat slabs on columns, ground slabs or in footings in order to increase the punching shear resistance of the slabs. They may also be used for the increase of the load-bearing capacity of the slabs subjected to high concentrated loads.

Double headed studs can also be used for semi-prefabricated slabs also in combination with lattice girders when the respective ETAs or national guidelines are observed. Double-headed studs installed as shear reinforcement are also effective as interface reinforcement between precast and in-situ concrete.

Double headed studs with smooth or ribbed shafts may be used for predominantly static and non-predominantly static (fatigue) loading.

The concrete strength class according to EN 206-1:2000 of the slabs or footings shall be at least C20/25 and shall not exceed C50/60.

The slabs shall have a minimum height of h = 180 mm.

For double headed studs with smooth shafts the maximum effective depth (d) of the slab shall not exceed d = 300 mm.

All studs in the punching area around a column or concentrated load shall be of the same diameter.

The arrangement pattern is given in clause 4.2 of the ETA.

Where no National Regulation for the design of slabs or footings reinforced with double headed studs exists, the design of slabs or footings reinforced with double headed studs shall be in accordance with Annexes 16 and 17 of the ETA.

The reinforcement element with double headed studs may be installed in an upright (rail at the bottom of the slab) or hanging position, but always perpendicular to the faces of the reinforced slab or footing.

The provisions made in this European technical approval are based on an assumed working life of the Double Headed Studs of 50 to 100 years, provided that the conditions laid down in sections 4.2 and 5.1 for the installation, use and maintenance. The indications given on the working life cannot be interpreted as a guarantee given by the producer, but are to be regarded only as a means for choosing the right products in relation to the expected economically reasonable working life of the works.

2 Characteristics of the Double Headed Studs and methods of verification

2.1 Characteristics of the product

2.1.1. Geometry

The essential geometrical properties of the product are given in the ETA in Annexes 1 and 2. This includes the dimensions of the studs (diameter of the shaft d_A, diameter of the stud head d_k, height of the stud h_A), dimensions of the non-structural rails or reinforcement bars.

2.1.2 Mechanical strength

The double headed studs comply with the specifications and drawings given in the Annexes 1 and 2.

The following conditions concerning the yield strength and tensile strength of the HDB-G and HDB double headed studs are considered proven:

- $f_{yk} \geq 500$ MPa
- ratio $(f_t/f_y)_k \geq 1.05$
- $\varepsilon_{uk} \geq 2.5$ %

The material characteristics, dimensions and tolerances of the double headed studs not indicated in Annexes 1 and 2 are given in the technical documentation[7] of the ETA.

[7] The technical documentation of the ETA is deposited with DIBt and, as far as relevant fort he tasks of the approved bodies involved in the attestation of conformity procedure, is handed over to the approved bodies.

2.1.3 Mounting of the studs

When installed correctly, the reinforcement elements have sufficient robustness to be withstand usual actions before concreting.

In case the studs are intended for use in prefabricated slab elements there are no requirements in terms of before mentioned robustness if there are other possibilities to ensure a safe transport and positioning.

2.1.4 Robustness and Durability of the studs

The robustness and durability in service conditions under repeated loading of double headed studs, in terms of mechanical resistance, is considered proven.

2.1.5 Fatigue strength of the double headed studs

The fatigue strength of the double headed studs for non-predominantly static loading shall deal with the fatigue of the reinforcement steel only.

The double headed studs can be used for a stress range of $\sigma_{Rs,k}$ = 70 N/mm² and $N \leq 2 \times 10^6$ load cycles in analogy to EN 1992-1-1, clause 6.8.6 (1) and (2).

Table 6.3N of EN 1992-1-1 is not applicable to double headed studs.

As the value of the stress range lies within the scope where simplified verification methods are applicable (see EN 1992-1-1, Clause 6.8.6), an evaluation of the concrete fatigue strength is not deemed necessary.

2.1.6 Reaction to fire

The double headed studs are considered to satisfy the requirements for performance class A1 of the characteristic reaction to fire, in accordance with the provisions of EC Decision 96/603/EC (as amended) without the need for testing on the basis of its listing in that decision.

2.1.7 Resistance to fire

Fire resistance performance cannot be claimed for individual products (non-installed), but for the installed double headed studs cast-in slabs or footings.

2.1.8 Durability

Supporting evidence that corrosion will not occur is not required if the steel parts are protected against corrosion, as set out below:

No separate verifications are necessary for durability against environmental influences if:

- the double headed studs are protected by a minimum concrete cover according to the requirements given at the place of use,
- or the reinforcing bars for securing the position (spacer bars) are made of steel which has been hot-dip galvanized (coating ≥ 50 µm) and will be installed in concrete member under dry internal conditions and the stud heads have at least the minimum concrete cover according to the national provisions of the Member States,
- or the bars are made of suitable stainless steel (1.4401/1.4404/1.4571) where they will be installed in slabs under dry internal conditions, in humid internal conditions, external environment, also in industrial environment or in marine environment proximity, if no particular aggressive conditions exist, and the stud heads have at least the minimum concrete cover according to the regulations and provisions at the place of use.

2.2 Methods of verification

2.2.1 General

The ETA is issued for the Halfen HDB-G and HDB double headed studs on the basis of agreed information, deposited with Deutsches Institut für Bautechnik (DIBt), which identifies the double headed studs that has been assessed and evaluated. Changes to the production process, the dimensions, materials or the elements which could result in this deposited information being incorrect, shall be notified to DIBt before the changes are introduced. DIBt will decide whether or not such changes affect the ETA and consequently the validity of the CE marking on the basis of the ETA, and, if so, whether further assessment and/or alterations to the ETA shall be necessary.

2.2.2 Mechanical resistance and stability of the double headed studs

The assessment of the fitness of the double headed studs for the intended use with regard to the requirements of mechanical resistance and stability as well as safety in use in the sense of the Essential Requirements 1 and 4 was performed based on the following verifications:

1. Verification for tensile loads
   - yield strength f_{yk}
   - elongation at maximum load ε_{uk}
   - ratio k $(f_t/f_y)_k$
2. Verification of robustness (mounting of the studs)
   - Test which ensures that the reinforcement element (stud welded on the steel rail) withstand horizontal forces
3. Verification for fatigue
   - Fatigue strength at $N = 2 \times 10^6$ load cycles $\Delta\sigma_{Rs,k}$

2.2.3 Punching shear resistance of slabs and footings with double headed studs

The assessment of the fitness of the double headed studs for the intended use with regard to the punching shear resistance of slabs in the sense of Essential Requirements 1 and 4 was performed based on the following verifications:

1. Punching shear resistance at interior columns

Full scale tests were carried out to determine the maximum punching shear resistance $v_{Rd,max}$. The punching shear resistance for centric loading is calculated by means of the method described in the Annexes 16 and 17.

2. Punching shear resistance at edge- and corner columns

For all edge and corner columns and asymmetrical systems, the load eccentricity is taken into account by means of a load-increase factor β on the design value of the applied load in accordance with the rules and regulations in EN 1992-1-1. The method using a reduced basic control perimeter according to EN 1992-1-1, 6.4.3 (4) and (5) is not applicable.

3. Punching shear resistance near openings

Openings near to columns in the punching area may decrease the punching shear resistance of the slab. Design shall be carried out according to EN 1992-1-1 6.4.2 (3).

4. Punching shear resistance of footings

The maximum punching shear resistance of footings is limited to the punching shear resistance $v_{Rd,max} = 1.5\ v_{Rd,c}$ (see Annex 17).

2.2.4 Safety in case of fire

2.2.4.1 Reaction to fire

The double headed studs are considered to satisfy the requirements for performance class A1 of the characteristic reaction to fire, in accordance with the provisions of EC Decision 96/603/EC (as amended) without the need for testing on the basis of its listing in that decision.

2.2.4.2 Resistance to fire

The assessment of slab or footing reinforced with the double headed studs that is required to provide a specific fire resistance class, may be determined for concrete failure by reference to EN 1992-1-2, as it may be assumed that the temperature distribution within the slab is comparable or at least no more unfavourable than in a slab or footing reinforced with stirrups as shear or punching shear reinforcement.

The concrete cover required by EN 1992-1-2 for verifying the resistance shall be measured from the surface of the slab to the outer face of the stud head or - in case of studs with steel rails - to the outer face of the steel rail.

3 Evaluation and attestation of conformity and CE marking

3.1 System of attestation of conformity

According to the communication of the European Commission[8] system 1+ of the attestation of conformity applies.

This system of attestation of conformity is defined as follows:

System 1+: Certification of the conformity of the product by an approved certification body on the basis of:

(a) Tasks for the manufacturer:
- (1) factory production control;
- (2) further testing of samples taken at the factory by the manufacturer in accordance with a prescribed test plan;

(b) Tasks for the approved body:
- (3) initial type-testing of the product;
- (4) initial inspection of factory and of factory production control;
- (5) continuous surveillance, assessment and approval of factory production control;
- (6) audit-testing of samples taken at the factory.

Note: Approved bodies are also referred to as "notified bodies".

3.2 Responsibilities

3.2.1 Tasks for the manufacturer

3.2.1.1 Factory production control

The manufacturer shall exercise permanent internal control of production. All the elements, requirements and provisions adopted by the manufacturer shall be documented in a systematic manner in the form of written policies and procedures, including records of results performed. This production control system shall ensure that the product is in conformity with this European technical approval.

[8] Letter of the European Commission of 4 October 1999 to EOTA

The manufacturer may only use initial materials stated in the technical documentation of this European technical approval.

The factory production control shall be in accordance with the control plan which is part of the technical documentation of this European technical approval. The control plan is laid down in the context of the factory production control system operated by the manufacturer and deposited with Deutsches Institut für Bautechnik.[9]

The results of factory production control shall be recorded and evaluated in accordance with the provisions of the control plan.

3.2.1.2 Other tasks for the manufacturer

The manufacturer shall, on the basis of a contract, involve a body which is approved for the tasks referred to in section 3.1 in the field of double headed studs in order to undertake the actions laid down in section 3.2.2. For this purpose, the control plan referred to in sections 3.2.1.1 and 3.2.2 shall be handed over by the manufacturer to the approved body involved.

3.2.2 Tasks for the approved bodies

The approved body shall perform the

- initial type-testing of the product,
- initial inspection of factory and of factory production control,
- continuous surveillance, assessment and approval of factory production control
- audit-testing of samples taken at the factory

in accordance with the provisions laid down in the control plan.

The approved body shall retain the essential points of its actions referred to above and state the results obtained and conclusions drawn in a written report.

The approved certification body involved by the manufacturer shall issue an EC certificate of conformity of the product stating the conformity with the provisions of this European technical approval.

In cases where the provisions of the European technical approval and its control plan are no longer fulfilled the certification body shall withdraw the certificate of conformity and inform Deutsches Institut für Bautechnik without delay.

3.3 CE marking

The CE marking shall be affixed on a small label which is fixed at each reinforcement element (double headed studs welded on steel rail or reinforcement bar). The letters "CE" shall be followed by the identification number of the approved certification body, where relevant, and be accompanied by the following additional information:

- the name and address of the producer (legal entity responsible for the manufacture),
- the last two digits of the year in which the CE marking was affixed,
- the number of the EC certificate of conformity for the product
- the number of the European technical approval,
- characteristic yield strength $f_{y,k}$ of the studs
- fatigue strength of the stud (allowable stress range)

[9] The control plan is a confidential part of the European technical approval and only handed over to the approved body involved in the procedure of attestation of conformity. See section 3.2.2.

4 Assumptions under which the fitness of the product for the intended use was favourably assessed

4.1 Manufacturing

The European technical approval is issued for the product on the basis of agreed data/information, deposited with Deutsches Institut für Bautechnik, which identifies the product that has been assessed and judged. Changes to the product or production process, which could result in this deposited data/information being incorrect, should be notified to Deutsches Institut für Bautechnik before the changes are introduced. Deutsches Institut für Bautechnik will decide whether or not such changes affect the approval and consequently the validity of the CE marking on the basis of the approval and if so whether further assessment or alterations to the approval shall be necessary.

4.2 Design requirements

The fitness of the double headed studs for the intended use is given under the following condition:

Where no National Regulation for the design of slabs or footings reinforced with double headed studs exists, the design of the double headed studs is based on EN 1992-1-1 and on Annexes 16 and 17 of this ETA for predominantly static load, non-predominantly static load or for fatigue.

The concrete strength class shall not be less than C20/25 and shall not exceed C50/60 according to EN 206-1:2000.

The slabs shall have a minimum height of h = 180 mm. For double headed studs with smooth shafts, the maximum effective depth (d) of the slab shall not exceed d = 300 mm.

It is assumed that

- The lower reinforcement of the slab is laid over the column according to the indication in EN 1992-1-1.
- The upper reinforcement of the slab is placed continuously over the loaded area.
- The load-bearing capacity of the column below the shear reinforcement as well as the local compressive stress at the joint between slab and column are each verified individually and by taking into account of national provisions and guidelines.
- The load-bearing capacity of the concrete slab outside the punching shear reinforced area is verified separately and in accordance with the relevant national provisions.
- The bending resistance of the entire slab is verified in accordance with the relevant national provisions.
- In case of cast in-situ slabs, the punching shear reinforced area is poured monolithically with the slab. In case of semi-prefabricated slabs, when the final concrete is cast on-site, one head of the double headed studs shall be cast in the prefabricated slab.
- The flexural reinforcement over the column has to be anchored outside the outer control perimeter u_{out}.

The favourable effect of normal compressive stresses on the maximum punching shear resistance shall not be taken into account for slabs with double headed studs as punching shear reinforcement. If inclined pre-stressed tendons cross the punching zone, a negative influence shall be considered, while a positive influence may be considered.

The position, the type, the size and the length of the double headed studs shall be indicated on the design drawings. The material of the double headed studs is given additionally on the drawings.

The double headed studs shall be positioned in the following way:

Flat slabs:

On each stud on a radius, the stud nearest to the column face or loaded area shall be placed at a radial distance between 0.35 d and 0.5 d, the second stud within 1.125 d from the column face nor loaded area. The area within 1.125 d from the column face is designated area C. The tangential distance of the studs shall not exceed 1.7 d within 1.00 d from the column face. The maximum distance between studs shall not exceed 0.75 d in the radial direction.

For flat slabs with both d > 50 cm and the diameter of the column c < 50 cm, at least three studs shall be arranged in area C in case that $V_{Ed} > 0.85\ V_{Rd,max}$.

Outside the area C (area D), the maximum tangential distance is 3.5 d. The number of punching reinforcement elements in the area D may be increased in comparison to area C to fulfil this requirement. If the number of elements is increased, additional elements shall be placed radially to the column between the existing elements.

In the area D the radial distance between the studs shall not exceed 0.75 d. In thick slabs, where three or more headed studs are arranged per rail in area C, the radial distance of the double headed studs in area D shall be reduced according to the following equation:

$$s_{w,D} = \frac{3 \cdot d \cdot m_D}{2 \cdot n_C \cdot m_C} \leq 0.75 \cdot d$$

m_C: number of elements (rows) in area C

m_D: number of elements (rows) in area D

n_C: number of studs of each element (row) in area C

For double headed studs placed next to free slab edges and recesses, a transverse reinforcement shall be provided to control the transverse tensile forces.

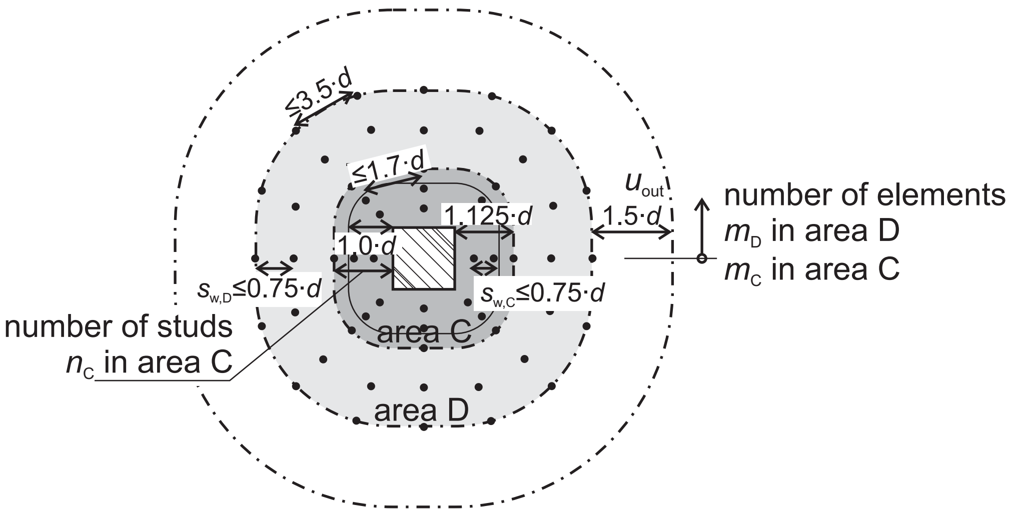


Figure 2: Maximum allowed spacing of studs in area C and D of flat slabs

Footings:

For footings, the first row of studs shall be placed at a distance of 0.3 d and the second row in a range up to 0.8 d from the column face.

Where outside 0.8 d further rows of double headed studs are required, the radial distance in compact footings with a small shear span-depth ratio of $a_\lambda/d \leq 2.0$ is limited to 0.5 d (a_λ according to Fig. 3). For slender footings ($a_\lambda/d > 2.0$) the radial distance outside of 0.8 d can be increased to 0.75 d. The double headed studs are evenly distributed along the circular sections and the maximum tangential distance may not exceed 2.0 d.

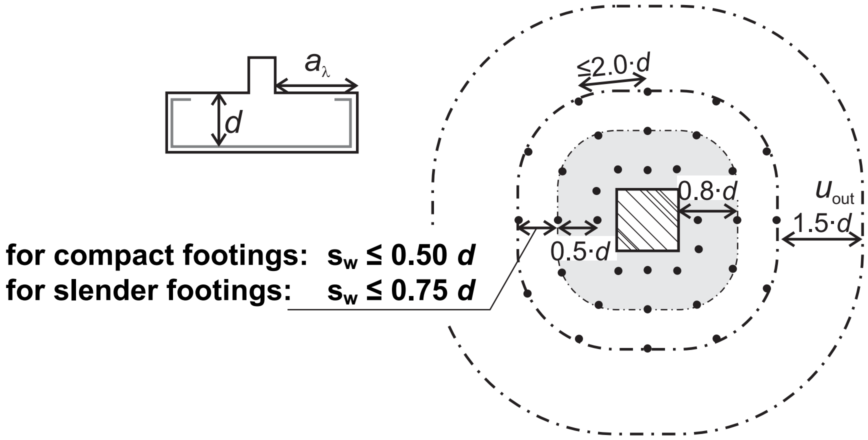


Figure 3: Maximum allowed spacing of studs in slender and compact footings

4.3 Installation

The fitness for use of the double headed studs can only be assumed if the following installation conditions are observed:

The reinforcement elements shall be positioned in such a way that the double headed studs are perpendicular to the slab surface and are directed in the radial direction towards the column and distributed evenly in the critical punching area.

The upper heads of the studs need to extend at least to include the uppermost layer of the flexural reinforcement, the lower heads of the studs need to extend at least to include the the lower layer of the flexural reinforcement. The concrete cover according to national regulations shall be ensured. In a punching area around any column or area of concentrated load, only studs with the same diameter may be used.

If the precast elements need to be joined in the punching area, the recess between the prefabricated elements shall be at least 40 mm wide and has to be meticulously filled with concrete on-site.

5 Indications to the manufacturer

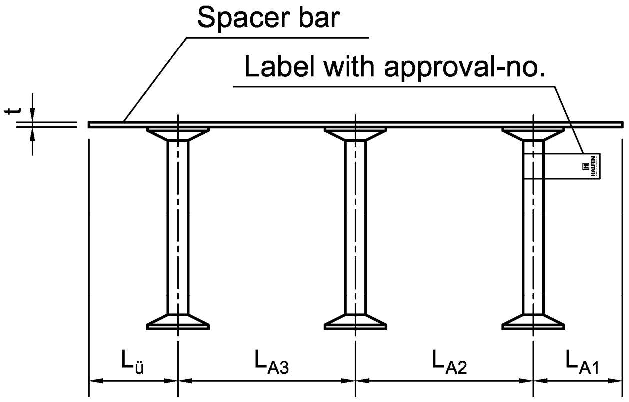
5.1 Packaging, transport and storage

Special considerations shall be given to the transportation of the prefabricated elements to avoid any damage to the anchorage of the headed studs in the precast concrete slab (see Annex 15).

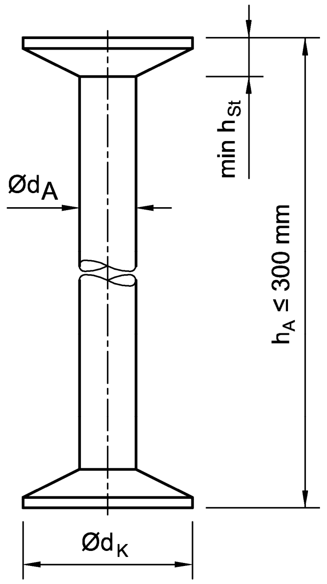
Georg Feistel
Head of Department

beglaubigt:
Dr.-Ing. Rosenbusch

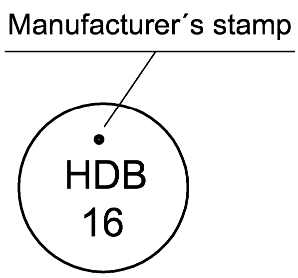
HDB-G Double-Headed Stud - Elements



HDB-G stud dimensions



HDB-G studs identification on both (heads/ends) e.g.



Material: steel with a characteristic yield strength of $f_{yk} \geq 500$ MPa acc.to EN 1992-1-1, annex C and provided data sheet

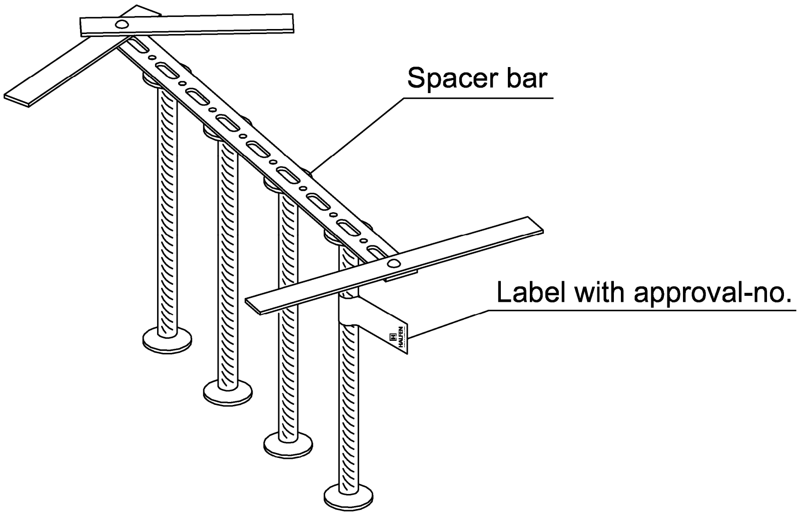
Stud Ø d_A [mm]	Head Ø d_K [mm]	Head thickness min h_{St} [mm]	Stud section $A_{S\,DKA}$ [mm²]	Characteristic value of yield strength f_{yk} [MPa]	Anchor height $h_A \leq 300$ mm
10	30	5	79	500	h_A = slab thickness – upper and lower concrete cover
12	36	6	113		
14	42	7	154		
16	48	8	201		
18	54	9	254		
20	60	10	314		

HALFEN HDB shear rail

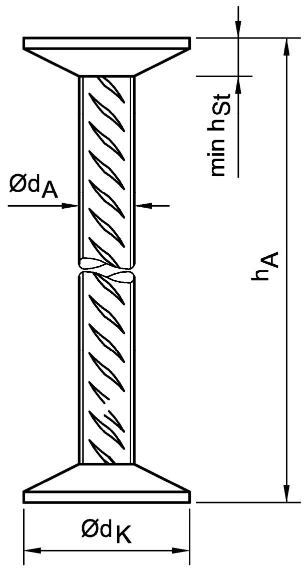
HDB-G double headed studs with smooth shaft

Annex 1

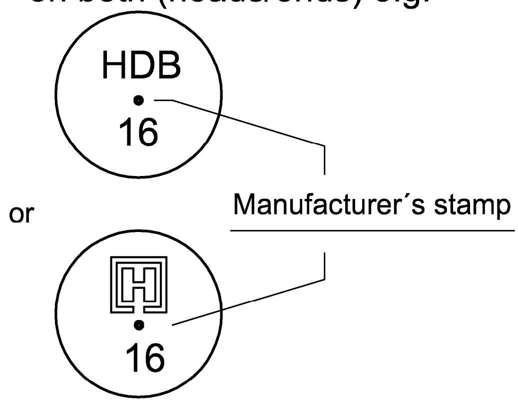
HDB Double-Headed Stud - Elements



HDB stud dimensions



HDB studs identification
on both (heads/ends) e.g.



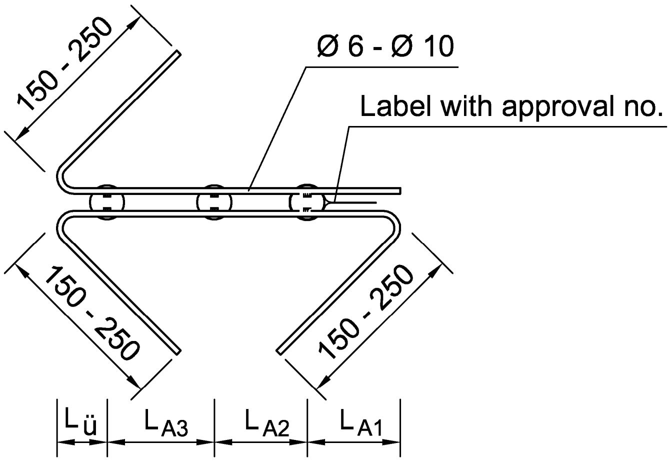
Material: reinforcing steel with a characteristic yield strength of $f_{yk} \geq 500$ MPa
acc.to EN 1992-1-1, annex C and provided data sheet

Stud Ø d_A [mm]	Head Ø d_K [mm]	Head thickness min h_{St} [mm]	Stud section $A_{S\,DKA}$ [mm²]	Characteristic value of yield strength f_{yk} [MPa]	Anchor height h_A [mm]
10	30	5	79	500	h_A = slab thickness – upper and lower concrete cover
12	36	6	113		
14	42	7	154		
16	48	7	201		
20	60	9	314		
25	75	12	491		

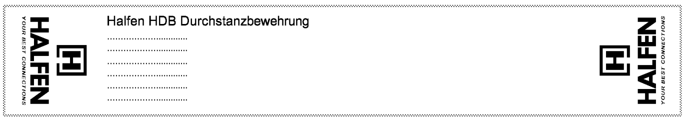
HALFEN HDB shear rail	Annex 2
HDB double headed studs with ribbed shaft	

Spacer bars from reinforcement bars or round bars

- with angled ends



Exampel:
Label with
approval no.



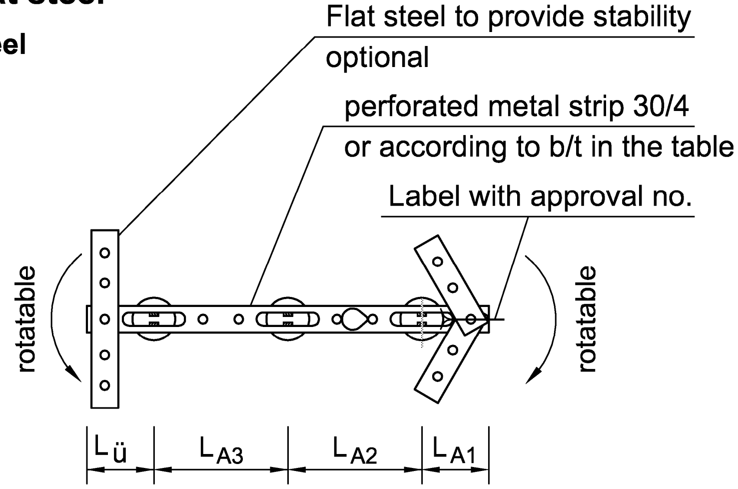
Material: Reinforcing steel with a characteristic yield strength of $f_{yk} \geq 500$ MPa acc.to EN 1992-1-1, annex C and provided data sheet

Round bars A4 = 1.4571/ 1.4401/ 1.4404 (acc. to EN 10088-5:2009)
S 235 JR = 1.0038 (acc. to EN10025-2:2004)

Spacer bar from flat steel

- with rotatable flat steel

Stud Ø d_A	b	t
10, 12	30	3
14, 16	40	3
18, 20, 25	60	3
[mm]		

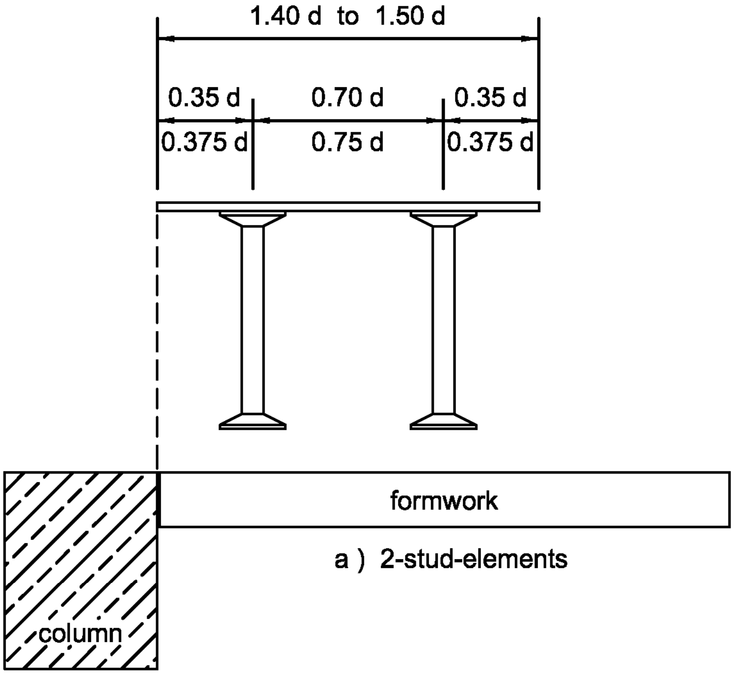


Material: A4 = 1.4571/ 1.4401/ 1.4404 (acc.to EN 10088-5:2009)
S 235 JR = 1.0038 (acc. to EN10025-2:2004)

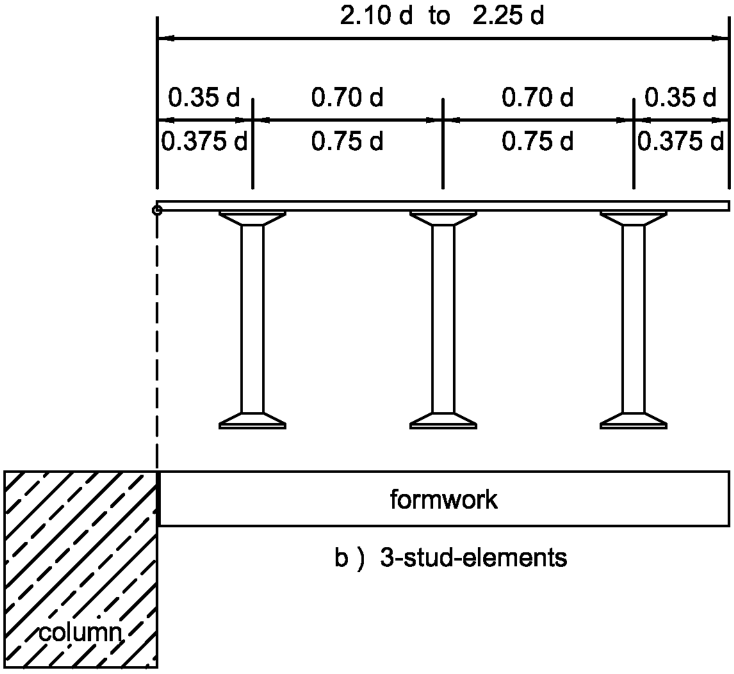
HALFEN HDB shear rail	Annex 3
Spacer bars	

Design of the HDB - system elements

The symmetric overlap of the spacer bar is used to ensure correct spacing of the elements from the column. Furthermore, it ensures the right radial spacing between two adjacent stud elements.



a) 2-stud-elements

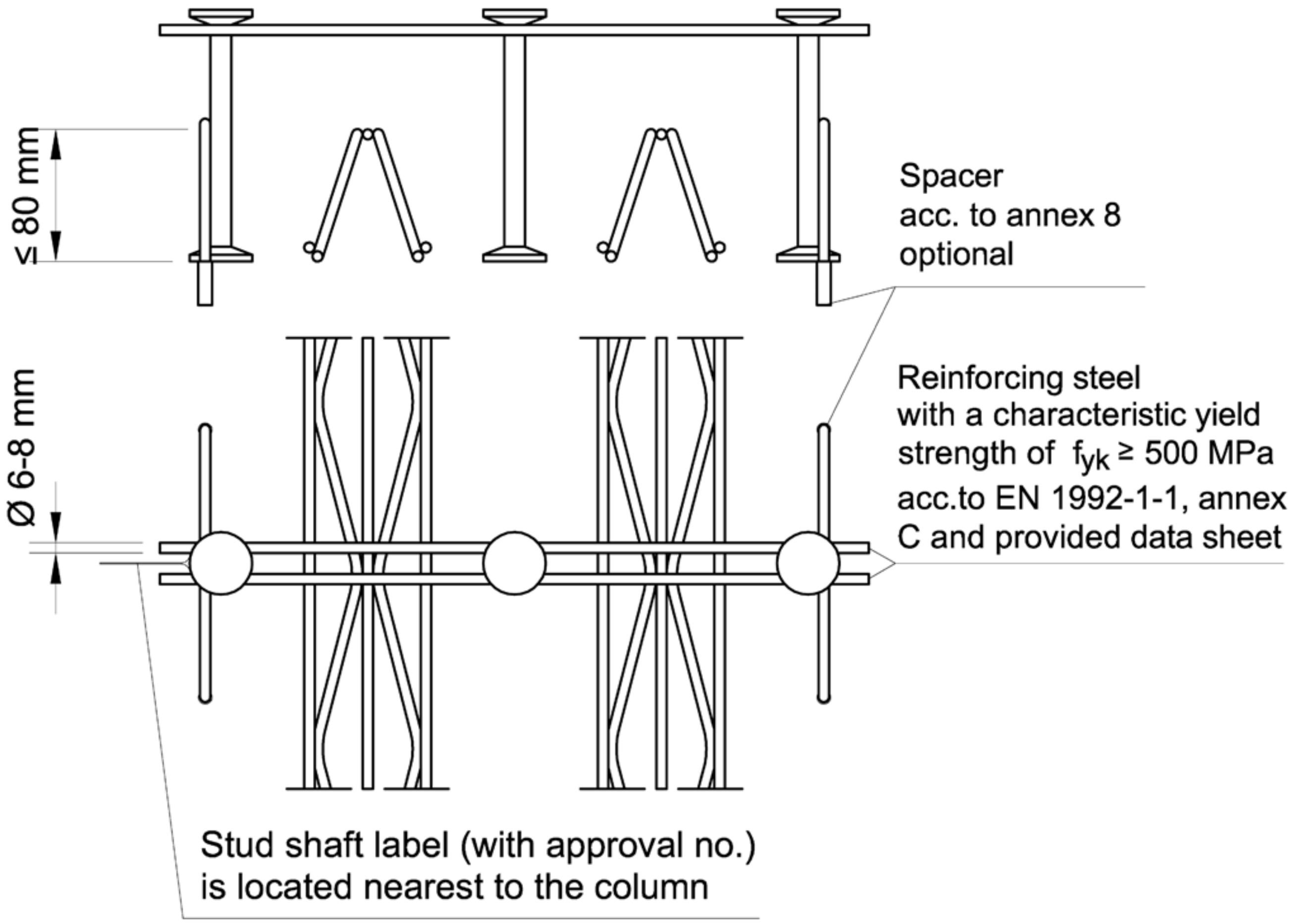


b) 3-stud-elements

HALFEN HDB shear rail	Annex 4
Design	

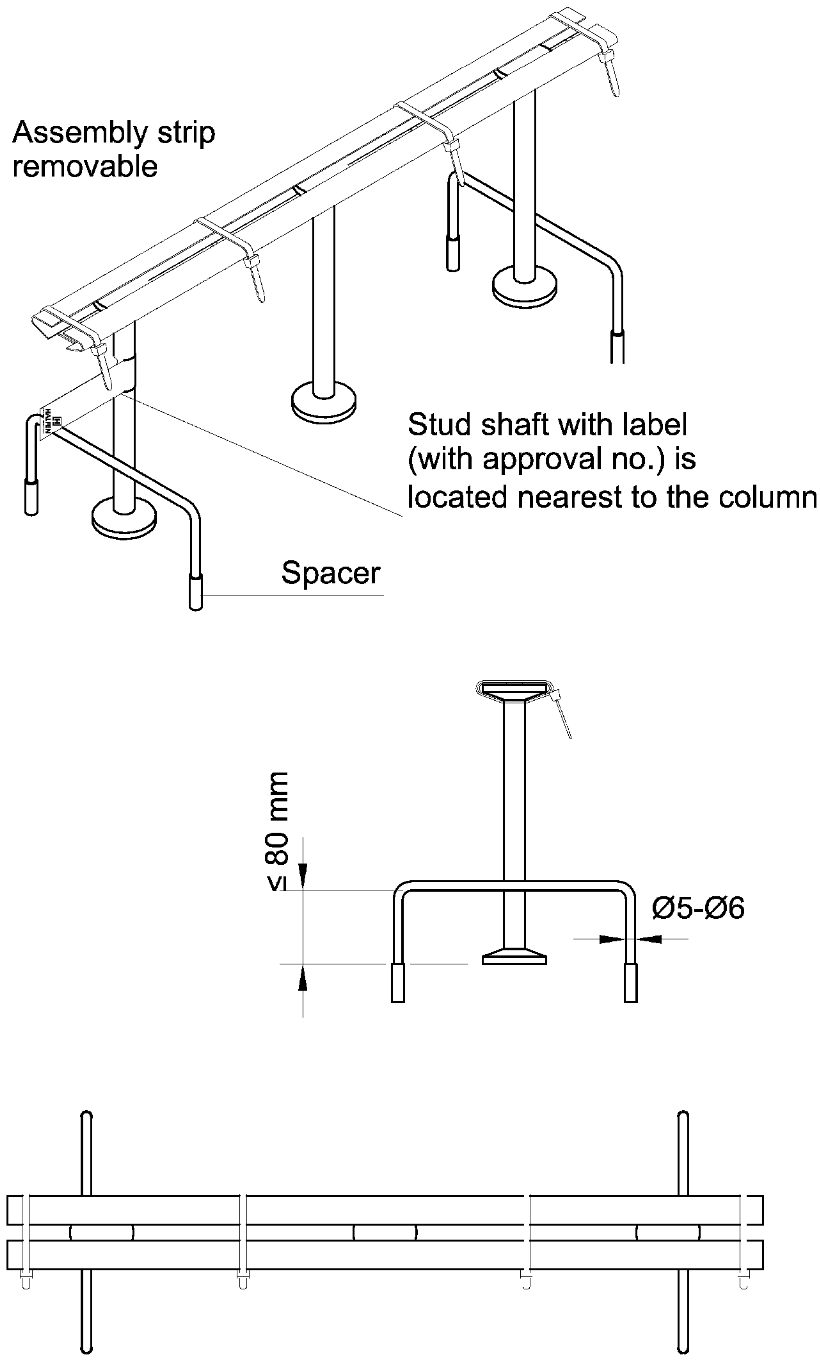
HDB - reinforcing elements for precast elements
Types with spot-welded positioning-elements

Fixing the HDB - reinforcing elements using spacers



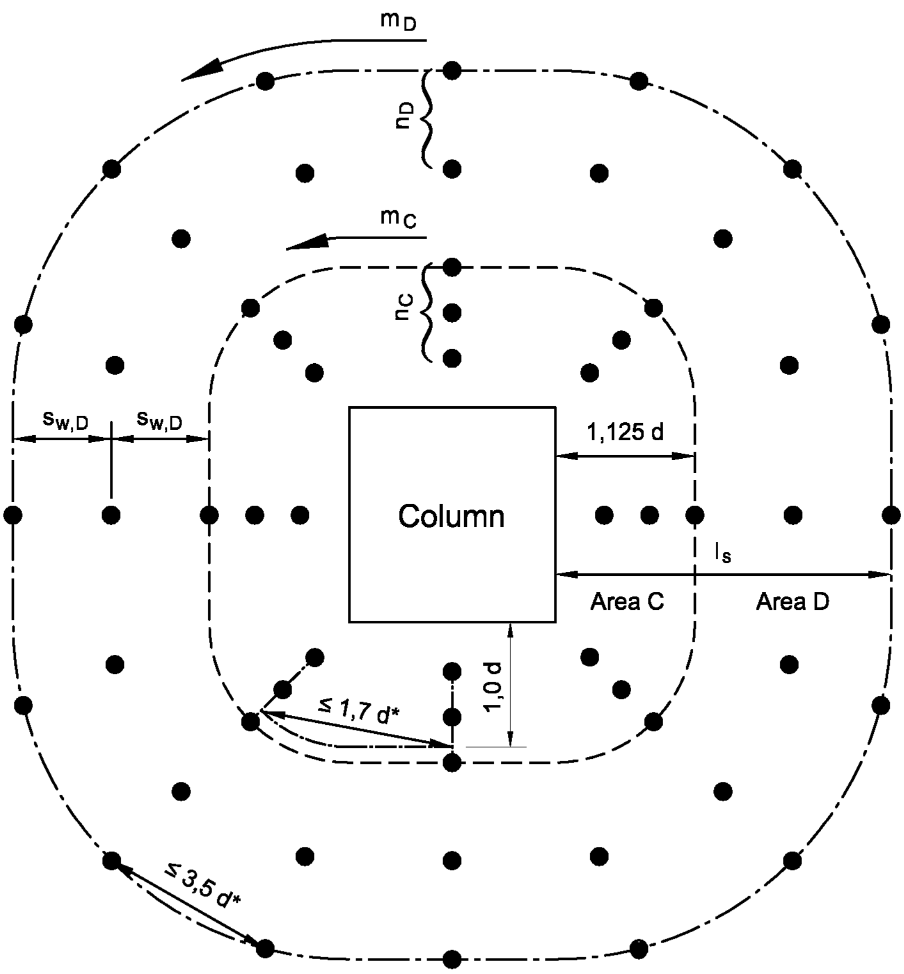
HALFEN HDB shear rail	Annex 5
HBD-G and HDB double headed studs in precast elements	

HDB - reinforcing elements for precast elements
Type with removable assembly-elements



HALFEN HDB shear rail	Annex 6
HBD-G and HDB double headed studs in precast elements	

Principle arrangement of the HDB - studs in slabs



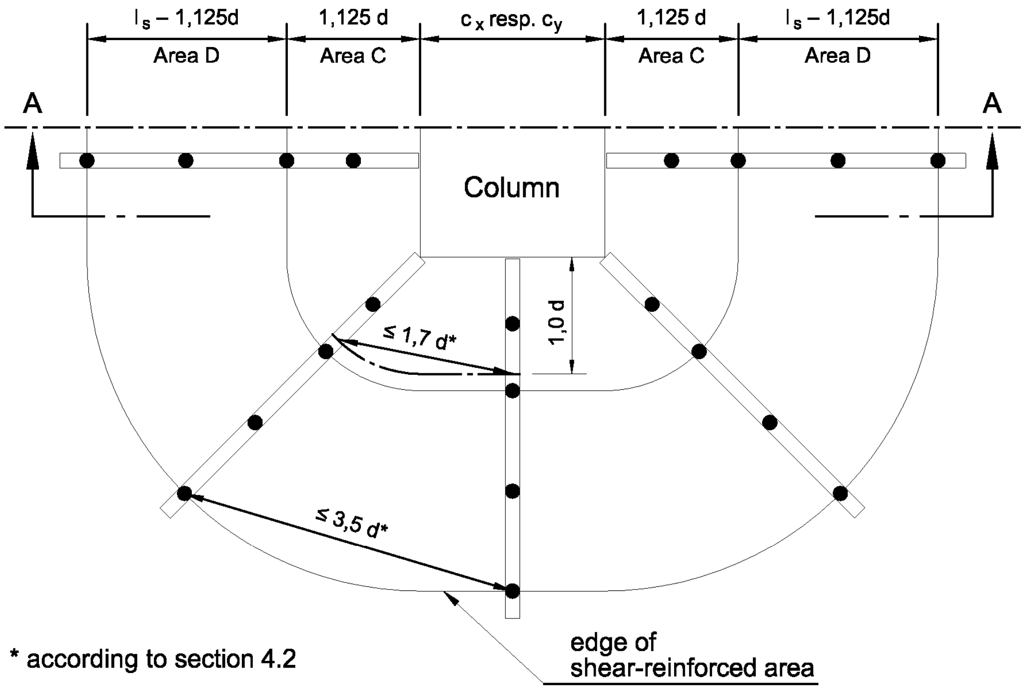
m_C number of elements (rows) in area C
m_D number of elements (rows) in area D
n_C number of studs of each element (row) in area C
n_D number of studs of each element (row) in area D
$s_{w,D}$ radial spacing in area D according to section 4.2

* according to section 4.2

HALFEN HDB shear rail	Annex 7
Arrangement of HDB studs in slabs	

Placing the punching shear reinforcement using HDB complete elements in slabs

Plan view

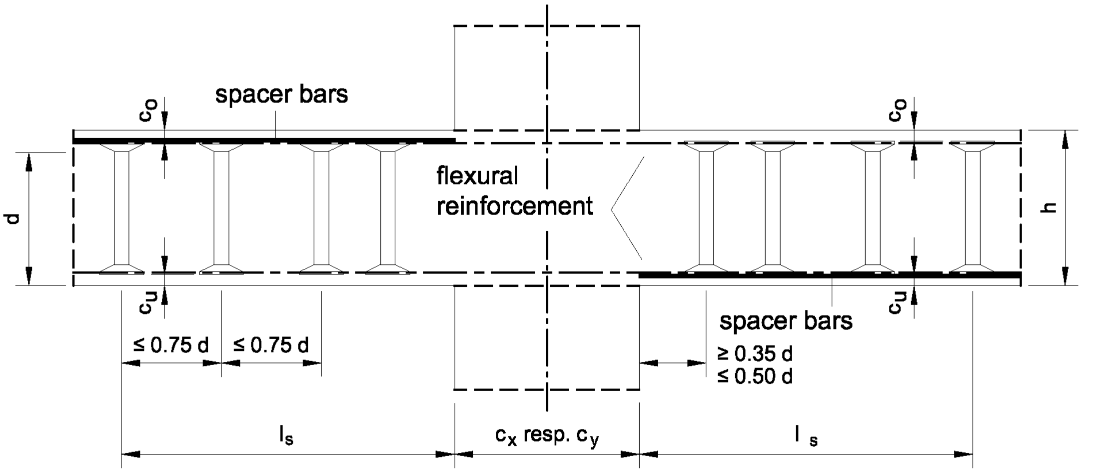


* according to section 4.2

Section A - A

Installation after placing the top and bottom reinforcement layers

Reverse installation; spacer bars are under the lower layer of reinforcement

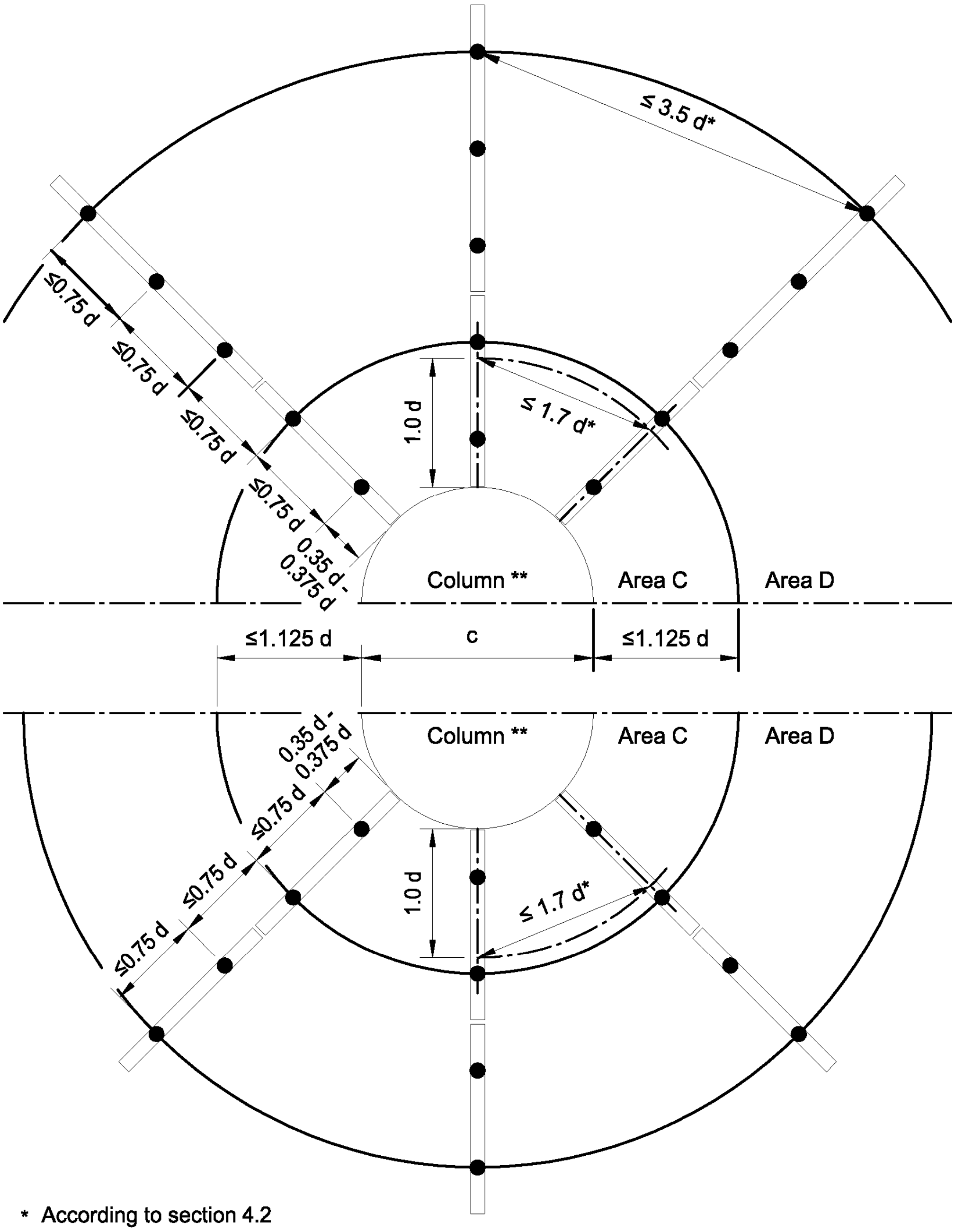


Concrete cover c_o resp. c_u acc. to EN1992-1-1 : 2004 + AC : 2010, section 4.4

HALFEN HDB shear rail	Annex 8
Complete elements	

English translation prepared by DIBt

Arrangement of punching shear reinforcement system elements with 2 or 3 studs in slabs

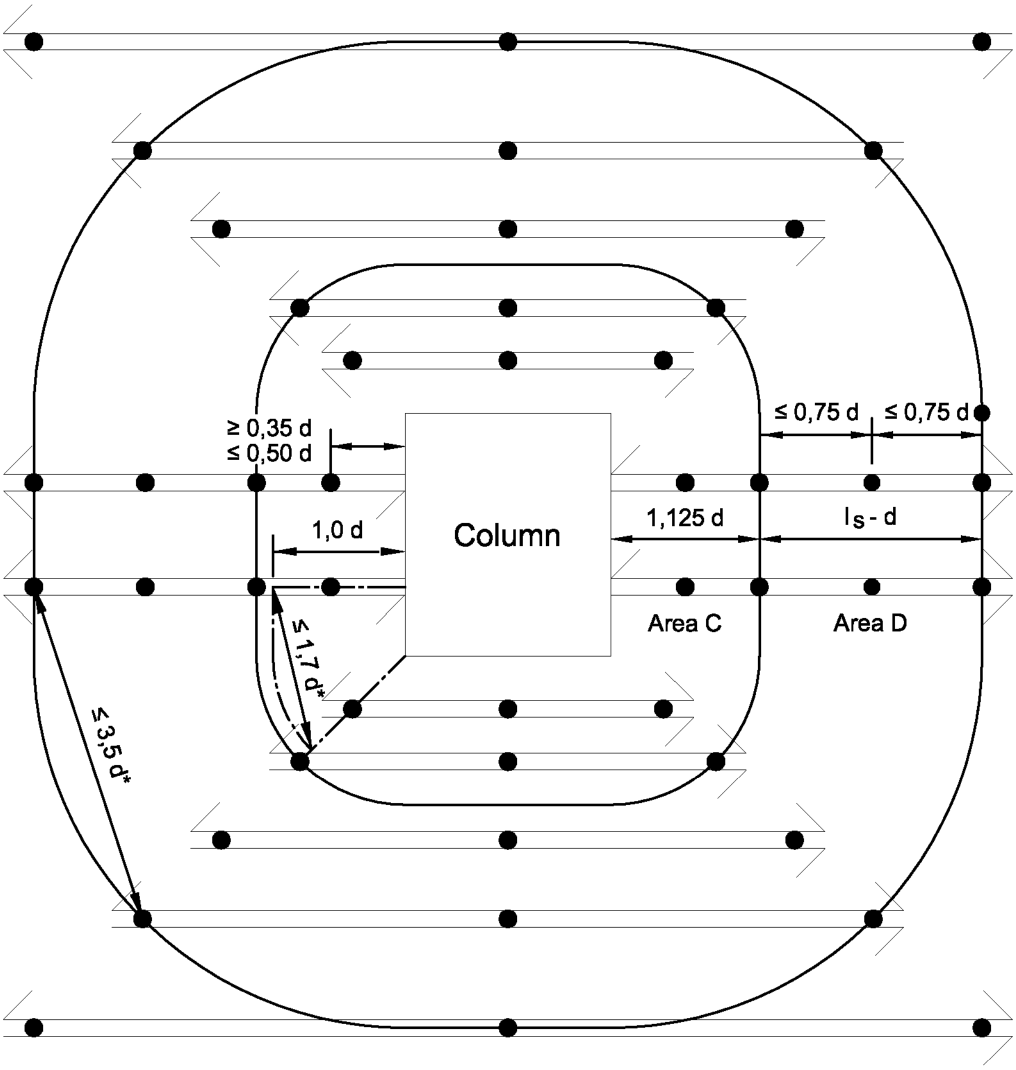


* According to section 4.2

** For rectangular columns, the system elements with 2 or 3 studs can be arranged analogously

HALFEN HDB shear rail	Annex 9
2- or 3-stud system element	

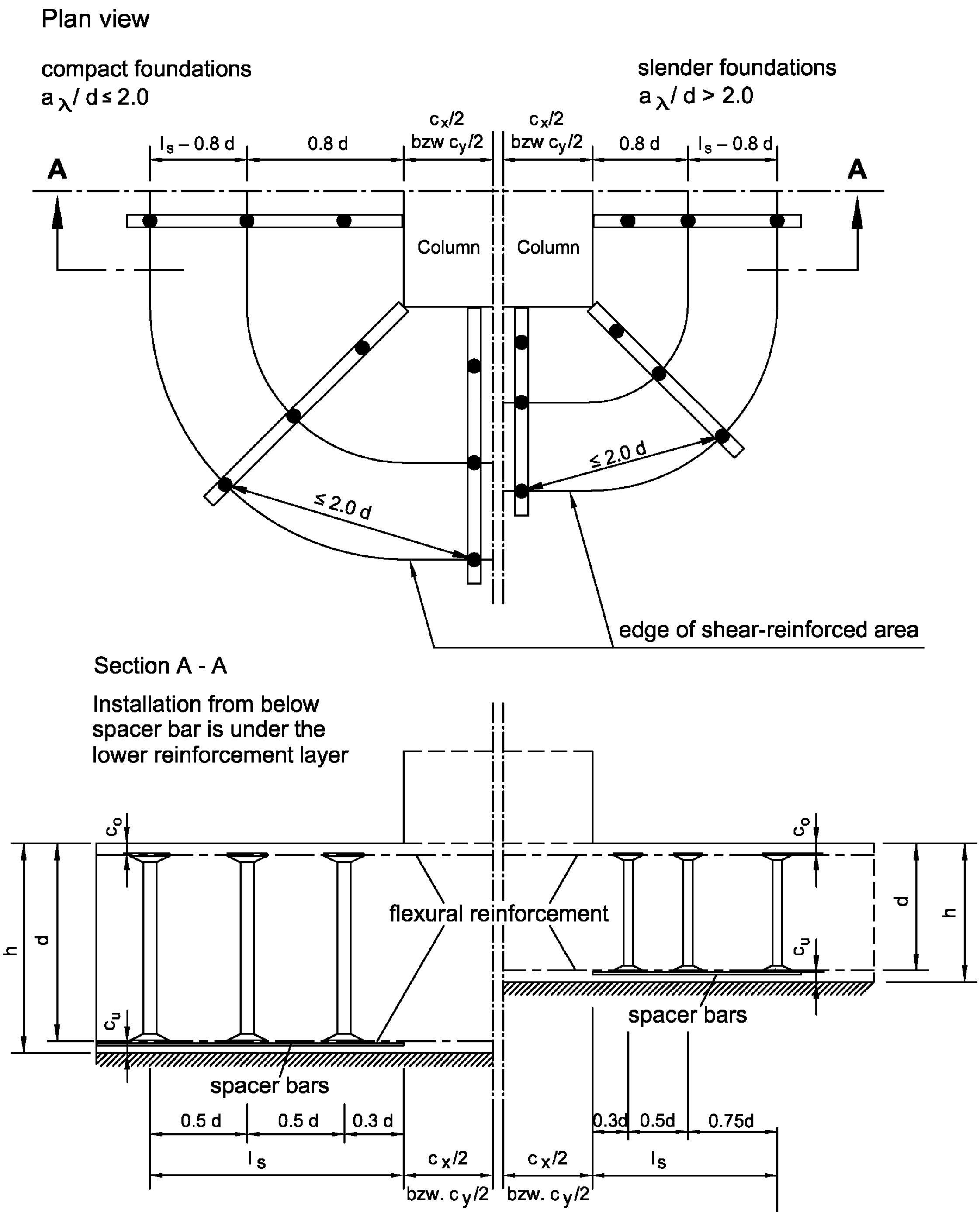
Parallel arrangement of punching shear reinforcement in slabs



* According to section 4.2

HALFEN HDB shear rail	Annex 10
Parallel arrangement	

Arrangement of punching shear reinforcement using complete elements in footings and ground slabs



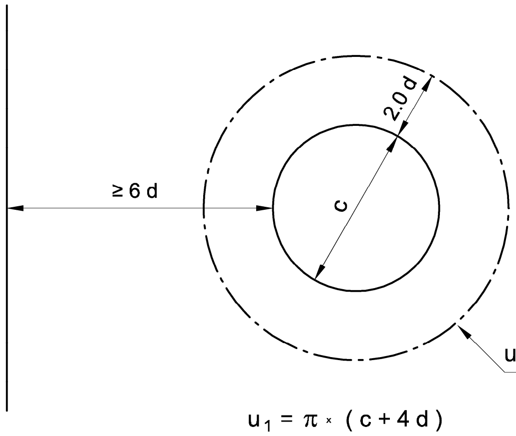
Concrete cover c_o resp. c_u acc. to EN1992-1-1 : 2004 + AC : 2010, section 4.4

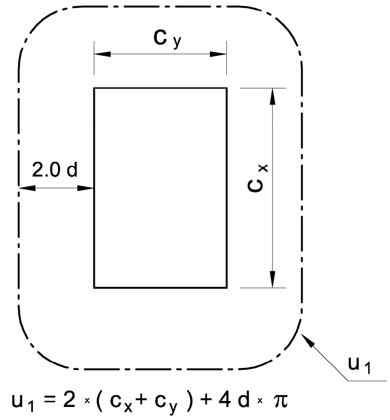
HALFEN HDB shear rail	Annex 11
Footings and ground slabs	

Defining the critical perimeters u_1 and u_{out} for punching shear verification

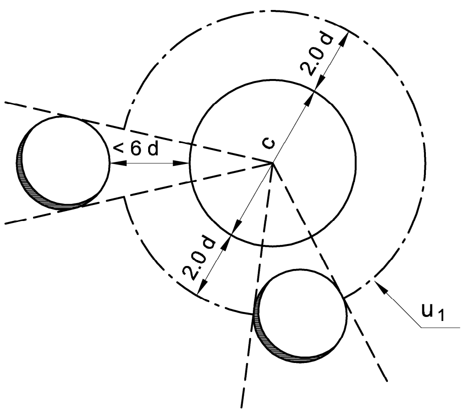
1. Critical perimeter u_1

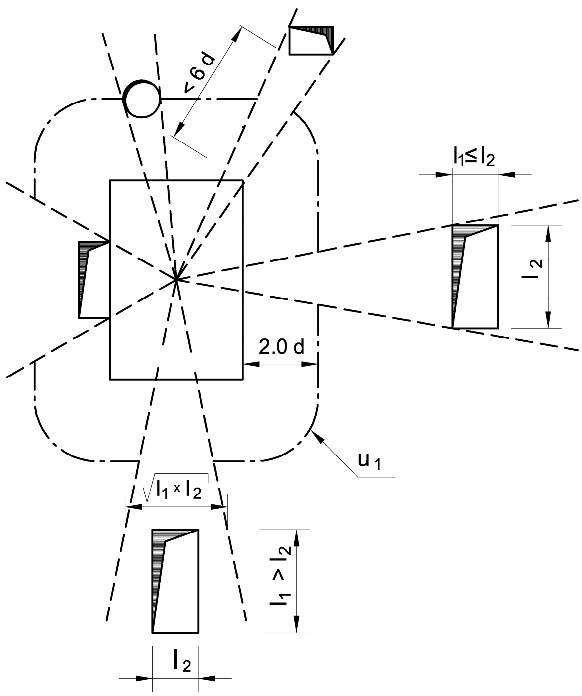
a) Loaded area (columns) is more than 6 d from openings or slab free edges





b) Load area (columns) is less than 6d from openings (voids) in the slab





HALFEN HDB shear rail	Annex 12
Critical perimeters	

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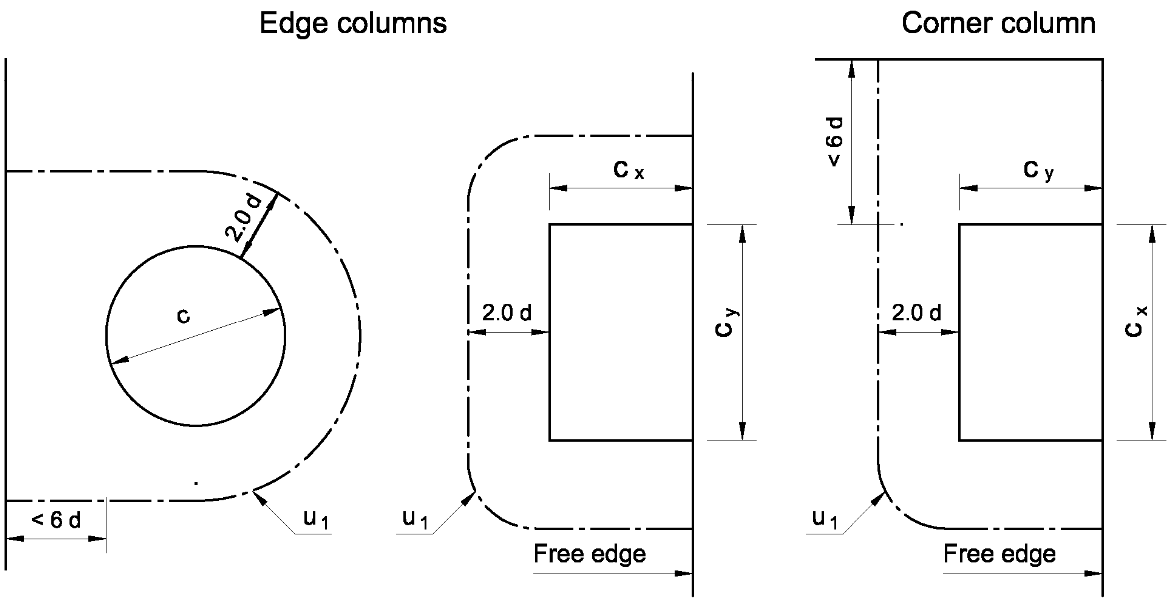
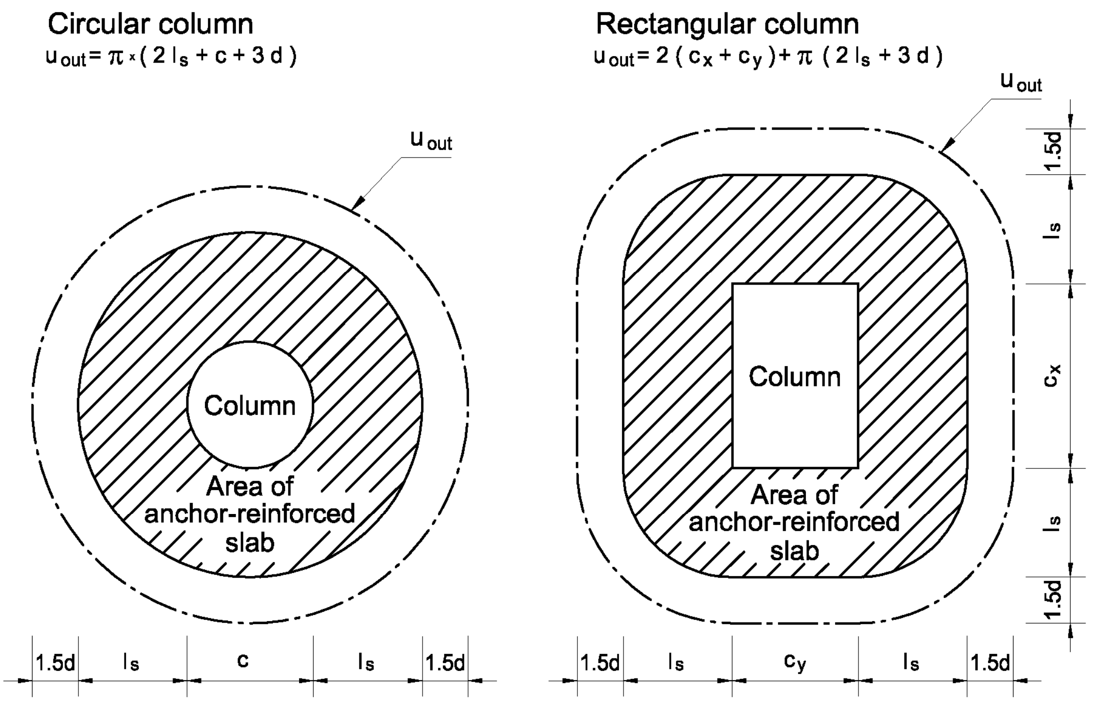
c) Loaded area (columns) at distances less than 6 d from free edges



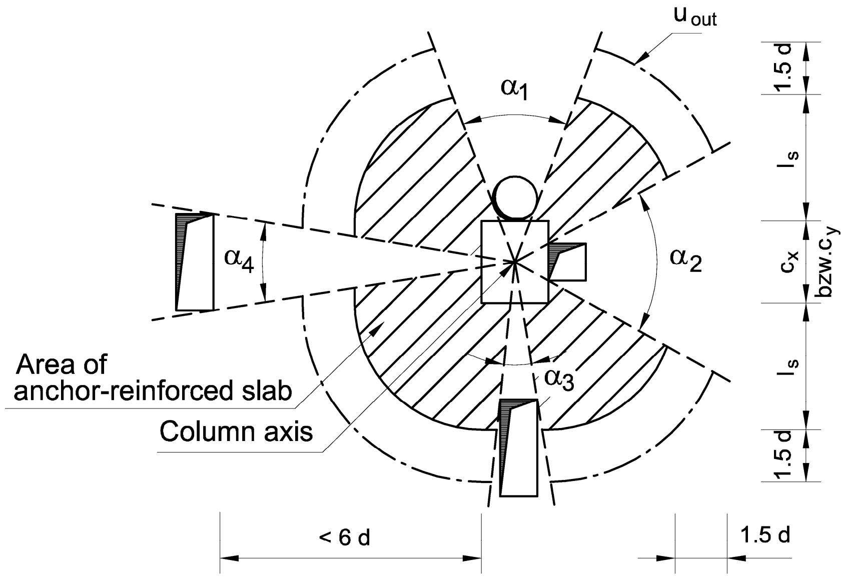
2. Outermost perimeter u_{out}

a) Load area (columns) are more than 6 d from openings or slab free edges

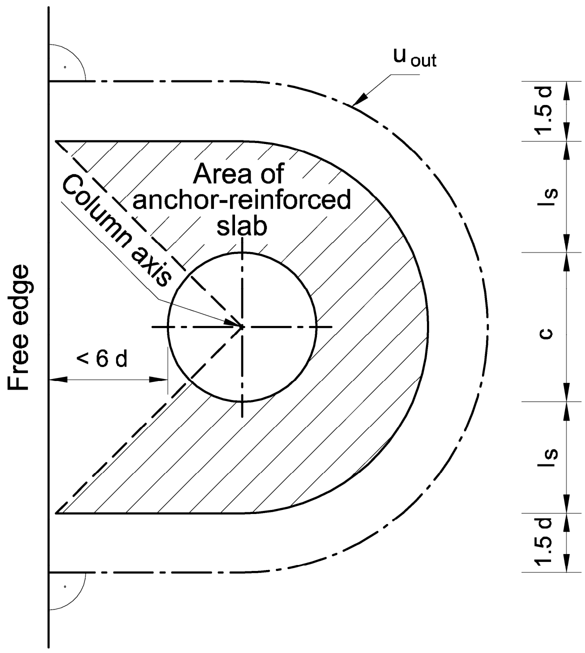


HALFEN HDB shear rail	Annex 13
Outer perimeter	

b) Load area (columns) is less than 6d from openings in the slab



c) Load area (columns) is less than 6 d from free edges



HALFEN HDB shear rail	Annex 14
Openings	

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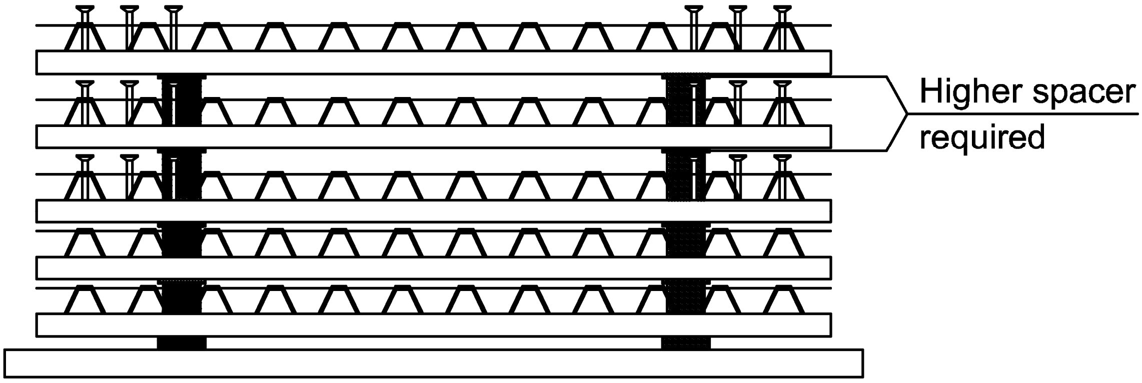
Storage and transport for use with precast elements



When storing and transporting precast elements, the height of the HDB Double-Headed Stud-Elements has to be considered. Higher spacers are required when stacking the precast elements.

HALFEN HDB shear rail	Annex 15
Storage and transport	

DETERMINATION OF PUNCHIMG SHEAR RESISTANCE

The verification of the punching shear resistance at ultimate limit state is performed as follows:

The ultimate limit state of punching shear shall be assessed in control perimeters. The slab shall be designed to resist a minimum of bending moments according to national guidelines. Outside the control perimeter the verification of the ultimate limit state design for shear and bending shall be carried out according to national guidelines.

To determine the punching shear resistance, an inner critical perimeter u_1 perpendicular to the flat slab surface at a distance 2.0 d (d = effective depth of the slab) around the column and an outer control perimeter u_{out} at a distance of 1.5 d from the outermost row of the punching shear reinforcement are considered. For footings, the distance to the critical perimeter has to be calculated with an iterative method.

The critical perimeter may be determined as stated above for columns with a perimeter u_0 less than 12 d and a ratio of the longer column side to the shorter column side not greater than 2.0. If these conditions are not fulfilled, the shear forces are concentrated along the corners of the column and the critical perimeter has to be reduced.

For irregular shaped columns the perimeter u_0 is the shortest length around the loaded area. The critical perimeters u_1 shall be determined according to EN 1992-1-1, 6.4.2.

In a first step, the design value of the shear stress v_{Ed} along the critical control perimeter u_1 is calculated:

$$v_{Ed} = \frac{\beta \cdot V_{Ed}}{u_1 \cdot d} \tag{A1}$$

v_{Ed}	shear stress calculated along the critical perimeter
β	coefficient taking into account the effects of load eccentricity.
V_{Ed}	design value of the applied shear force
u_1	perimeter of the critical section with a distance of 2.0 d from the column face

For structures where the lateral stability does not depend on frame action between the slabs and the columns, and where the adjacent spans do not differ in length by more than 25 %, approximate values for β may be used:

interior columns	β = 1.10	
edge columns	β = 1.40	
corner columns	β = 1.50	(A2)
corner of wall	β = 1.20	
end of wall	β = 1.35	

Alternatively, the more detailed calculation according to EN 1992-1-1 (6.39) can be used to determine the factor β, but the method with the reduced basic control perimeter is not applicable.

In flat slabs, where the total shear force is greater than the resistance of the slab without punching reinforcement according to equation (A3) punching shear reinforcement is necessary:

$$v_{Rd,c} = C_{Rd,c} \cdot k \cdot (100 \cdot \rho_l \cdot f_{ck})^{1/3} + k_1 \cdot \sigma_{cp} \geq (v_{min} + k_1 \cdot \sigma_{cp}) \qquad \text{(A3)}$$

$C_{Rd,c}$ empirical factor, the recommended value is $C_{Rd,c} = 0.18/\gamma_C$

γ_C partial safety factor for concrete ($\gamma_C = 1.5$)

k coefficient for taking into account size effects, d in [mm]

$$k = 1 + \sqrt{\frac{200}{d}} \leq 2.0$$

ρ_l mean reinforcement ratio of the y- and z-directions

$$\rho_l = \sqrt{\rho_{lz} \cdot \rho_{ly}} \leq \begin{cases} 2.0 \\ 0.5 \cdot f_{cd} / f_{yd} \end{cases}$$

f_{cd} design value of cylinder concrete strength

f_{yd} design value of yield stress of the reinforcing steel

k_1 empirical factor, the recommended value is $k_1 = 0.1$

σ_{cp} normal concrete stresses in the critical section

v_{min} $(0.0525/\gamma_C) \cdot k^{3/2} \cdot f_{ck}^{1/2}$ for $d \leq 600$ mm
$(0.0375/\gamma_C) \cdot k^{3/2} \cdot f_{ck}^{1/2}$ for $d > 800$ mm, intermediate depths are linearly interpolated

In case of small ratios of the column perimeter to the effective depth (u_0/d), the punching shear resistance has to be reduced.

$$u_0/d < 4{,}0: \qquad C_{Rd,c} = \frac{0{,}18}{\gamma_C}\left(0{,}1\frac{u_0}{d} + 0{,}6\right) \geq \frac{0{,}15}{\gamma_C}$$

If punching shear reinforcement is necessary, an adequate amount of punching reinforcement elements has to be placed in the slab. The length of the control perimeter u_{out} at which shear reinforcement is not required shall be calculated using the following expression:

$$u_{out} = \frac{\beta_{red} \cdot V_{Ed}}{v_{Rd,c} \cdot d} \qquad \text{(A4)}$$

β_{red} reduced factor for taking into account the effects of eccentricity in perimeter u_{out}

$v_{Rd,c}$ design punching shear resistance without punching reinforcement according to expression (A3),

$C_{Rd,c}$ can be taken from the national guidelines for members not requiring design shear reinforcement (EN 1992-1-1, 6.2.2(1)), the recommended value is $0.15/\gamma_C$

For the calculation of the shear resistance along the outer perimeter (u_{out}) of edge and corner columns, a reduced factor β_{red} in combination with equation (4) can be used:

$$\beta_{red} = \kappa_\beta \cdot \beta \geq 1.10 \qquad \text{(A5)}$$

edge columns $\kappa_\beta = \dfrac{1}{1.2 + \beta/20 \cdot l_s/d}$

corner columns $\kappa_\beta = \dfrac{1}{1.2 + \beta/15 \cdot l_s/d}$

corner of wall $\kappa_\beta = 1.0$

end of wall $\kappa_\beta = 1.0$

l_s: distance between the face of the column and the outermost stud

The punching shear resistance $v_{Rd,c}$ for footings and ground slabs is defined according to the following equation:

$$v_{Rd,c} = C_{Rk,c}/\gamma_C \cdot k \cdot (100 \cdot \rho_l \cdot f_{ck})^{1/3} \cdot \frac{2 \cdot d}{a} \qquad \text{(A6)}$$

$C_{Rk,c}$ 0.15 for footings with $a_\lambda/d \leq 2.0$
0.18 for slender footings and ground slabs

a the distance from the column face of the column to the control perimeter considered

PUNCHING DESIGN OF FLAT SLABS AND FOR FOOTINGS AND GROUND SLABS

Slabs

It has to be distinguished between area C (adjacent to the column) and the area D (further than 1.125·d from the column face). The double headed studs in the area C shall be dimensioned according to the following equation:

$$\beta \cdot V_{Ed} \leq V_{Rd,sy} = m_C \cdot n_C \cdot \frac{d_A^2 \cdot \pi \cdot f_{yk}}{4 \cdot \gamma_s \cdot \eta} \quad \text{(A7)}$$

m_C	number of elements (rows) in the area C
n_C	number of studs of each element (row) in the area C
d_A	shaft diameter of the double headed stud
f_{yk}	characteristic value of yield strength of the stud
γ_s	partial safety factor for steel (γ_s = 1.15)
η	factor to take into account the effective depth, interim values have to be interpolated:

$$\eta = \begin{cases} = 1.0 & \text{for } d \leq 200\,\text{mm} \\ = 1.6 & \text{for } d \geq 800\,\text{mm} \end{cases}$$

For flat slabs with both d > 50 cm and the diameter of the column c < 50 cm, at least three studs shall be arranged in area C in case that $V_{Ed} > 0.85\ V_{Rd,max}$.

In the area D, the dimensioning of the studs is governed by the rules for positioning of the studs as given in clause 4.3.

The maximum punching shear resistance in the critical perimeter u_1 is defined as a multiple value of the resistance of the slab without shear reinforcement according to expression (A8):

$$v_{Rd,max} = 1.96 \cdot v_{Rd,c} \quad \text{(flat slabs)} \quad \text{(A8)}$$

$v_{Rd,c}$ is the calculated design value of the punching shear resistance according to (A3), taking into account the relevant partial safety factors for material properties.

The favourable effect of normal compressive stresses on the maximum punching shear resistance $v_{Rd,max}$ of the slab according to Eq. (A8) may not be included. If inclined pre-stressed tendons influence the punching shear resistance negatively, the effect shall be included with the maximum value of the negative influence when dimensioning the studs. If inclined pre-stressed tendons increase the punching shear resistance, they have to be effective in both area C and area D.

Footings and ground slabs

In footings, the amount of double headed studs shall be dimensioned according to the following equation:

$$V_{Ed,red} \leq V_{Rd,s} = f_{yd} \times A_{sw,0.8d}: \qquad (A9)$$

with $V_{Ed,red} = V_{Ed} - V_{Ed} \cdot \frac{A_{crit}}{A}$

f_{yd} design value of the yield strength of the double headed studs

$A_{sw,0.8d}$ cross section of punching reinforcement in a distance between 0.3·*d* and 0.8·*d* from the column face

A_{crit} area within the critical perimeter *u* in the iteratively determined distance *a* from the column face

A area of the footing; for ground slabs the area within the line of contraflexure for the bending moment in radial direction

If outside of 0.8 *d* further rows of studs are necessary, the required cross section may be determined as a shear reinforcement for 33 % of the design shear force taking into account the reduction by the soil pressure within the outermost row of double headed studs.

The maximum punching shear resistance along the critical perimeter u_{crit} is defined as a multiple value of the resistance of the footing without shear reinforcement:

$$v_{Rd,max} = 1.5 \cdot v_{Rd,c} \quad \text{(Footings and ground slabs)} \qquad (A10)$$

$v_{Rd,c}$ is the calculated punching shear resistance (A6), taking into account the relevant partial safety factors for material properties.