

HALFEN HDB SHEAR RAIL

PUNCHING SHEAR REINFORCEMENT AND SHEAR REINFORCEMENT

TECHNICAL PRODUCT INFORMATION



HALFEN SHEAR RAIL

HDB 13-E

CONCRETE

NEW!

Punching shear reinforcement
calculation according to European
Technical Approval
ETA-12/0454

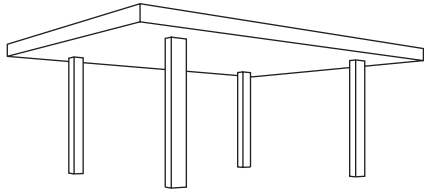


HALFEN
YOUR BEST CONNECTIONS

HALFEN HDB SHEAR RAIL – PUNCHING SHEAR REINFORCEMENT

System Description - HDB Shear Rails as Punching Shear Reinforcement

Point-load supported slabs with no enlarged column heads



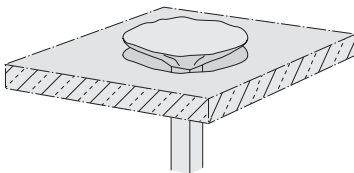
Reinforced concrete slabs with no beams and no enlarged column heads are inexpensive to manufacture and provide good conditions for optimal use of space and further construction-work without obstructions.

Particular advantages are:

- low formwork costs
- no obstructions to further construction (piping, ventilation ducts) under the slab
- floor heights can often be reduced

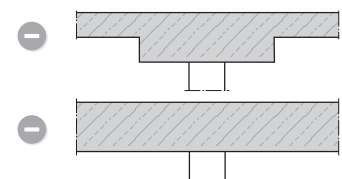
The problem: punching shear verification around columns

Load concentration around the column head generally leads to increased stresses which cannot be absorbed solely in thin slab thicknesses.

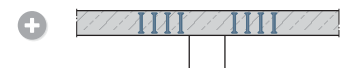


Punching failure in a slab

Previously, to prevent punching shear failure, uneconomical and unfavourable solutions were used, e.g. increasing the slab thickness or using enlarged column heads (see illustration). However these methods reduce the usable height between floors and therefore limit building space.



Uneconomical: increasing slab thickness locally around the column or over the whole slab

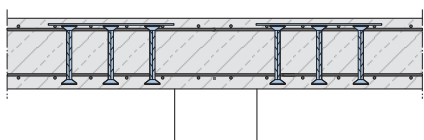


Efficient: flat slab with HDB shear rails around the column

The solution: HALFEN HDB Shear rails

HDB Shear rails consist of double-headed studs (B 500 smooth or ribbed) with forged heads. The individual studs are welded onto a spacer-bar to make a HDB Shear rail.

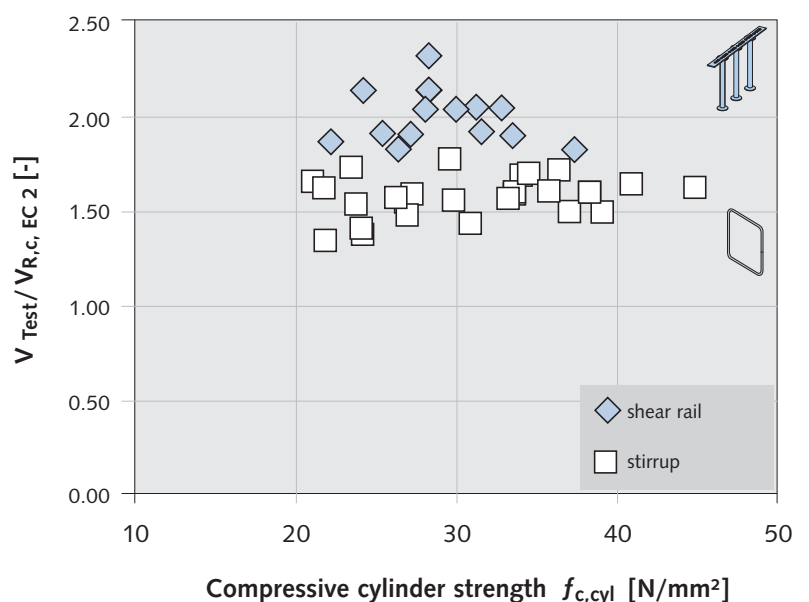
A main advantage of the HDB Shear rail is the positive-form-locking and nearly slippage free anchorage. Tests show that the maximum load capacity using conventional punching shear reinforcement, e.g. stirrups is restricted. This is due to the greater slippage with stirrups. Large diagonal cracks develop around the column, which ultimately lead to failure.



Flat ceiling with HDB Shear rails around the column head (schematic)

The slippage free anchorage of the HDB Studs means shear cracks are kept to a minimum. Compared to stirrups this system is therefore more suitable for the higher loads around columns.

The diagram illustrates the proven higher punching shear capacity of shear rails compared to stirrups.



HALFEN HDB SHEAR RAIL – PUNCHING SHEAR REINFORCEMENT

Introduction

Advantages of HDB Shear rails



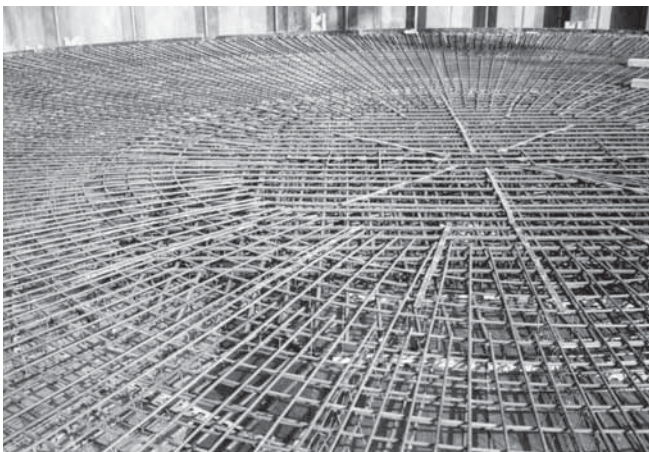
Installation:

- simple and quick installation
- reduced build-time
- no caging required as with stirrup reinforcement
- installed after placing the main upper and lower longitudinal reinforcement



Planning:

- building authority approved as punching shear reinforcement in slabs, foundation slabs and footings
- HDB Shear rails can also be used in precast elements and semi-precast elements
- also approved for non- predominantly static loads
- standardised product range for typical dimensions



Safety:

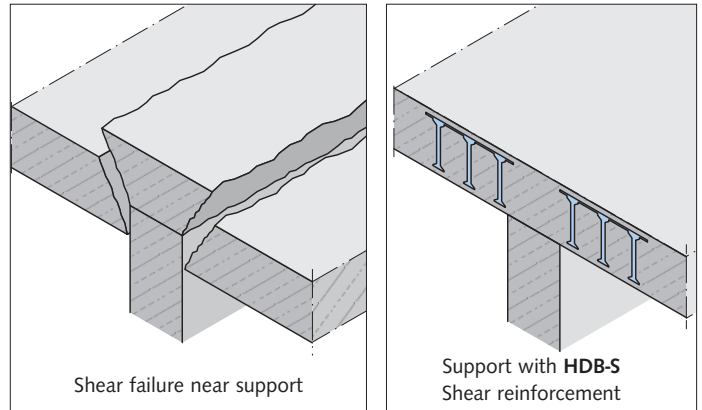
- European-wide building authority approved by the German Institute for building technology (DIBt) in Berlin
- simple visual control of installed elements
- negligible slippage of anchorage in the shear reinforcement
- correct concrete cover ensured with matching accessories (spacers and clamps)

HALFEN HDB-S SHEAR RAIL – SHEAR REINFORCEMENT

System Description - HDB Shear Rails as Shear Reinforcement

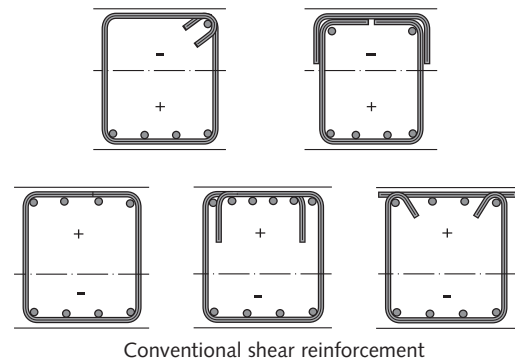
Linear supported slabs – Verification of shear load capacity

Shear load capacity for reinforced concrete slabs must be verified according to EN 1992-1-1:2011-01 in all shear cross-sections. The regulations according to the National Annex must also be observed.



The problem: complex installation of shear reinforcement

According to EN 1992-1-1:2011-01, high-load slabs ($V_{Ed} > \frac{1}{3} \times V_{Rd,max}$) require stirrup reinforcement to be calculated for at least 50% of expected shear force. The stirrups should enclose the longitudinal reinforcement in the tension and compression zone. Fitting these stirrups is very difficult as bending needs to be finalised during installation. This method is not just time-consuming but also inaccurate and can also result in an inadequate concrete cover for the stirrups.

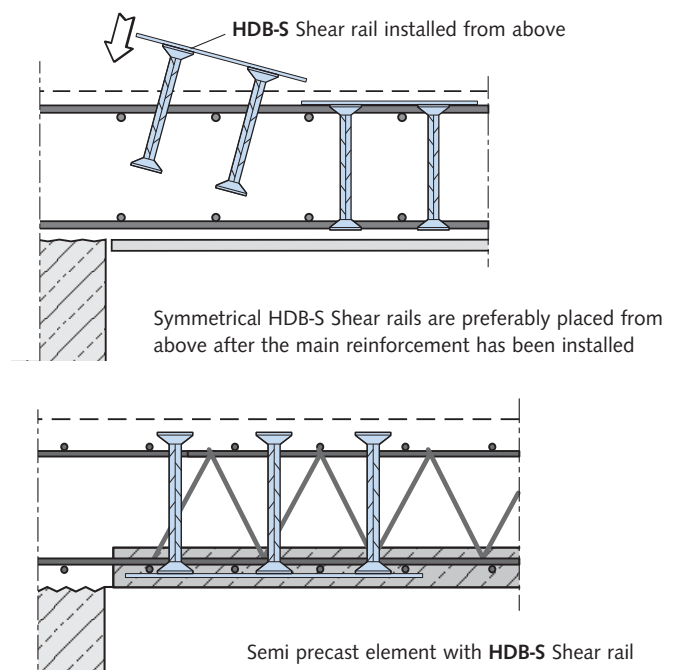


The solution: HALFEN HDB-S Stud rails

HDB-S Shear rails consist of double-headed, forged head studs (B 500 smooth or ribbed). A spacer-bar strip tack-welded to the anchor heads connects the individual anchors to make a HDB-S Shear rail.

HDB-S Shear rails with a maximum of 10 anchors are possible. Placing the individual elements end to end, in rows, allows large areas to be reinforced quickly and efficiently.

A further advantage is the negligible slippage in the concrete guaranteed by the positive bond of the forged head. This gives the shear reinforcement better anchorage, especially in thin slabs, allowing the HDB-S Anchor reinforcement cross-section to be reduced by up to 20%.



HALFEN HDB-S SHEAR RAIL – SHEAR REINFORCEMENT

Introduction

Advantages of the HDB-S Shear rails



Installation:

- simple and quick installation
- reduced build-time
- no caging required as with stirrup reinforcement
- installed after placing the upper and lower longitudinal reinforcement



Planning:

- HDB Shear rails can also be used in precast elements and semi-precast elements
- also approved in Germany for non- predominantly static loads
- standardised product range for typical dimensions



Safety:

- simple visual control of installed elements
- negligible slippage of anchorage in the shear reinforcement
- correct concrete cover is ensured when using suitable accessories (spacers and clamps)

HALFEN HDB / HDB-S SHEAR RAIL – PUNCHING SHEAR / SHEAR REINFORCEMENT

Introduction

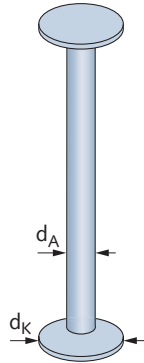
The product as punching shear and shear reinforcement

Double-headed stud

Is made of reinforcing steel B 500 (smooth or ribbed):
supplied in $\varnothing d_A$
10 - 12 - 14 - 16 - 18 - 20 - 25 mm

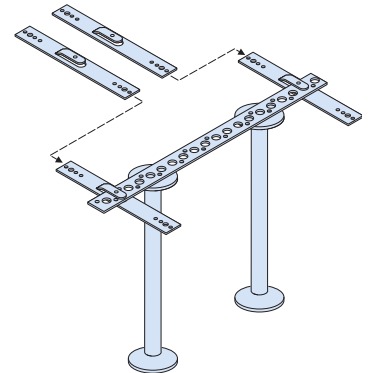
The stud head diameter is 3 times the bar diameter d_A :

$$d_K = 3 \cdot d_A$$



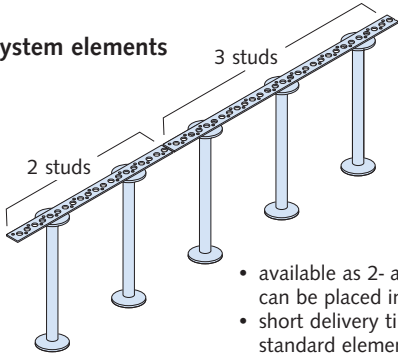
HDB Elements

The double-headed studs are connected using a welded-on spacer-bar. Clip bars are used to secure the spacer-bar to the reinforcement. Clip bars can be attached anywhere on the spacer-bar (order separately, see page 23).



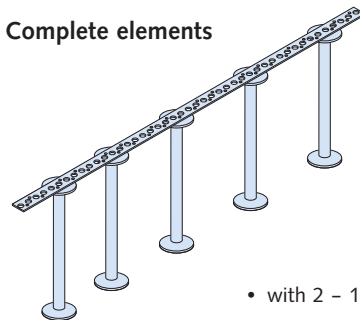
Two variants

HDB System elements



- available as 2- and 3-stud elements, can be placed in rows
- short delivery times, in-stock as standard elements

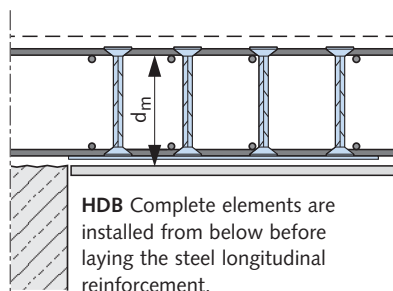
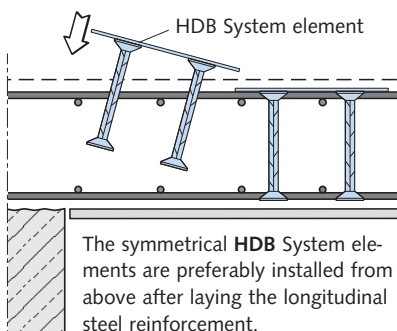
HDB Complete elements



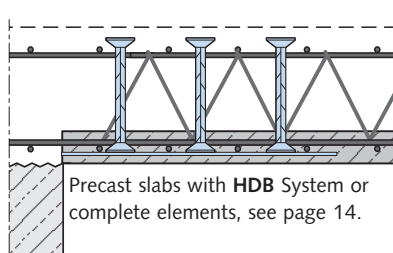
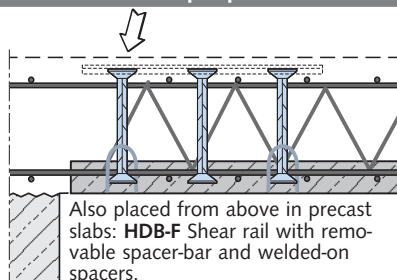
- with 2 – 10 studs on one spacer-bar

HALFEN HDB Shear rail - Punching shear reinforcement

Installation example for on-site cast concrete slabs



Installation example precast slab



Advantages of the HALFEN HDB Shear rails as punching shear reinforcement:

- higher load-bearing capacity than conventional shear reinforcement
- for slabs thicker than 180 mm
- can also be fitted into precast slabs. See page 25, 26
- time-effective installation from above
- standardised product range with short delivery times, standard elements can be delivered from stock
- user-friendly software. See page 18 and 19.
- Building Authority approved for predominantly static and moderately non-static loads
- European Technical Approval ETA-12/0454

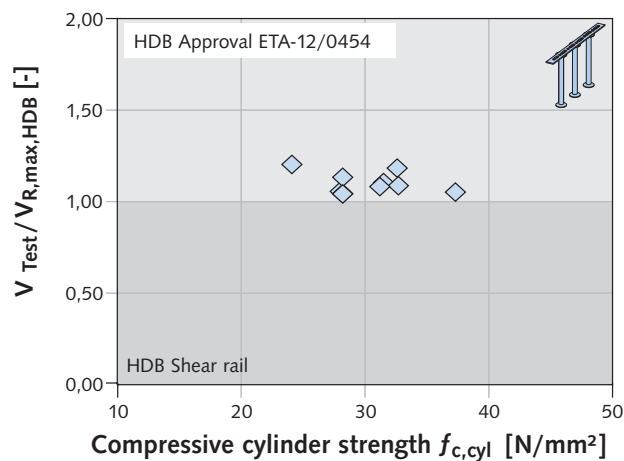
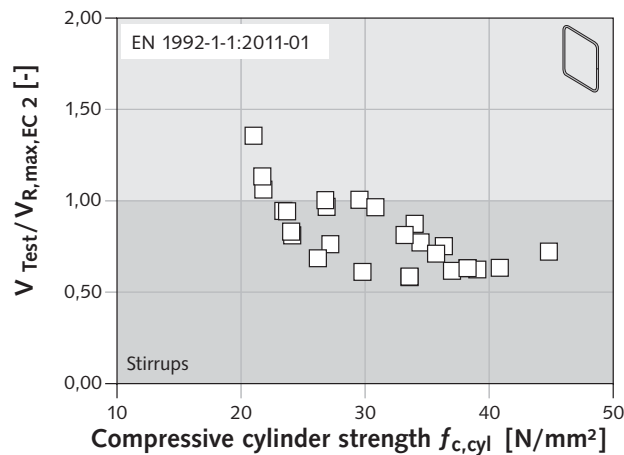
HALFEN HDB SHEAR RAIL – PUNCHING SHEAR REINFORCEMENT

Calculation: Basic Principles

Point-load supported slabs with no enlarged column heads

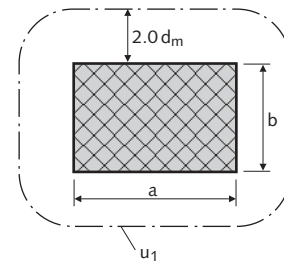
Design concept in accordance with EN 1992-1-1:2011-01 (Eurocode 2)

EN 1992-1-1:2011-01 determines the maximum punching shear capacity for flat slabs analogically to the strength of the compression strut of beams. However, test evaluations prove that this method is not applicable for flat slabs. Particularly in tests using stirrups as punching shear reinforcement, the level of safety required by EN 1990:2010-12 was not achieved. This is why an improved design concept was derived for the HDB Shear rail punching reinforcement based on current punching shear tests and incorporated into the European Technical Approval ETA-12/0454. The selected design method achieves the required level of safety as the test evaluations with double-headed studs prove.



Calculation basics for the HDB Shear rail punching reinforcement can be found in the European Technical Approval ETA-12/0454. The following illustrates the main equations required for calculation.

1. Verification of punching shear capacity without punching shear reinforcement



$$u_1 = 2(a + b) + 2 \cdot \pi \cdot 2.0 d_m$$

with: $b \leq a \leq 2b$
and $(a + b) \cdot 2 \leq 12 d_m$
 d_m = mean effective static depth

Design value for effective shear stress along the critical perimeter:

$$v_{Ed} = \frac{\beta \cdot V_{Ed}}{u_1 \cdot d_m} \quad [\text{N/mm}^2]$$

with: β = load increase factor (see page 9, 10)
 V_{Ed} = design value of effective shear force
 u_1 = length of the critical perimeter

Punching shear resistance value for slab without punching shear reinforcement

$$v_{Rd,c} = C_{Rd,c} \cdot k \cdot (100 \cdot \rho_l \cdot f_{ck})^{1/3} \quad [\text{N/mm}^2]$$

with: $k = 1 + \sqrt{200/d_m} \leq 2.0$ (taking the influence of the effective depth into account; d_m in [mm])

HALFEN HDB SHEAR RAIL – PUNCHING SHEAR REINFORCEMENT

Calculation: Basic Principles

with: $\rho_I = \sqrt{\rho_{Ix} \cdot \rho_{Iy}} \leq \begin{cases} 0.02 \\ 0.5 \cdot f_{cd} / f_{yd} \end{cases}$

(Longitudinal reinforcement in the column width area increased each side by $3d_m$, compare with no. 7 on page 10)

f_{ck} = characteristic concrete compressive strength [N/mm²]
 f_{cd} = design value for concrete compressive strength [N/mm²]
 f_{yd} = design yield strength for reinforcement steel [N/mm²]

Proof: $V_{Ed} \leq V_{Rd,c} \Rightarrow$ no punching shear reinforcement necessary
 $V_{Ed} > V_{Rd,c} \Rightarrow$ punching shear reinforcement necessary

The empirical pre-factor $C_{Rd,c}$ is dependent on the respective column perimeter u_0 / d_m and is defined as follows:

$$u_0 / d_m \geq 4 : C_{Rd,c} = \frac{0.18}{\gamma_C}$$

$$u_0 / d_m < 4 : C_{Rd,c} = \frac{0.18}{\gamma_C} \left(0.1 \cdot \frac{u_0}{d_m} + 0.6 \right) \geq \frac{0.15}{\gamma_C}$$

with: $\gamma_C = 1.5$: partial safety factor for concrete

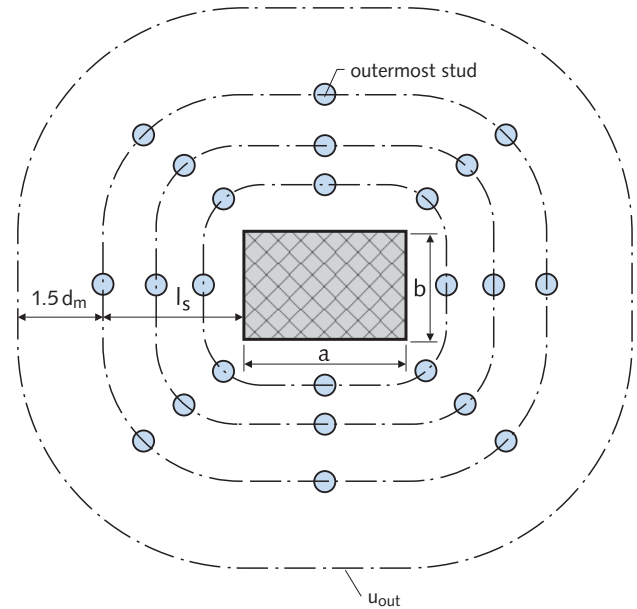
2. Verification of maximum punching shear capacity

Verification:

$$V_{Ed} \leq V_{Rd,max}$$

with $V_{Rd,max} = 1.96 V_{Rd,c}$ flat slabs
 $V_{Rd,max} = 1.50 V_{Rd,c}$ foundations

3. Verification outside of the punching shear reinforced area



$$u_{out} = 2 \cdot (a + b) + 2\pi \cdot (l_s + 1.5 d_m)$$

with l_s = distance of the outermost stud from the column edge

Design value for effective shear stress in the outermost perimeter:

$$v_{Ed} = \frac{\beta \cdot V_{Ed}}{u_{out} \cdot d_m} \quad [N/mm^2]$$

Calculated resistance along the outermost perimeter:

$$V_{Rd,c,out} = \frac{C_{Rk,c}}{\gamma_C} \cdot k \cdot (100 \cdot \rho_I \cdot f_{ck})^{1/3} [N/mm^2]$$

The empirical factor $C_{Rk,c}$ is according to the applicable National Annex. The recommended value according to EN 1992-1-1 is 0.18.

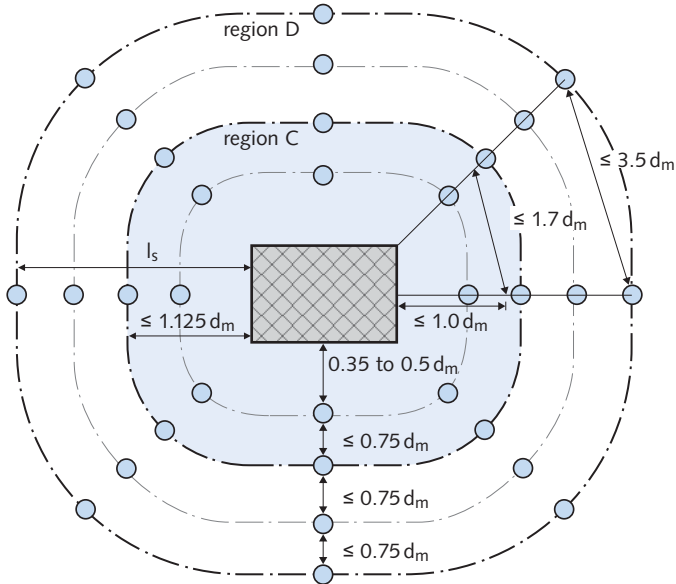
Proof:

$$V_{Ed} \leq V_{Rd,c,out} \Rightarrow \text{calculation of } l_{s,req}$$

HALFEN HDB SHEAR RAIL – PUNCHING SHEAR REINFORCEMENT

Design: Basic Principles

4. Calculating the required punching shear reinforcement



Required punching shear reinforcement in region C

$$A_{s,req} = V_{Ed} \cdot \beta \cdot \eta / f_{yd}$$

with: β = load increase factor (page 9, 10)

$\eta = 1.0$ for $d_m \leq 200$ mm and 1.6 for $d_m \geq 800$ mm
(interpolate intermediate values)

Required number of studs $n_{C,total}$ in region C

$$req\ n_{C,total} = A_{s,req} / A_{anchor}$$

Stud layout:

The number of element rows is derived by the geometrical requirements for tangential stud spacing according to the approval (appendix 7, 11 of the ETA-12/0454). The number of anchors required for region C is calculated according to the approval. See spacing rule for the radial direction. In region C, at least two studs of equal diameter must be used in each element row.

Verification:

$$V_{Rd,sy} = m_C \cdot n_C \cdot A_{Anker} \cdot f_{yd} / \eta \geq V_{Ed} \cdot \beta \quad [kN]$$

5. Stud spacing

Apart from the static relevant boundary conditions, further geometric specifications have to be observed when placing studs and elements:

- the distance of the first stud from the column edge must be between $0.35 d_m$ and $0.50 d_m$
- maximum studs spacing in radial direction must be $\leq 0.75 d_m$
- maximum tangential anchors spacing at a distance of $1.0 d$ from the column edge must be $\leq 1.7 d_m$
- maximum tangential anchor spacing in region D must be $\leq 3.5 d_m$

For thick slabs ($d_m > 500$ mm) with a column diameter of $c < 500$ mm, at least three studs are to be placed in region C in case of increased load ($V_{Ed} > 0.85 V_{Rd,max}$). The element rows required in region C are to be continued up to the edge of the shear reinforced zone whilst observing the spacing rules for the section. If necessary, to ensure the tangential spacing required in section D, additional rows of elements must be evenly distributed between the rows continuing out of region C.

In addition, the following applies for the radial spacing s_D in region D:

$$s_D = \frac{3 \cdot d_m}{2 \cdot n_C} \cdot \frac{m_D}{m_C} \leq 0.75 d_m$$

where:

m_D = number of element rows in region D

m_C = number of element rows in region C

n_C = number of anchors in one element row in region C

6. Factor for unequal shear load distribution (Load increase factor β)

The load increase factors, taking into account an unequal shear load distribution are taken from EN 1992-1-1.

$$\begin{aligned} \beta &= 1.15 && \text{for internal columns} \\ \beta &= 1.40 && \text{for edge columns} \\ \beta &= 1.50 && \text{for corner columns} \end{aligned}$$

HALFEN HDB SHEAR RAIL – PUNCHING SHEAR REINFORCEMENT

Calculation: Basic Principles

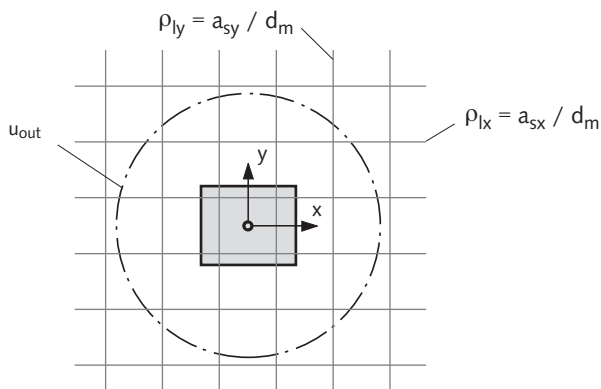
Additionally for wall ends and wall corners, the following generic load factors can be used:

$$\begin{aligned}\beta &= 1.35 && \text{for wall ends} \\ \beta &= 1.20 && \text{for wall corners}\end{aligned}$$

The more precise method of assuming a plastic shear distribution as in EN 1992-1-1:2011-01 can be used as an alternative or as soon as the span width of adjoining slabs deviate more than 25% from one another.

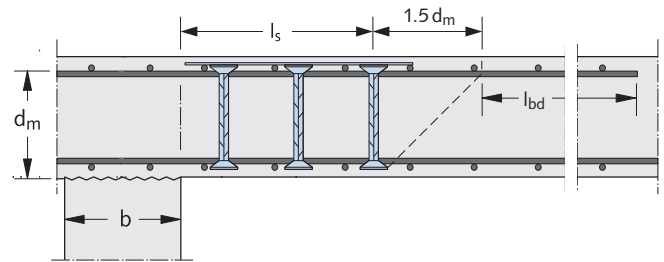
7. Reinforcement ratio ρ_l

When calculating punching shear, the mean value in the outer perimeter is used as the average ratio of reinforcement. The zone must be at least as wide as the column width with an additional 2-times $3.0d_m$ in all directions.



$$\rho_l = \sqrt{\rho_{lx} \cdot \rho_{ly}} \leq \begin{cases} 0.02 \\ 0.5 \cdot f_{cd} / f_{yd} \end{cases}$$

a_{sx}, a_{sy} present flexural reinforcement for each metre in x- and y direction
 d_m mean effective static depth



Minimum bar lengths – example for interior column

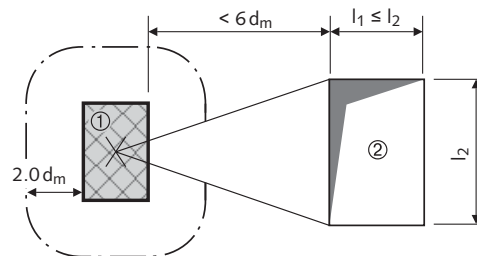
$$\begin{aligned}\text{Bar length } l_{\text{bar}} &= b + 2 \cdot l_s + 2 \cdot 1.5 d_m + 2 \cdot l_{bd} \\ &\geq b + 2 \cdot 3 d_m + 2 \cdot l_{bd} \\ l_{bd} &= \text{anchorage length according to} \\ &\quad \text{EN 1992-1-1:2011-01 and applicable} \\ &\quad \text{National Annex}\end{aligned}$$

8. Allowing for soil pressure

The design shear force V_{Ed} may be reduced for foundation slabs and footings by the favourable effect of ground pressure inside the critical zone A_{crit} . The A_{crit} zone is within the decisive control perimeter. For foundation slabs, a constant distance of $1.0d_m$ from the loaded area may be assumed for the critical perimeter. The decisive control perimeter for footings with no punching reinforcement is calculated iteratively and is dependent on ground pressure and must be within $2.0d_m$ from the column edge.

9. Allowing for voids and openings

Voids and openings with at least one edge less than $6d_m$ away from the loaded area have to be taken into account when determining the critical perimeter and further perimeters. The section of the critical perimeter within the angle of the opening is to be considered as ineffective.



Critical perimeter near openings

- ① loaded area A_{load}
- ② opening

$$\text{If } l_1 > l_2, \text{ then } l_2 = \sqrt{l_1 \cdot l_2}$$

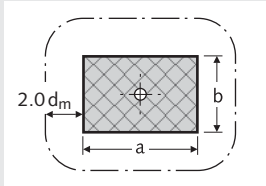
HALFEN HDB SHEAR RAIL – PUNCHING SHEAR REINFORCEMENT

Calculation: Basic Principles

10. Case 1 - 9

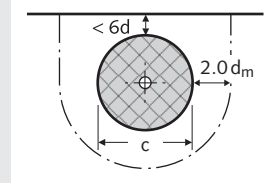
Case 1 Rectangular interior column

with: $b \leq a \leq 2b$
and $(a + b) \cdot 2 \leq 12 d_m$
 d_m = mean effective static depth
Recommended
load factor is $\beta = 1.15$



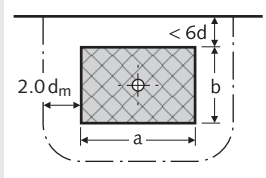
Case 6 Circular edge column

Recommended load factor
 $\beta = 1.4$



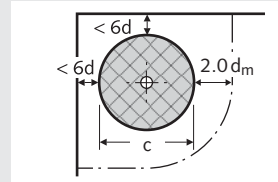
Case 2 Rectangular edge column Edge parallel to a

with: $b \leq a \leq 2b$
Recommended
load factor is $\beta = 1.4$



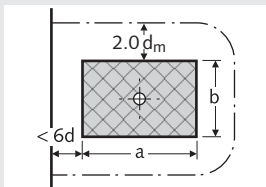
Case 7 Circular corner column

Recommended load factor
 $\beta = 1.5$



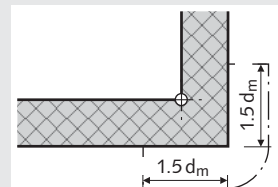
Case 3 Rectangular edge column Edge parallel to b

with: $b \leq a \leq 2b$
Recommended load factor
 $\beta = 1.4$



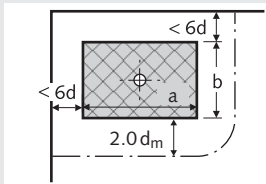
Case 8 Wall corner

Recommended load factor
 $\beta = 1.2$



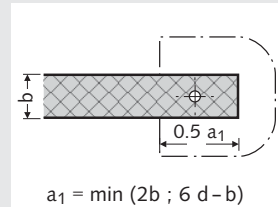
Case 4 Rectangular corner column Edge parallel to a and b

with: $b \leq a \leq 2b$
Recommended load factor
 $\beta = 1.5$



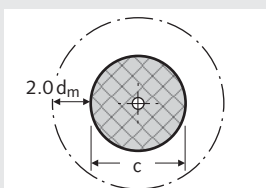
Case 9 Wall end

Recommended load factor
 $\beta = 1.35$



Case 5 Circular interior column

Recommended load factor
 $\beta = 1.15$



Recommended values are according to EN 1992-1-1.
Deviating specifications according to the applicable
National Annex have to be considered.

HALFEN HDB SHEAR RAIL – PUNCHING SHEAR REINFORCEMENT

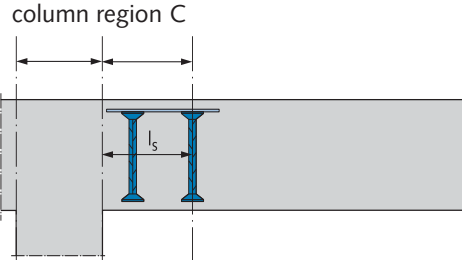
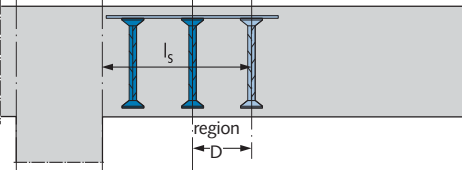
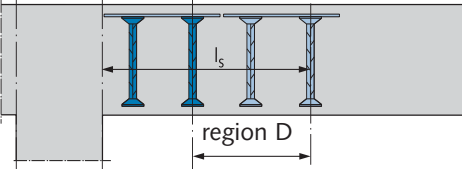
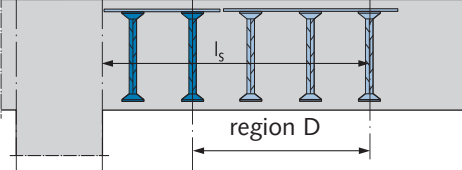
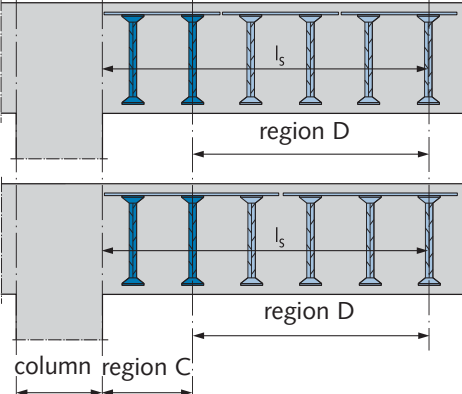
Layout of the Punching Shear Reinforcement

Combinations of HDB System elements

HDB Shear rail punching reinforcement in a shear reinforced slab is preferably a combination of 2- and 3-stud System elements. This makes on-site installation easier.

In thick slabs, e.g., foundation slabs and where high ratios of reinforcement steel are used, it is recommended to install the HDB Elements first, using the bottom-up method.

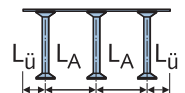
Table: values l_s for HDB Element combinations

For $l_{s,req}$ compare to page 8	Available 2- and 3-stud system HDB combination elements	$l_{s, prov}$	Number of anchors in each HDB combination
$l_{s,req} \leq \sim 1.125 \cdot d_m$	2-stud 	$l_{s, prov} \approx 1.05 \cdot d_m$	2
$l_{s,req} \begin{cases} > 1.125 \cdot d_m \\ \leq \sim 1.875 \cdot d_m \end{cases}$	3-stud 	$l_{s, prov} \approx 1.75 \cdot d_m$	3
$l_{s,req} \begin{cases} > 1.875 \cdot d_m \\ \leq \sim 2.5 \cdot d_m \end{cases}$	2 + 2 studs 	$l_{s, prov} \approx 2.45 \cdot d_m$	4
$l_{s,req} \begin{cases} > 2.5 \cdot d_m \\ \leq \sim 3.2 \cdot d_m \end{cases}$	2 + 3 studs 	$l_{s, prov} \approx 3.15 \cdot d_m$	5
$l_{s,req} \begin{cases} > 3.2 \cdot d_m \\ \leq \sim 4.0 \cdot d_m \end{cases}$	$\begin{cases} 2 + 2 + 2 \text{ studs} \\ \text{or} \\ 3 + 3 \text{ studs} \end{cases}$ 	$l_{s, prov} \approx 3.85 \cdot d_m$	6

 Stud dark blue
= region C

 Stud light blue
= region D

Stud layout
 $L_A \approx 0.7 \cdot d_m$
 $L_{\ddot{u}} \approx 0.35 \cdot d_m = L_A/2$



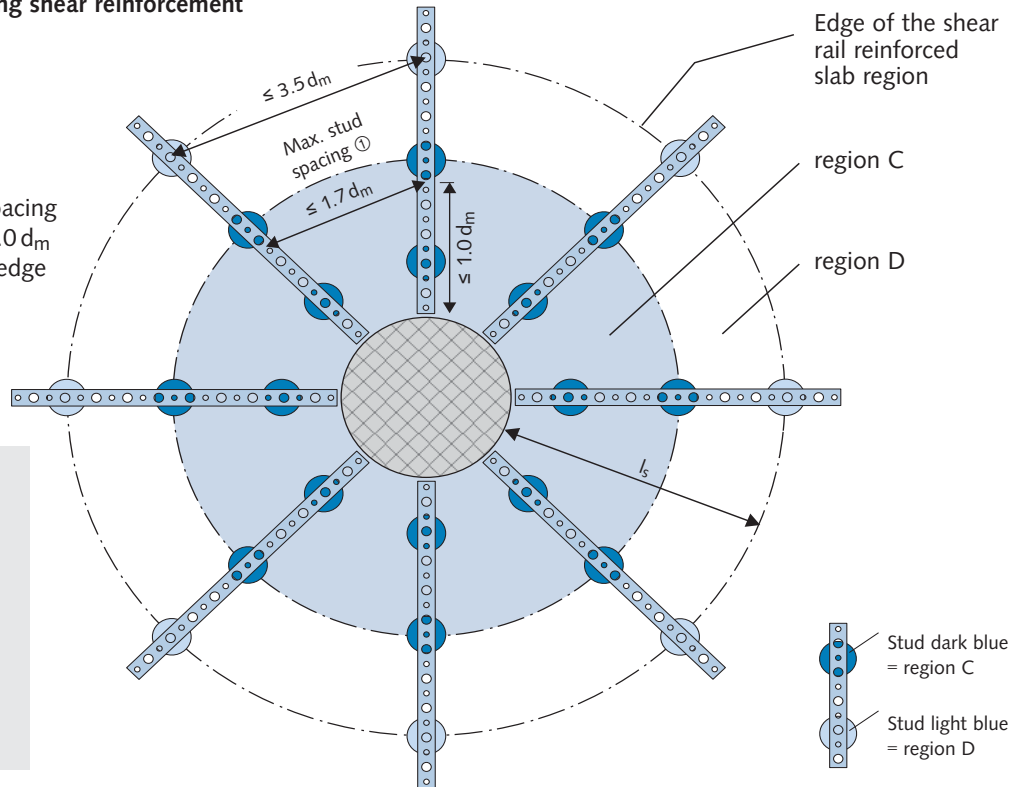
HALFEN HDB SHEAR RAIL – PUNCHING SHEAR REINFORCEMENT

Installation

Installation in on-site cast concrete slabs

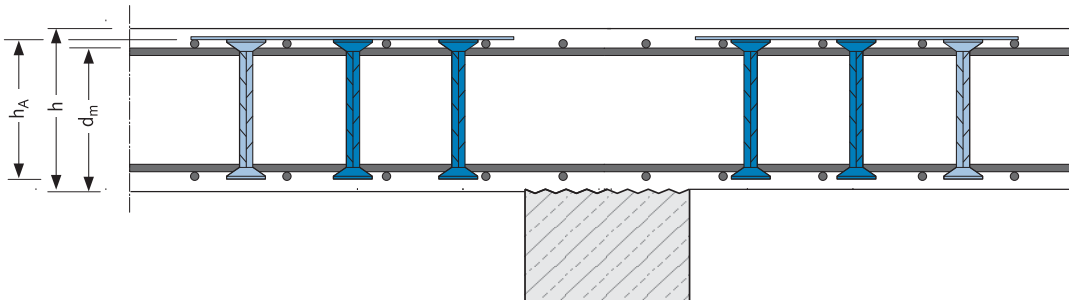
Layout of the punching shear reinforcement

- ① Maximum stud spacing at a distance of $1.0 d_m$ from the column edge (see page 9)



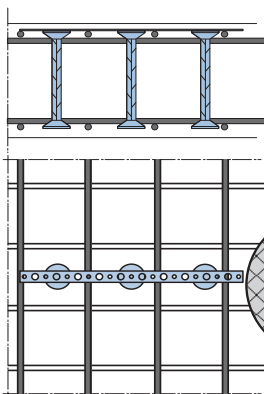
Note:

The simultaneous use of ribbed and smooth studs at one column is not permitted!

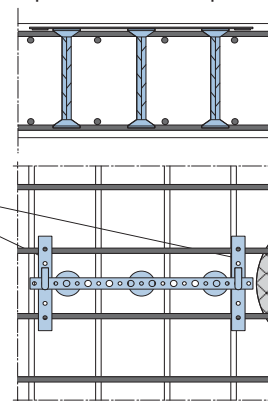


Fixing HDB Elements to the reinforcement

- without clip bars
shear rails at right angles to the top reinforcement
- with clip bars
shear rails parallel to the top reinforcement



Clip bars (order separately); for accurate placement, we generally recommend calculating an average of 1.5 clip bars for each HDB Element.



Note:
To avoid overlap, clip bars can be attached anywhere on the spacer-bar.

HALFEN HDB SHEAR RAIL – PUNCHING SHEAR REINFORCEMENT

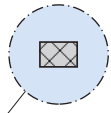
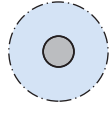
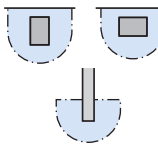
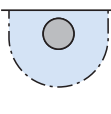
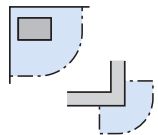
Constructive Design

Layout of HDB Elements and pressure joints (≥ 4 cm) in precast slabs

Depending on the proximity of the columns to the slab edges and the geometric shape of the columns, different layouts for the HDB Punching shear reinforcement are necessary.

Even if only a few HDB Elements are mathematically required for a low load, additional punching shear elements may be necessary to meet the mandatory maximum spacing requirements between the studs (see also page 9).

Table: HDB Standard layouts

 Edge of the shear reinforced slab region	A 8	A 12	A 16	A 20	
	B 10	B 14	B 18	Legend " " recommended position of the pressure joint ≥ 4 cm for precast slabs	
	C 8	C 10	C 12	C 14	C 16
	D 5	D 6	D 7	D 8	
	E 5	E 6	E 7	E 8	
	F 3	F 4	F 5		
	G 3	G 4	G 5		

Note for precast element slabs:

Depending on the location of the pressure joints, the HDB Shear rail punching reinforcement layouts shown above are distributed over the individual slabs.

HALFEN HDB-S SHEAR RAIL – SHEAR REINFORCEMENT

Simplified Calculation

Simplified calculation with a FE-calculation program

Reinforced concrete slabs are currently mainly calculated with finite-elements based calculation programs. The following describes a simple method to determine the required shear reinforcement based on FE calculations. This avoids the complexity required with a separate calculation of HDB-S shear reinforcement.

1. Calculating a reinforced concrete slab using FE-software:

- it is recommended to use a variable inclination of the compression strut for shear design

2. Calculating the required shear reinforcement using FE-calculation software:

- checking the maximum load capacity ($V_{Rd,max} > V_{Ed}$)
- calculating the concrete load capacity ($V_{Rd,c}$)
- required shear reinforcement output

3. Distribution in plan:

- dividing the plan into identical amounts of shear reinforcement
- calculating the dimension of each individual area

The result from this example was two areas with a length of 800 mm and a width of 4000 mm

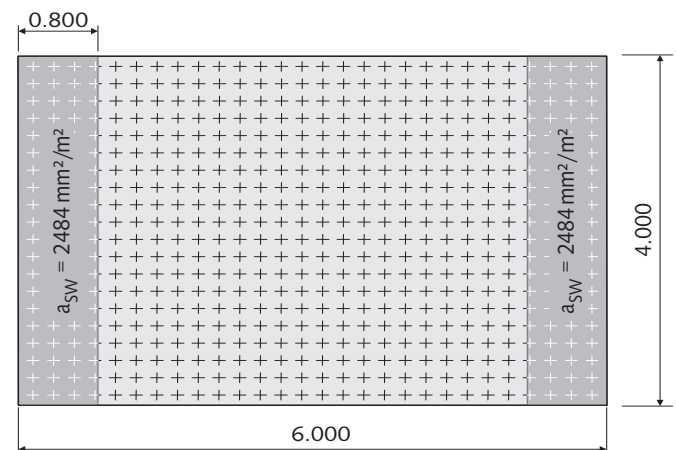
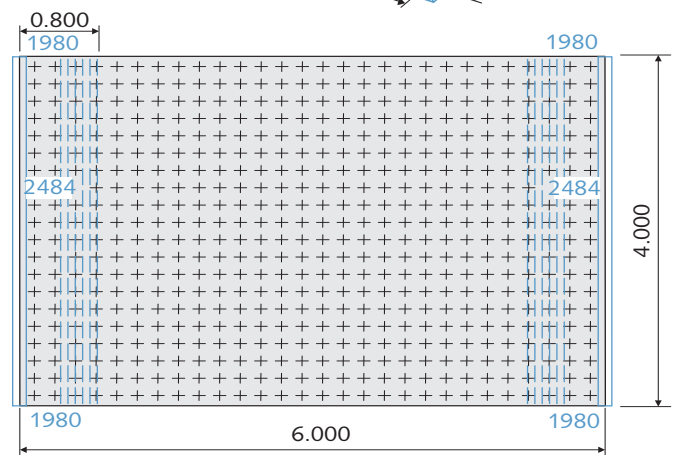
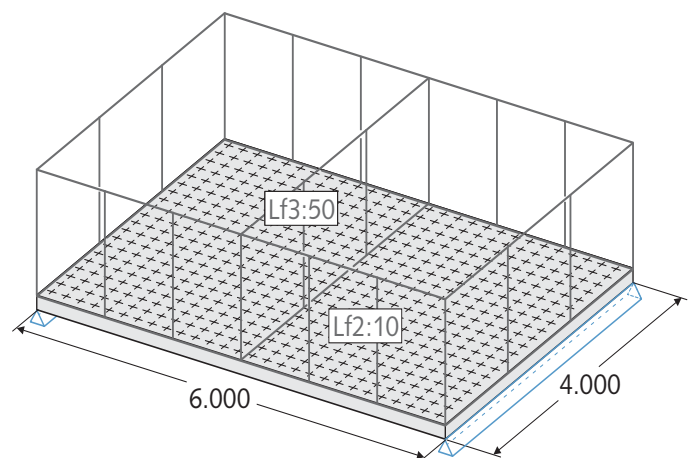
Example

Single axis spanned reinforced concrete slab $L = 6$ m; C 20/25; $h = 200$ mm; $d = 160$ mm; $\rho_l = 0.5\%$; transverse reinforcement 50%; Live load $q_k = 18$ kN/m²; the dead-load will automatically be taken into account by the program.

A wall in the middle of the slab is assumed as a linear load:

$W_k = 90$ kN/m

Concrete cover $c_{nom} = 25$ mm



HALFEN HDB-S SHEAR RAIL – SHEAR REINFORCEMENT

Simplified Calculation

Simplified Calculation using a FE-Calculation program

4. Calculating the allowable crosswise and lengthwise spacing for HDB-S Anchor (see page 17):

- checking the boundary conditions
- allowable anchor spacing in slab span direction ($s_{L,HDB-S}$)
- allowable anchor spacing transverse to slab span direction ($s_{Q,HDB-S}$)

5. Calculating the anchor height and defining a grid for the HDB-S Anchor (further notes on page 17):

- distribution of anchors according to the approved anchor spacing
- if possible consider spacings with HDB Anchors available from standard stock (see page 22)

6. Defining the required anchor diameter (see table on page 21):

- calculating the required anchor diameters using the selected anchor spacings and the required reinforcement cross-section

7. Establishing the number of elements and compiling an item list:

- calculating the required number of element rows
- dividing the anchor row into 2- and 3 anchor-elements
- checking present edge spacing against the minimal required edge spacing (see page 17)
- understanding the element description (see page 20)

Data from the FE-Program:

- maximum load capacity $V_{Rd,max} = 440 \text{ kN/m}$
- concrete load capacity $V_{Rd,c} = 69.5 \text{ kN/m}$
- load $V_{Ed} = 172.8 \text{ kN/m}$
- utilisation factor $V_{Ed} / V_{Rd,max} = 0.39$

required boundary conditions

- slab thickness $h = 200 \text{ mm} \geq 160 \text{ mm} (h_{min})$
- mean effective static depth $d = 160 \text{ mm}$

Maximal anchor spacing (see page 17):

- max. lengthwise spacing $s_{L,HDB-S} = 0.75 d = 120 \text{ mm}$
- max. crosswise spacing $s_{Q,HDB-S} = 1.5 d = 240 \text{ mm}$

Calculating anchor height:

- anchor height $h_A = h - 2 \times c_{nom} = 200 - 2 \times 25 = 150 \text{ mm}$
Selected: $h_A = 155 \text{ mm}$

- max anchor diameter $d_A \leq 4 \sqrt{\frac{200}{10}} = 17.9 \text{ mm}$

selected anchor spacing:

- lengthwise $s_{L,HDB-S} = 120 \text{ mm} \approx 7 \text{ anchors/elements row}$
- crosswise $s_{Q,HDB-S} = 240 \text{ mm} \approx 4.2 \text{ elements / m}$

Given:

- required shear reinforcement req. $a_{sw} = 2484 \text{ mm}^2/\text{m}^2$
- cross-section each element row req. $a_{sw} = 2484/4.2 = 591.4 \text{ mm}^2/\text{m}$

selected anchor diameter (see table on page 21)

- anchor diameter $d_A = 10 \text{ mm}$
 - present shear reinforcement: $a_{sw, prov} = 652 \times 4.2 = 2738.4 \text{ mm}^2/\text{m}^2$
- Verification
- given: $a_{sw} > \text{req. } a_{sw} !$

Distribution of elements:

- number of anchor rows $m = 4000/240 = 16 \text{ rows}$
- no. of anchors in each row $n = 800/120 = 7 \text{ anchors}$
- configuration: 16 elements rows, each with two 2-stud and one 3-stud HDB-S element

checking the present edge spacing (see page 17)

- present edge spacing $a_{Q,HDB-S} = (4000 - 15 \times 240)/2$
present $a_{Q,HDB-S} = 200 \text{ mm}$
 $> \min a_{Q,HDB-S} = 120 \text{ mm}$

Element description:

- HDB-S – $d_A / h_A - n / L_{Ges}$ ($L_{Ges} = n \times s_{L,HDB-S}$)

Itemised list and element description:

- $2 \times 32 \times \text{HDB-S-10/155-2/240}$ (60 / 120 / 60)
- $2 \times 16 \times \text{HDB-S-10/155-3/360}$ (60 / 120 / 120 / 60)

HALFEN HDB-S SHEAR RAIL – SHEAR REINFORCEMENT

Technical Notes

Allowable anchor spacings

The maximal anchor spacing, lengthwise and crosswise, depends on the thickness of the slab. When absolute and relative values are given the lower of the two is decisive. The first anchor in a row is placed at a distance of $s_{L,HDB-S}$ from the centre line of the load. In single-axis-span slabs a transverse reinforcement of at least 20% of the main reinforcement is required for tension forces and transverse bending moments.

If not otherwise stated in the applicable National Annex, the following design criteria applies:

Maximal stud diameter

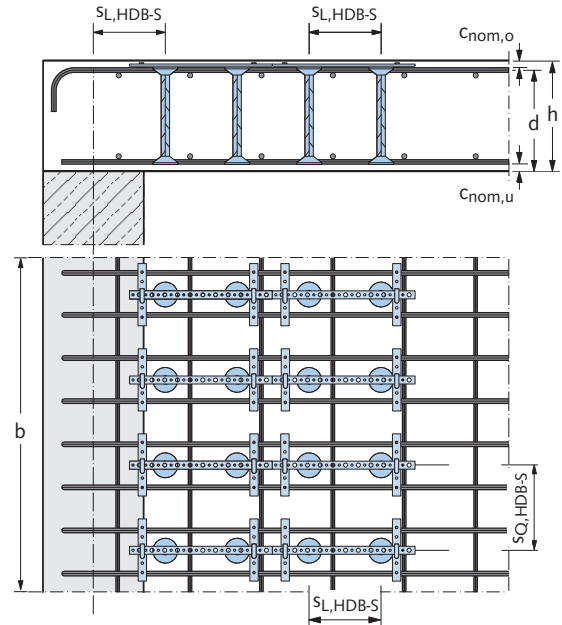
$$d_A \leq 4 \sqrt{\frac{h}{10}} \quad \text{slab thickness } h \text{ in [mm]}$$

Maximal anchor spacing in span direction

$$\begin{aligned} d < 400 \text{ mm} & \quad s_{L, HDB-S} = 0.75d \\ d \geq 400 \text{ mm} & \quad s_{L, HDB-S} = 0.50d \end{aligned}$$

Maximal anchor spacing in transverse direction

$$s_{L, HDB-S} = 1.5d \text{ or } 600 \text{ mm}$$



Installation notes

Reinforcement stirrups must be placed in all free edges of slabs to secure and hold the concrete cover. At least one longitudinal reinforcement bar must be placed at anchor head height

between the free component edges and the HDB-S Anchor. The minimal edge spacing $a_{Q,HDB-S}$ and minimal slab thickness for each anchor diameter can be found in the following table.

anchor diameter d_A [mm]	minimal slab thickness h [mm]	minimal stud spacing to free edges depending on the concrete strength class $a_{Q,HDB-S}$ [mm]				
		C 20/25	C 30/37	C 35/45	C 45/55	C 50/60
10	160*	120	110	90	80	80
12	160*	150	130	110	100	100
14	160*	170	150	130	120	120
16	160	200	170	150	130	130
18	205	230	190	170	150	150
20	250	250	210	190	170	170
25	395	310	260	230	210	210

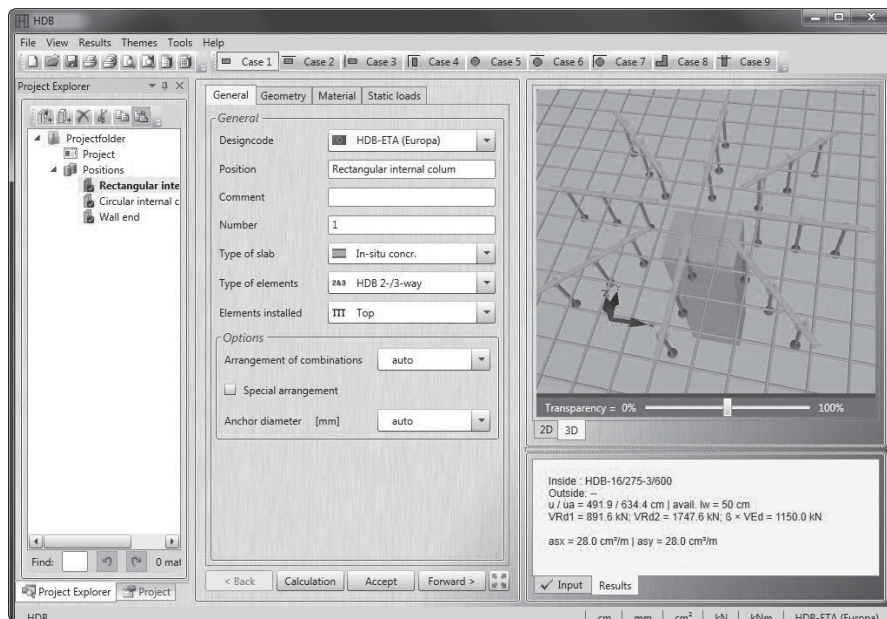
* minimal slab thickness according to the German approval for HDB-S

HALFEN HDB / HDB-S SHEAR RAIL – PUNCHING SHEAR / SHEAR REINFORCEMENT

Calculation Software

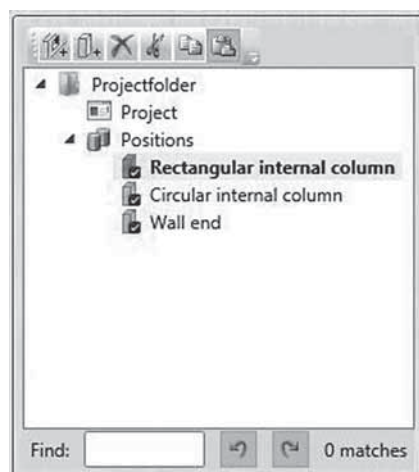
The HALFEN Calculation program is a convenient tool to help calculate HDB Shear rail punching reinforcement. The program was compiled based on current approvals and expert reports.

The program helps to determine the optimal punching shear reinforcement for the slab geometry and loads. Various calculation methods based on national and international codes and approvals are included.



Project administration

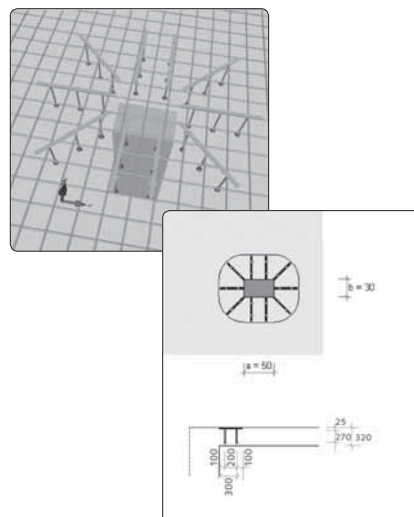
A large number of different calculations can be done within a project and stored in the project file. The user can immediately access stored projects for any future changes. Save the data after every calculation by clicking the "accept" button, otherwise the data will be overwritten by subsequent input.



Administration window for fast navigation

Edit window

The edit window is available in 2D or 3D and serves to display the system geometry and to move, add or delete shear rails. Any openings can also be moved.



Design alternatives

Calculation is possible for flat slabs (on-site cast concrete elements, precast element slabs), foundation slabs and footings. For punching shear, system elements with 2 or 3 studs and optimised complete elements are available. All elements can be installed from above or below.

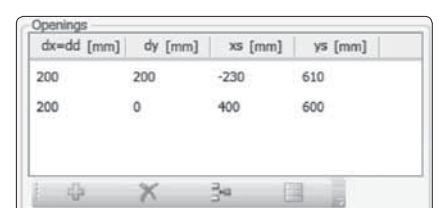
Two methods are available to determine the load increase factor while considering an unequal shear distribution in the critical perimeter:

- constant load factor according to EN 1992-1-1
- a more precise method using a plastic shear stress distribution according to EN 1992-1-1:2011-01

Anchor diameters of 10, 12, 14, 16, 18, 20 and 25 mm can be automatically selected and optimised by the program, or specified manually. This also applies when selecting combinations of punching shear elements. In standard mode the program optimises the number of elements. It is possible to freely select the number of elements manually to individual requirements in compliance with the approval.

Openings

Data-input for openings near to the punching shear region is straightforward; simply enter the values for the centre of gravity for the surface-area and the dimensions.

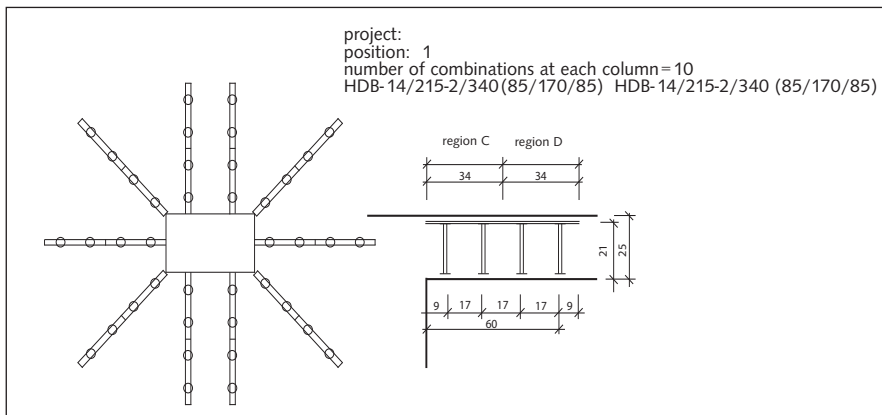


HALFEN HDB / HDB-S SHEAR RAIL – PUNCHING SHEAR / SHEAR REINFORCEMENT

Calculation Software

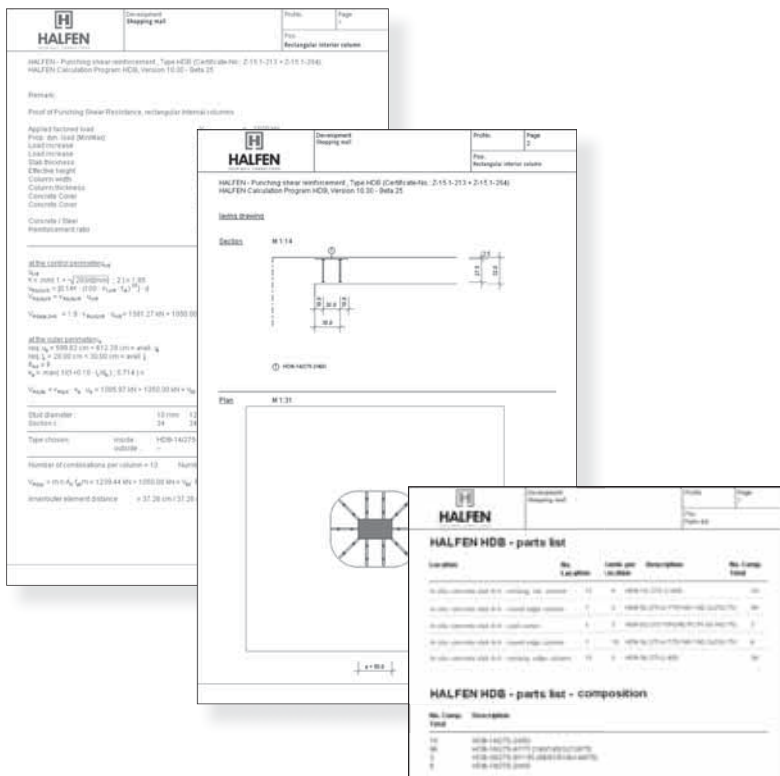
Output in DXF file format

DXF data can be created with a plan view, section and optional dimensioning information. This data can then be integrated into reinforcement plans.



Printouts

After calculating the punching shear or shear reinforcement the HDB calculation program creates a calculation report, the necessary plans, parts lists and if required an order list.



Internet download

The latest version of the calculation program is available for download on the internet under www.halfen.de.

The HDB Software can be set up to automatically check if a newer version of the program is available.

If requested, a DVD with all calculation programs, catalogues and approvals is also available. You will find our contact address at the back of this catalogue.



HALFEN HDB design software:
System requirements

- Windows XP, Vista, Windows 7

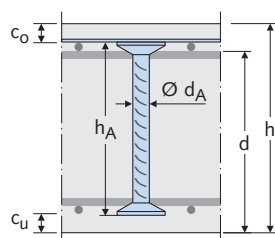
HALFEN HDB / HDB-S SHEAR RAIL – PUNCHING SHEAR / SHEAR REINFORCEMENT

Selection of Type, Purchase Order, Accessories

HDB Order descriptions

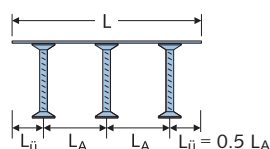
Dimensioning

of HDB Shear rails as punching shear and shear force reinforcement



HDB System elements

2 or 3 studs

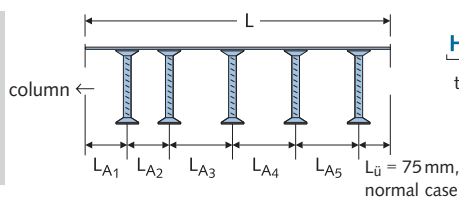


HDB - 16 / 205 - 3 / 420

type stud dimension d_A/h_A number element of length L studs

HDB Complete elements

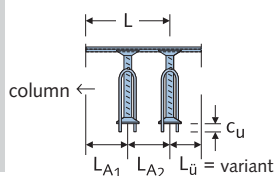
2 to 10 studs



HDB - 16 / 205 - 5 / 725 (100 / 100 / 150 / 150 / 150 / 75)

type stud dimension d_A/h_A number of studs element length L stud spacings $L_{A1}/L_{A2}/\dots / - L_{An}$ end spacing $L_{\bar{u}}$

HDB-F Elements



HDB - F - 16 / 275 - 2 / 270 (135 / 135) $c_u = 25 \text{ mm}$

type stud dimension d_A/h_A number of studs element length L stud spacings $L_{A1}/L_{A2}/\dots / - L_{An}$ dimension c_u for spacer

Installation accessories

Clip bars

- are optional but not always required
- to facilitate top installation, we generally recommend calculating an average of 1.5 clip bars for each HDB element (see page 23)

HDB KLEMM

type

Spacer

- for installation from below with HDB Complete elements
- the dimension c_u depends on the concrete cover
- type selection (see page 23)

HDB ABST - 30

type dimension c_u

HALFEN HDB-S SHEAR RAIL – SHEAR REINFORCEMENT

Calculation

Anchor cross-section for each element row $a_{sw,HDB-S}$ [mm²/m]

stud distance $s_{L,HDB}$ [mm]	element length L_E [mm]		stud diameter d_A [mm]							studs/m
	2-stud	3-stud	10	12	14	16	18	20	25	
										
60	120	180	1312							16.7
65	130	195	1210							15.4
70	140	210	1123							14.3
75	150	225	1045	1504						13.3
80	160	240	982	1414						12.5
85	170	255	927	1335	1816					11.8
90	180	270	872	1255	1709					11.1
95	190	285	825	1188	1616					10.5
100	200	300	785	1131	1539	2011				10
105	210	315	746	1074	1462	1910				9.5
110	220	330	715	1029	1401	1830	2316			9.1
115	230	345	683	984	1339	1749	2214			8.7
120	240	360	652	939	1278	1669	2112	2608		8.3
125	250	375	628	905	1232	1608	2036	2513		8
130	260	390	605	871	1185	1548	1959	2419		7.7
135	270	405	581	837	1139	1488	1883	2325		7.4
140	280	420	558	803	1093	1428	1807	2231		7.1
145	290	435	542	780	1062	1387	1756	2168		6.9
150	300	450	526	758	1031	1347	1705	2105	3289	6.7
155	310	465	511	735	1001	1307	1654	2042	3191	6.5
160	320	480	495	713	970	1267	1603	1979	3093	6.3
165	330	495	479	690	939	1226	1552	1916	2994	6.1
170	340	510	463	667	908	1186	1501	1854	2896	5.9
175	350	525	448	645	877	1146	1450	1791	2798	5.7
180	360	540	440	633	862	1126	1425	1759	2749	5.6
185	370	555	424	611	831	1086	1374	1696	2651	5.4
190	380	570	416	599	816	1066	1349	1665	2602	5.3
195	390	585	401	577	785	1025	1298	1602	2503	5.1
200	400	600	393	565	770	1005	1272	1571	2454	5.0
205	410	615	385	554	754	985	1247	1539	2405	4.9
210	420	630	377	543	739	965	1221	1508	2356	4.8
215	430	645	369	532	724	945	1196	1477	2307	4.7
220	440	660	353	509	693	905	1145	1414	2209	4.5
225	450	675	346	498	677	885	1120	1382	2160	4.4
230	460	690	338	486	662	865	1094	1351	2111	4.3
235	470	705	338	486	662	865	1094	1351	2111	4.3
240	480	720	330	475	647	844	1069	1319	2062	4.2
245	490	735	322	464	631	824	1043	1288	2013	4.1
250	500	750	314	452	616	804	1018	1257	1963	4.0

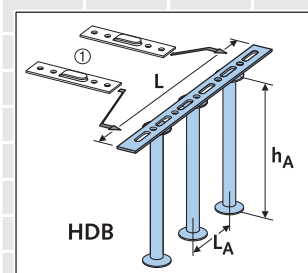
stud spacing $s_{L,HDB-S} < 6 d_s$!

HALFEN HDB / HDB-S SHEAR RAIL – PUNCHING SHEAR / SHEAR REINFORCEMENT

Type Selection System Elements

HDB Element lengths L with stud diameter d_A [mm]

$\varnothing d_A$ (a)	$\varnothing 10$		$\varnothing 12$		$\varnothing 14$		$\varnothing 16$		$\varnothing 18$		$\varnothing 20$		$\varnothing 25$		stud spacing L_A [mm]
number of studs (c)	2	3	2	3	2	3	2	3	2	3	2	3	2	3	
stud height h_A (b) [mm] ②	II	III	II	III	II	III	II	III	II	III	II	III	II	III	
105	#	#													80
115	#	#													80
125	#	#	#	#	#	#									100
135	200	300	#	#	#	#									100
145	200	300	#	#	#	#									100
155	220	330	220	330	#	#	#	#							110
165	240	360	240	360	#	#	#	#							120
175	240	360	240	360	#	#	#	#							120
185	280	420	280	420	280	420	#	#			#	#			140
195	280	420	280	420	280	420	#	#			#	#			140
205	280	420	280	420	280	420	280	420	#	#	#	#			140
215	300	450	300	450	300	450	300	450	300	450	#	#			150
225	#	#	320	#	320	480	320	#	320	#	#	#			160
235	#	#	340	510	340	510	340	510	340	510	340	510	#	#	170
245	#	#	360	540	360	540	360	540	360	540	360	540			180
255	#	#	#	#	360	540	360	540	360	540	360	540			180
265			#	#	#	#	#	#	#	#	#	#	#	#	200
275			#	#	#	#	400	600	400	600	400	#	#	#	200
285			#	#	420	630	420	630	420	630	420	630	#	#	210
295			#	#	#	#	440	#	440	660	440	660	#	#	220
305			#	#	#	#	#	#			440	660	#	#	220
315			#	#	#	#	#	#			#	#	#	#	240
325					#	#	#	#			#	#	#	#	240
335							#	#			480	#	#	#	240
345			#	#	#	#	#	#			#	#	#	#	260
355							#	#			520	#	#	#	260
365					#	#	#	#			#	#	#	#	270
375											#	#	#	#	280
395											#	#	#	#	300
405											#	#	#	#	300
425											#	#	#	#	320
435											#	#	#	#	320
455											#	#	#	#	320



420

In-stock system elements (dark grey)
For example, element length $L = 420$ mm
System element available on order (light grey)
Element length on customer's request

- ① Assembly clip bars are ordered separately (see page 23).
② Other stud heights on request.

Ordering example:

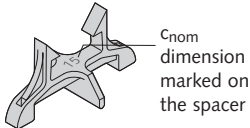
HDB - 16 / 205 - 3 / 420
type _____
stud diameter d_A [mm] (a) _____
stud height h_A [mm] (b) _____
number of studs per element (c) _____
element length L (set or required value) _____

HALFEN HDB / HDB-S SHEAR RAIL – PUNCHING SHEAR / SHEAR REINFORCEMENT

Accessories, Tender Specification

Installation accessories

Spacer HDB ABST

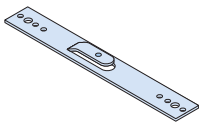


① Dimension c_{nom} is the nominal dimension for the lower concrete cover
Material:
KS = plastic

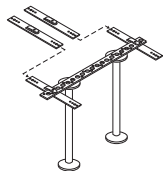
Designation: ① Type	Dimension c_{nom} [mm]	Order no. 0066.010-
HDB ABST-15/20		00001
HDB ABST - 25		00002
HDB ABST - 30		00003
HDB ABST - 35		00004
HDB ABST - 40		00005

We recommend two spacers for each HDB Element when installing from below.

Clip bars HDB Klemm



Application diagram

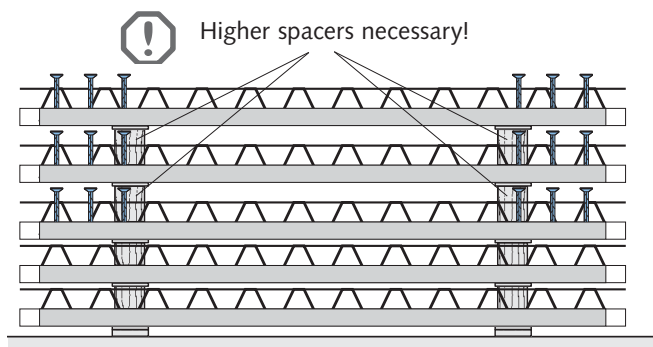


Can be fitted anywhere on the HDB Element spacer-bar

Note: Clip bars are not included in the scope of delivery for HDB Elements. **Please order separately.**

Storage and transport

When storing and transporting semi-precast slabs, it should be noted that due to their height, the HDB Shear rails protrude above the lattice girders. Use appropriately high spacers for supporting the semi-precast slabs.



HDB Punching shear reinforcement – tender specification

HALFEN HDB Shear rail (System element) - $d_A / h_A - n / L$

HALFEN Shear rail HDB as punching shear reinforcement in flat slabs, foundation slabs or footings according to European Technical Approval ETA-12/0454; RAL-GZ 658/2; approved by the quality control association for anchorage and reinforcement technology (Gütegemeinschaft Verankerungs- und Bewehrungstechnik e.V.), in ribbed or smooth reinforcement steel B 500, to strengthen punch-critical areas in flat slabs or foundation slabs for non-predominantly static and predominantly static loads.

Type HDB (System element) - $d_A / h_A - n / L$ with

stud diameter $d_A = \dots\dots\dots$ [mm]
stud height $h_A = \dots\dots\dots$ [mm]
number of studs $n = \dots\dots\dots$ [studs/element]
length of shear rail $L = \dots\dots\dots$ [mm]

Note: refer to the table on page 22 for sizes of in-stock system elements.

deliver and install using clip bars and spacers (accessories) according to the manufacturer's instructions.

Further tender specifications can be found at www.halfen.de under "Service" .

HALFEN HDB-S SHEAR RAIL – SHEAR REINFORCEMENT

Installation

HDB-S Shear reinforcement – tender specification

HALFEN HDB-S Shear rail - d_A / h_A - n / L (Stud spacing)

HALFEN Shear rail HDB-S as shear reinforcement in reinforced concrete slabs or beams according to Technical Approval Z-15.1-249 and Z-15.1-270; RAL-GZ 658/2; approved by the quality control association for anchorage and reinforcement technology (Gütegemeinschaft Verankerungs- und Bewehrungstechnik e.V.), in ribbed or smooth reinforcement steel

B 500, to strengthen the critical shear areas in beams or slabs for non-predominantly static and predominantly static loads.

Type HDB-S - d_A / h_A - n / L (L_{A1} / L_{A2} / ... / L_{An} / $L_{ü}$) with

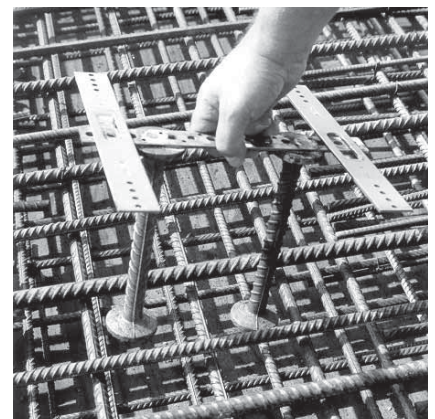
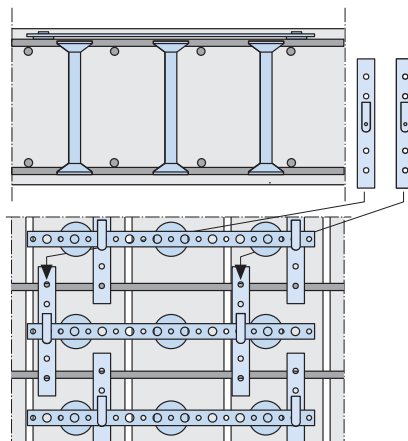
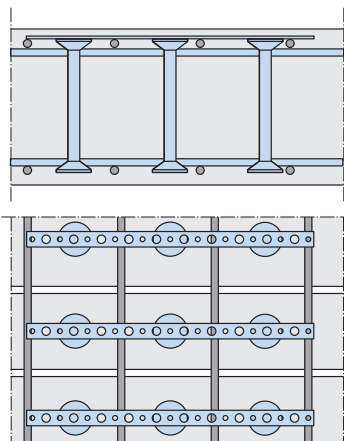
stud diameter	d_A = [mm]
stud height	h_A = [mm]
number of studs	n = [Anchor / element]
length of shear rail	L = [mm]
stud distances	L (L_{A1} / L_{A2} / ... / L_{An} / $L_{ü}$) = [mm]

deliver and install using clip bars and spacers (accessories) according to manufacturer's instructions.

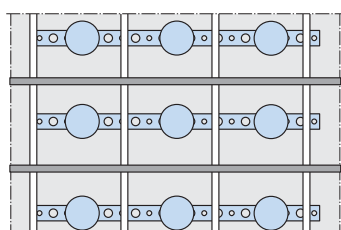
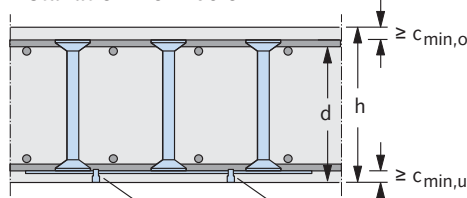
Fixing HDB-S elements to the reinforcement

Top installation:

- without clips bars,
transverse to upper reinforcement
- with clip bars (order separately)
parallel to upper reinforcement



Installation from below

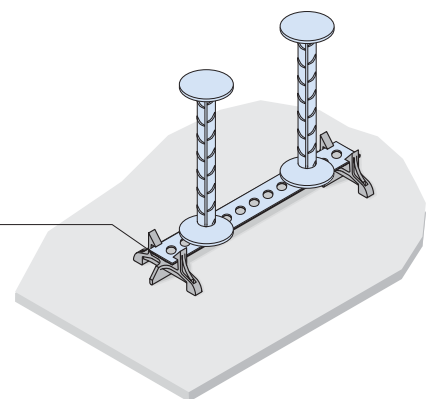


Spacers

Type HDB ABST - ①

Concrete cover $c_{nom,o}$ and $c_{nom,u}$ according to EN 1992-1-1:2011-1 and the appropriate National Annex

① The dimension $c_{nom,u}$ is required see page 23

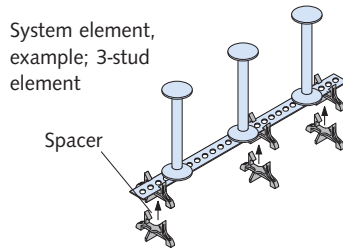


HALFEN HDB SHEAR RAIL – PUNCHING SHEAR REINFORCEMENT

Punching Shear Reinforcement in Semi-precaster Slabs

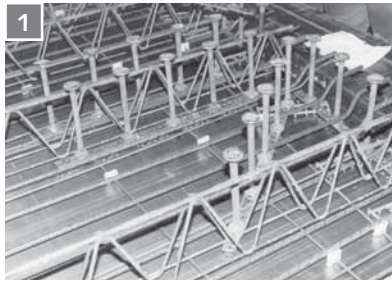
Installation in precast slabs

For assembly from below, e.g. in precast slabs, the HDB Shear rail punching reinforcement is installed with spacers. This applies to both HDB System elements and HDB Complete elements.



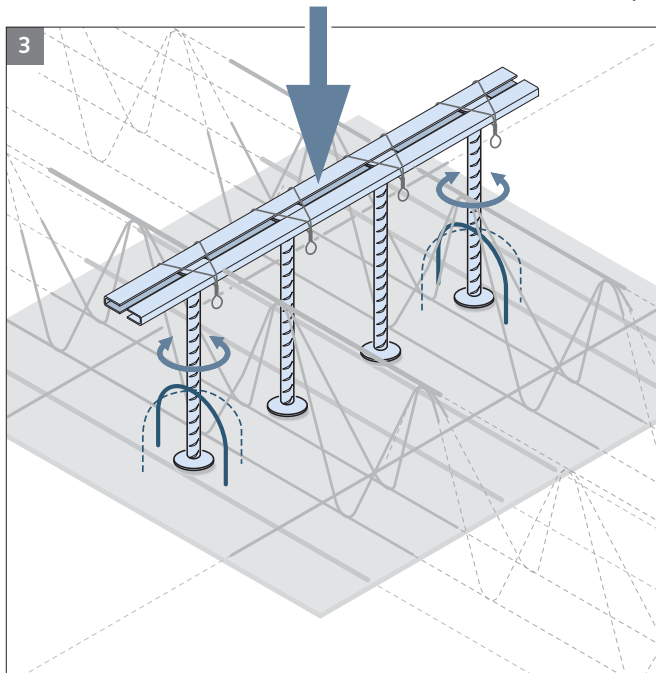
HDB Punching shear reinforcement in precast element slabs

- 1 Installing flexural reinforcement and HDB Shear rail punching elements in precast concrete element production. Additional lattice girder reinforcement is generally required to ensure a good bond.
- 2 On-site: precast slab with HDB Shear rail punching reinforcement.

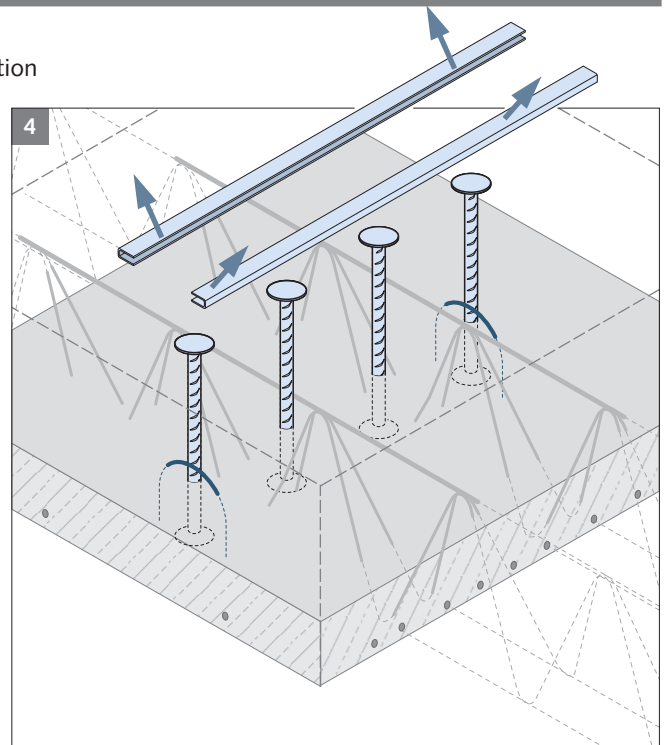


HALFEN HDB-F Shear rail for precast slabs

The shear rail for efficient installation; ideal for automated production



- 3 HALFEN HDB-F Shear rails are installed after the lower reinforcement from above. The double-headed studs can be individually rotated. This allows the spacers to be easily aligned. The removable assembly bar is placed on top of the lattice girders.



- 4 After the concrete has sufficiently hardened, remove the two-piece assembly bar from the HDB-F Studs. The upper reinforcement layer can now be fitted at the construction site.

HALFEN HDB SHEAR RAIL – PUNCHING SHEAR REINFORCEMENT

Punching Shear Reinforcement in Semi-precast Slabs

HDB-F – product advantages that count

50% reduced production time

Using HALFEN HDB-F Shear rails can reduce factory production times for pre-cast components by up to 50%, significantly increasing plant efficiency.

Installation independent of other reinforcement

The HALFEN HDB-F Shear rails are fitted after the lower reinforcement has been installed. This allows installation of the required lower reinforcement for pre-fabricated slabs including the lattice girders to be completed, hindrance free.

Removable spacer-bars rails

The stud heads are connected by two U-shaped sheet steel assembly rails. These are kept securely in position with easily removable tying-wire or non-metallic straps.

Rotatable studs with spacers

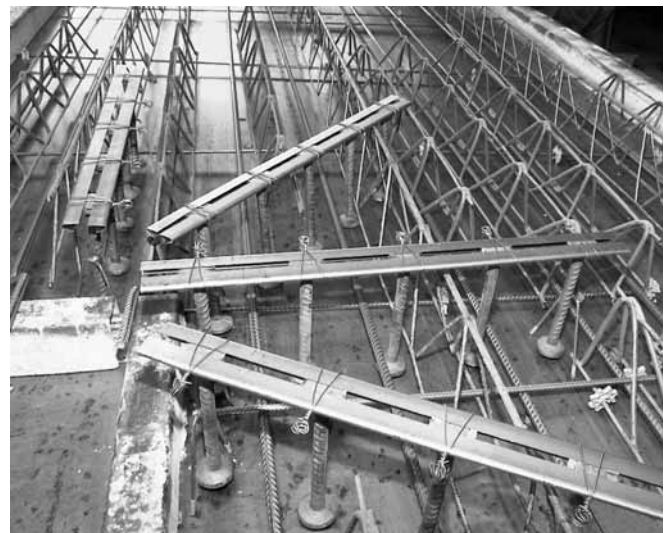
The double-headed studs in HDB-F Shear rails with spacers are fixed freely rotatable to the spacer-bar. This allows the spacers to be easily inserted between the previously placed pre-cast slab reinforcement. Please state the thickness of the lower concrete cover c_{nom} when ordering.

Complete elements

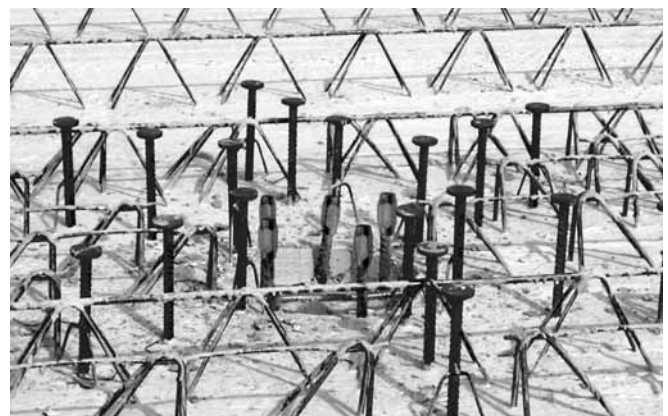
HALFEN HDB-F Shear rails are manufactured as finished elements with 2 to 8 anchors. HALFEN HDB-F Shear rails finished elements are easily fitted from above as no upper reinforcement is placed in semi-precast components at the production plant.

Note on design

The punching shear design is generally the same for cast-on-site concrete slabs and pre-fabricated slabs. However, the shear force transfer in precast slab joints must also be verified according to EN 1992-1-1, section 6.2.5, and the appropriate National Annex: the necessary bonding reinforcement also needs to be verified.



HALFEN HDB-F Shear rails are easy to install.



Precast slab with HDB-F Shear rails in place on the construction site. The spacer-bars have been removed; the top reinforcement can now be installed without any obstructions.

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