HALFEN HAB MH ANCHOR BOLT

APPROVAL Z-21.5-1758

HALFEN COLUMN SHOE SYSTEM

Z HAB MH 13-E

CONCRETE

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General Certificate of Approval

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Applicant:
Halfen GmbH
Liebigstraße14, 40764 Langenfeld, GERMANY

Approved article:
Halfen - Anchor Bolt HAB MH

Deutsches Institut für Bautechnik

The above-mentioned product is hereby granted general certificate of approval.
This general certificate of approval includes eleven pages and 19 appendices.
This general certificate of approval replaces the general certificate of approval no. Z-21.5-1758 issued October 28th 2003. This article first gained General Building Approval on the 5th May 2004

I.GENERAL PROVISIONS

1. The general certificate of approval confirms the usability or applicability of the object of licence in terms of the building regulations of the German federal states.

2. Please note; if the General Certificate of Approval requires specialist knowledge and expertise for persons responsible for production of building products and methods, according to federal regulations § 17 sect. 5 Musterbauordnung (German model Building regulations), this knowledge and experience may also be verified by qualifications of similar status valid in other member states of the European Union. If appropriate this also applies for treaties pertaining to the European Economic Area EEA or other provided comparable qualifications as per bilateral agreements.

3. The general certificate of approval does not replace the statutory approvals, permits and certificates for the implementation of construction projects.

4. The general certificate of approval does not preclude the rights of third parties and, in particular, private proprietary rights.

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7. The general certificate of approval is issued subject to revocation. The provisions of the general certificate of approval can be extended and amended, particularly to include current technical research.

Deutsches Institut für Bautechnik

II. SPECIAL PROVISIONS

1. **Object of approval and area of application**

1.1 **Object of approval**

The Halfen HAB MH Anchor Bolts (hereafter referred to as Anchor Bolts) consist of a steel bolt (threaded part) with a thread turned at one end, two hexagonal nuts and two washers.
Attached to the other end of the steel bolt are studs made from ribbed concrete reinforcing steel with a swage fitted head (headed anchor studs) welded on one end. The Anchor Bolt types are listed in table 1.1.

Table 1.1: Anchor Bolt types, number and size of welded anchor studs

HAB MH Anchor Bolt type . . . (thread size of bolt)	22	27	36	39	45	52	60
Number of shear-bolt anchors Ø...	2 Ø20	2 Ø25	4 Ø20	3 Ø25	4 Ø25	4 Ø32	4 Ø32

The Anchor Bolt is embedded in the concrete up to the mark which indicates the anchor depth.
Appendix 1 shows the Anchor Bolt in its installed state.

1.2 **Object of approval and area of application**

The Anchor Bolts may only be used for the connection of precast columns with the matching Halfen Column Shoe and of steel or steel composite columns with baseplate.
The Anchor Bolts may be used under predominantly static loads in normal concrete with a strength class of at least C12/15 and at most C50/60 according to DIN 206-1:2001-7 unless there are no requirements regarding the fire endurance of the construction as a whole, including the anchor systems. The Anchor Bolts may only be used in cracked and uncracked concrete, where there are no requirements regarding the duration of fire resistance for the structure as a whole, including the anchor systems.
To ensure that the Anchor Bolts are protected from corrosion, the joints between the reinforced concrete structural element and the reinforced concrete column with the Column Shoe and the recesses for the Anchor Bolts must be completely grouted after installation with high-strength, shrink-free mortar.
Ensure the concrete cover is not less than the minimum values specified in DIN 1045-1:2008-08 or DIN EN 1992-1-1 :2011-01 with DIN EN 1992-1-1/NA:2011-01.
Anchor bolts in connection with steel columns may only be used in interior rooms e.g. living space, office space, educational buildings, hospitals and sales offices, except of damp rooms.

2 **Regulations for the construction product**

2.1 **Properties and composition**

The dimensions of the Anchor Bolts must comply with the values listed in table 1 appendix 4.
Any material properties, dimensions and tolerances of the Anchor Bolts which are not specified in this general certificate of approval must comply with the specifications approved and documented by the Deutsches Institut für Bautechnik, at the certification authority and at the external auditor.

A ribbed, B 500 B concrete reinforcing steel according to DIN 488 with a 0.2% yield strength of 500 N/mm² and a minimum tensile strength of 550 N/mm² must be used for the welded-on 20 mm and 25 mm anchor studs.

A ribbed, B 500 B concrete-reinforcing steel in accordance with a general certificate of approval with a 0.2% yield strength of 500 N/mm² and a minimum tensile strength of 550 N/mm² must be used for the 32 mm. anchor studs.

The anchor bolt is made from a Class A non-flammable construction material in accordance with DIN 4102-1:1998-05 Fire Behaviour of Construction Materials and Structural Elements; Construction Materials, Terms, Requirements and Tests.

2.2 Packaging, Storage and Labelling

2.2.1 Packaging and Storage

The Anchor Bolt must only be packaged and supplied as one fixing unit.

2.2.2 Labelling

The manufacturer must label the packaging, packaging leaflet or delivery note with the conformity symbol (Ü symbol) in accordance with the symbol of conformity regulations of the German federal states. The manufacturer's identification mark, the approval number and a full description of the Anchor Bolts must also be provided. The label may only be applied after the requirements according to section 2.3 have been fulfilled.
The anchor bolts must be labelled according to their type and thread diameter, e.g. HAB MH 22.
Each anchor bolt must be stamped with the manufacturer's identification mark and the thread diameter in accordance with appendix 4. The depth of anchorage is indicated by the end of the thread.

2.3 Proof of conformity

2.3.1 General information

Compliance of the Anchor Bolt with the provisions of this general certificate of approval must be confirmed for each manufacturing works with a certificate of conformity based on an in-house production check and regular external auditing including initial testing of the Anchor Bolt according to the following provisions.
In order to issue a certificate of conformity and for the external auditing including the product tests that have to be carried out in this regard, the manufacturer of the Anchor Bolts must notifiy a recognized certification body and an auditor which is recognized for this purpose.
To indicate that the product has been awarded a conformity certificate (Übereinstimmungszertifikat), the manufacture is required to identify the product with the conformity U Symbol (Übereinstimmungszeichen) with reference to the application.
In addition, a copy of the initial test report must be submitted to the Deutsches Institut für Bautechnik for information purposes.

2.3.2 In-house production check

An in-house production check must be set up and carried out at each manufacturing plant. An in-house production check is understood to mean a system of continual monitoring of the production process which must be set up by the manufacturer in order to ensure that the construction products manufactured comply with the provisions of this general certificate of approval.

The inspection and supervision plan on record at the Deutsches Institut für Bautechnik and at the external auditor is authoritative for the scope, type and frequency of the in-house production check.

The results of the in-house production check must be documented and evaluated. The records must contain at least the following details:

- Name of the construction product or raw material and the components
- Type of inspection or test
- Date of manufacturing and testing of the construction product, raw material or components.
- Result of the inspection and tests and, where applicable, comparison with the requirements.
- Signature of the person responsible for the in-house production check.

These records must be archived for at least five years and made available to the external auditor selected for third party monitoring. They must be submitted on request to the Deutsches Institut für Bautechnik and the highest responsible building supervisory authority.
If the test result is unsatisfactory, the manufacturer must immediately take the necessary action to eliminate the defect. Construction products that do not satisfy the requirements must be handled so as to prevent them from being confused in any way with parts which do conform. After the defect has been eliminated, the relevant test must be repeated without delay where this is technically feasible and necessary to prove that the defect has been eliminated.

2.3.3 External auditing

The in-house production check must be inspected by an external auditor at each manufacturing location on a regular basis at least once a year. The inspection and supervision plan on record at the Deutsches Institut für Bautechnik and the external auditor are authoritative for the scope, type and frequency of the external auditing. The certification and external auditing results must be archived for at least five years. They must be submitted on request by the certification body or auditor to the Deutsches Institut für Bautechnik and the highest responsible building supervisory authority.

3 Provisions for design and dimensioning

3.1 Design

3.1.1 General information

The anchor connections must be designed according to standard engineering principles.
Calculations and construction designs which can be tested and which include the position of the anchor connections and possible dimensional deviations must be prepared, taking the intended loads to be anchored into consideration.

Unless otherwise defined; for design, detailed planning, calculation of required dimensions and sizes DIN 1045-1 or DIN EN 1992-1-1 applies for design and calculation of the structural system as a whole. Mixing both technical building standards is not permissible
DIN EN 1992-1-1 applies only when used in conjunction with DIN EN 1992-1-1/NA.

Only groups consisting of four, six or eight Anchor Bolts in accordance with appendix 4 are permitted. The terms and symbols which are used here are explained in appendices 5 and 6.

The anchor connection may only be dimensioned as Anchor Bolt group for precast concrete columns, if the Column Shoe recesses for the Anchor Bolts are completely grouted with a high-strength, non-shrink mortar and the effective loads are transferred via the bond into the individual Anchor Bolts of the group. Only Anchor Bolts of the same diameter and length may be used in any one group of Anchor Bolts.

The internal forces of the Anchor Bolts must be calculated from forces and moments acting on the anchor plate of the Column Shoes according to the theory of elasticity.
The following assumptions must be made:

a) The anchor plate remains flat under the stress of the internal forces.

b) The rigidity is the same for all Anchor Bolts. It corresponds with the rigidity of the steel cross section.

c) The modulus of elasticity of the concrete is assumed as E_c= 30,000 N/mm²

Anchor Bolts with a drill hole clearance in the direction of the transverse load, exceeding the values of table 3.1 (e.g. slotted holes) may not be taken in consideration for transverse load bearing.

For anchor connections with a drill hole clearance in the direction of the transverse load, smaller than the values of table 3.1, only the Anchor Bolts near to the edge may be taken into consideration for transverse load bearing.

All Anchor Bolts take up transverse loads only, if

– the clearance of the drill hole in the direction of the transverse load is smaller than the values of table 3.1 and
– the anchor connection has a large distance to the edge ($c \geq 10h_{ef}$) and
– steel failure or concrete failure is decisive on the side facing away from the load direction.

Table 3.1 Diameter of the drill hole in the anchor base plate

Anchor Bolt HAB MH . . (thread size)	22	27	36	39	45	52	60
Diameter of the drill hole [mm]	24	30	39	42	48	55	63

3.1.2 **Minimum centre spacings and edge distances**

The centre spacings and distances from the edge must not be less than the minimum values listed in table 1, appendix 4.

3.1.3 **Minimum thickness of the structural element**

The required thickness h_{min} of the structural element results from the anchoring depth l_2 according to appendix 4 and the required concrete cover c_{nom}

$$h_{min} = l_2 + c_{nom} \qquad (3.1)$$

l_2 = Installation depth acc. to appendix 4, table 1

c_{nom} = Required concrete cover acc. to DIN 1045-1:2008-08
or DIN EN 1992-1-1 :2011-01 with DIN EN 1992-1-1/NA:2011-01

3.2 **Dimensioning**

3.2.1 **General information**

The anchor connections must be dimensioned according to engineering methods with partial safety factors as described below.
Proof of the direct local transfer of loads into the concrete is given.
The transfer of the loads to be taken up into the structural element must be proven.
Stresses which can be generated in the anchor or the connected structural component by constricted deformation (e.g. due to temperature changes) must be considered.

3.2.2 **Required proofs**

It must be proved that the design value of the effect (stress) S_d does not exceed the design value of the resistance (load capacity) R_d

$$S_d \leq R_d$$

S_d = Design value of the stress
R_d = Design value of the resistance

For the simplest case (constant load) and a variable load acting in same direction), the following applies for the design values of the effects:

$$F_d = S_d = \gamma_G \cdot G_k + \gamma_Q \cdot Q_k \qquad (3.3a)$$

G_k; Q_k = Characteristic value of a constant or a variable effect according to the applicable standards for design loads
γ_G; γ_Q = Partial safety factor for constant or variable effects

The design value of the resistance for the proof of the load capacity results from the characteristic load capacity of the Anchor Bolt anchoring with:

$R_d = R_k/\gamma_M$ (3.3b)

R_k = Characteristic value of the resistance (load capacity, e.g. N_{Rk} or V_{Rk}). This value must be calculated for the individual causes of failure by the calculation methods specified in the appendices 5 to 20 respectively according to the indicated method.

γ_M = Partial safety factor for the resistance of the material.

The required proofs of the load capacity at tensile or perpendicular loads are listed in the following tables 3.2 and 3.3.

Table 3.2 Required proofs for tensile loads

Nr.	Causes of failure		Anchor Bolt groups
1	Steel failure (Anchor Bolt)		$N^h_{Sd} \leq N_{Rk,s} / \gamma_{Ms}$
2	Pull-out		$N^h_{Sd} \leq N_{Rk,p} / \gamma_{Mc}$
3	Local concrete blow-out, anchoring close to edge [1]		$N^g_{Sd} \leq N_{Rk,cb} / \gamma_{Mc}$
4a	Concrete blow-out without suspension reinforcment [2]		$N^g_{Sd} \leq N_{Rk,c} / \gamma_{Mc}$
4b	Concrete blow-out with suspension reinforcement	Steel failure of the suspension reinforcement	$N^h_{Sd} \leq N_{Rk,re} / \gamma_{Ms,re}$
		Failure of the anchoring of the suspension reinforcement	$N^h_{Sd} \leq N_{Rd,a}$
5	Splitting		Minimum reinforcement acc. to sect. 3.2.4 required

1 This proof is not required, if the actual edge distance c is > 0.5 h_{ef} in both directions.
2 This proof is not required, if a restraint reinforcement acc. appendix 13 is provided (proofs according to 4b above).

Table 3.3. Required proofs for transverse loads

Nr.	Causes of failure	Anchor Bolt groups
1	Steel failure (Anchor Bolt) Transverse load without torsion arm	$V^h_{Sd} \leq V_{Rk,s} / \gamma_{Ms}$
2	Steel failure (Anchor Bolt) Transverse load with torsion arm	$V^h_{Sd} \leq V_{Rk,s} / \gamma_{Ms}$
3	Concrete blow-out on the side facing away from the load	$V^g_{Sd} \leq V_{Rk,cp} / \gamma_{Mc}$
4a	Concrete edge fracture with anchor connection near to the edge [1]	$V^g_{Sd} \leq V_{Rk,c} / \gamma_{Mc}$
4b	Load capacity of the suspension reinforcement with anchor connection near to the edge	$V^h_{Sd} \leq V_{Rk,re} / \gamma_{Ms,re}$

1 This proof is not required, if a restraint reinforcement according to appendices 19 or 20 is provided (proofs according to 4b above)

In the presence of combined tensile and transverse loads (diagonal tensile load), the following interaction condition must be observed:

$$(N_{Sd}/N_{Rd})^{\alpha} + (V_{Sd}/V_{Rd})^{\alpha} \leq 1 \qquad (3.4)$$

The highest value from the individual causes of failure must be used for the ratios N_{Sd}/N_{Rd} and V_{Sd}/V_{Rd} in each case.

The value α in the equation (3.4) must be taken as 1.5 for the anchor connection without restraint reinforcement respectively for the anchor connection with restraint reinforcement for tensional and transverse loads. If for the dimensioning a restraint reinforcement is used only for tensile loads (sect. 3.2.4.2) or only for transverse loads at the edge (sect. 3.2.4.3), the value α must be taken as 2/3.

If the Anchor Bolts at precast concrete columns are subject to transverse loads, the total transverse load must be transferred into the anchoring substrate by bending on the Anchor Bolts.

Considering a bending load on the Anchor Bolts can only be omitted, if all the following conditions apply:

- the material of the structure to be connected is metal, and the structure is tightened against the concrete without any intermediate layer and
- the hole diameter of the structure to be connected does not exceed the values listed in table 3.1.

3.2.3 **Partial safety factors**

In general, for constant or variable effects, the partial safety factors of the effects for the proof of the load-bearing capacity are:
$\gamma_G = 1.35$ or $\gamma_Q = 1.5$
The partial safety factors for material resistance for the proof of the load bearing capacity must be taken as follows:

$\gamma_{Mc} = 1.5$	Concrete failure (pull-out or concrete blow-out)
$\gamma_{Ms} = 1.5$	Steel failure of the Anchor Bolts (centric tension)
$\gamma_{Ms} = 1.25$	Steel failure of the Anchor Bolts (perpendicular or bending load)
$\gamma_{Mh} = 1.15$	Steel failure of the restraint reinforcement

Partial safety factors of γ_G, γ_Q and γ_M of 1.0 must be used for the proof of fitness for use.

3.2.4 **Reinforcement**

3.2.4.1 Minimum reinforcement (splitting)

A minimum reinforcement with the following cross section A_s must be provided in order to prevent the concrete structural element from splitting:

$$A_{S\,erf} = 0.5 \cdot \frac{\Sigma N_{Sd}}{f_{yk} / \gamma_{Ms,re}} \qquad \mathbf{(3.5)}$$

$\sum N_{sd}$	=	Sum of tensile loads in Anchor Bolts subjected to tensile stress under the design value for the effects
f_{yk}	=	Yield strength of the reinforcement
$\gamma_{Ms,re}$	=	1.15

The above mentioned verification can be omitted if at least one crosswise reinforcement (B 500 B) diameter 8 / 15 is provided in the area of the Anchor Bolt anchorings.

In flat load-bearing structures, splitting tensile reinforcement is necessary in both directions. With structural elements which are predominantly subject to tensile stress, the reinforcement must be arranged on both sides of the cross section, and with structural elements which are predominantly under bending stress the reinforcement must be arranged on the side which is tensile stressed. The reinforcement should consist of at least three bars spaced s ≤150 mm apart and must be anchored outside the anchor connection with an anchoring length of l_b in accordance with DIN 1045-1:2008-08 or $l_{b,rqd}$ according to DIN EN 1992-1-1:2011-01 with DIN EN 1992-1-1/NA:2011-01.
With linear load-bearing structures, the shear reinforcement need only be arranged in one direction.
With anchor connections at the edges of the structural element, this reinforcement must also be provided in the form of edge reinforcement with appropriate restraint reinforcement.

3.2.4.2 Restraint reinforcement for tensile loads

Proof for concrete blow-out failure acc. to appendices 10 to 12 can be omitted under the condition, that for anchor connections with tensile loads a restraint reinforcement is provided according to figure 8, appendix 13.
The calculation of the characteristic steel load bearing capacity $N_{Rk,re}$ and the design resistance $N_{Rd,a}$ of the restraint reinforcement is given in appendix 13.
If the restraint reinforcement is not connected to the Anchor Bolt, a surface reinforcement must be calculated and installed according to the strut and tie model.
The restraint reinforcement must be anchored in the concrete outside of the fracture cone with an anchoring length $l_{b,net}$ acc. to DIN 1045-1:2008-08. or $l_{b,d}$ according to DIN EN 1992-1-1:2011-01 with DIN EN 1992-1-1/NA:2011-01
The minimum anchoring length $l_{b,min}$ and the maximum bar diameter according to appendix 13 must be observed.
In case of non-centric tensile loads the reinforcement designed for the Anchor Bolt with the highest load must be provided for all Anchor Bolts.

3.2.4.3 Restraint reinforcement for transverse loads at the edge
A proof for concrete edge blow-out failure acc. to appendices 16 to 18 can be omitted under the condition, that for anchor connections at the edge, of the element and transverse loads towards the edge a restraint reinforcement is provided according to figures 15 and 16, appendices 19 and 20.

The characteristic transverse load capacity $V^0_{Rk,re}$ of a bar (B 500 B) of the restraint reinforcement is shown in table 8, appendix 19.
The restraint reinforcement must be anchored in the concrete on the side facing away from the load direction with an anchoring length $l_{b,net}$ acc. to DIN 1045-1:2008-08 or $l_{b,d}$ according to DIN EN 1992-1-1:2011-01 with DIN EN 1992-1-1/NA:2011-01.
In case of non-centric transverse loads the reinforcement designed for the Anchor Bolt with the highest load must be provided for all Anchor Bolts.

3.2.5 **Proof of the structural element load-bearing capacity according to DIN 1045-1:2008-08 or DIN EN 1992-1-1 :2011-01 with DIN EN 1992-1-1/NA:2011-01**

It must be proved that the shear stresses caused by the bolt loads $V_{Sd,a}$ do not exceed the value 0.4 $V_{Rd,ct}$ ($V_{Rd,ct}$ = design value of the resistance for transverse stress acc. to DIN 1045-1:2008-08), design value for shear force resistance according to DIN EN 1992-1-1 :2011-01 with DIN EN 1992-1-1 INA:2011-01).

For the calculation of $V_{sd,a}$, the Anchor Bolt loads are to be considered as point loads with a load direction width of $t_1 = s_{t1} + 2h_{ef}$ and $t_2 = s_{t2} + 2h_{ef}$, assuming s_{t1} (s_{t2}) = centre spacing between the outer bolts of a group of bolts in direction 1 (2). The effective width is to be calculated according to the elasticity theory.
This proof can be omitted, if one of the following conditions is present (see also table 3.4):

a) The transverse load on the structural element, caused by the design value of the loads including the bolt loads is $V_{sd} \leq 0.8\ V_{Rd,ct}$ or $\leq 0.8\ V_{Rd,c}$

b) Under the characteristic effects the resulting tensile load N_{sk} of the tensile stressed anchor connections (Anchor Bolt groups) is $N_{sk} \leq 30$ kN, and the centre spacing between the outer bolts of adjacent groups complies with equation (3.6.1)

$$a \geq 200\ \sqrt{N_{Sk}} \qquad a\ [mm];\ N_{Sk}\ [kN] \qquad (3.6.1)$$

N_{sk} means here the tensile load component of the characteristic effective load on the Anchor Bolt connection (Anchor Bolt group)

c) The Anchor Bolt loads are taken up by a restraint reinforcement. Hoops which enclose the tensile reinforcement and which are arranged in an area of a maximum distance of $0.5\ h_{ef} \leq 50$ mm apart from the outer bolt of an Anchor Bolt group can be considered as sufficient restraint reinforcement, if these links can be proven for the additional loads resulting from the anchor connection.

If the resulting tensile load N_{sk} of the tensile stressed anchor connections under the characteristic effects is $N_{sk} \geq 60$ kN, a restraint reinforcement according to paragraph c must be provided.

Table 3.4: Proofs for ensuring the load-bearing capacity of the structural element under the effect of Anchor Bolt loads

Calculated transverse stress of the structural element ta-king bolt loads into account	Centre spacing ´a` between the Anchor Bolt groups [mm]	N_{sk} [KN]	Proof of the calculated transverse stress from the bolt loads
$V_{sd} \leq 0.8 \cdot V_{Rd,ct}$ or $> 0{,}8 \cdot V_{Rd,c}$	$a \geq 3\ h_{ef}$	≤ 60	not required
$V_{sd} > 0{,}8 \cdot V_{Rd,ct}$ or $> 0{,}8 \cdot V_{Rd,c}$	$a \geq 3\ h_{ef}$ and $a \geq 200 \cdot \sqrt{N_{sk}}$	≤ 30	not required
	$a \geq 3\ h_{ef}$	≤ 60	required $V_{sd} \leq 0.4\ V_{Rd,ct}$ or $V_{sd} \leq 0.4 \cdot V_{Rd,c}$ or restraint reinforcement
		> 60	not required, but restraint reinforcement required

3.2.6 Displacement behaviour

The expected displacements under the given associated loads are listed in the following table.

Table 3.5: Displacements [mm]

HAB MH Anchor Bolt Size		22	27	36	39	45	52	60
Displacement under tensile load	Tensile load	112	171	212	283	340	418	502
	Associated displacement	0.6	1.6	3.7	3.9	5.4	3.7	5.2
Displacement under transverse load	Transverse load	62	94	168	201	269	362	486
	Associated displacement	1.7	2.4	4.9	5.2	7.1	9.7	13.3

4 Provisions for execution

4.1 Installation of anchor connections

The anchor connections must be installed according to the compulsory design drawing. The design drawings must show the exact position and the execution data (position, size and lengths of the Anchor Bolts) of the anchor connections. The anchor connections must be fastened to the formwork so that they are not displaced when the reinforcement is placed and the concrete is poured and compacted. During concreting, it must be ensured that the concrete is particularly well compacted under the heads of the anchor bolts. After installation, the recesses for the nuts and the concrete –steel joint between the precast reinforced concrete column and the corresponding bolt connection must be filled with grout. The grout must be according to DAfstb guide-lines "composition and application of cement based pouring concrete and pouring grout" and must be flush with the column.
The maximum installation moment T_{inst} acc. to table 1, appendix 4, may not be exceeded, in particular with the fastening of the base plate according to appendix 3.
The use of a torque wrench is not required for Anchor Bolt load bearing capacity.

4.2 Checking execution of work

The contractor who is responsible for anchoring the Anchor Bolts or the construction supervisor assigned by him or a competent representative of the construction supervisor must be present on site while the anchor connections are being installed. He must ensure that the work is executed properly. In particular, he must check the design and position of the anchor connections as well as any restraint reinforcement. Records must be available on site during the construction period and must be submitted to authorised supervisory personnel on request. After completion of the work, the records must be archived by the contractor as with the delivery notes for at least five years.

4.3 Fitting the Column Shoe

The matching Halfen Column Shoes must be fitted in accordance with the installation instructions from Halfen. The assembly joint between the concrete structural element and the Column Shoe as well as the recesses for the nuts must be completely grouted afterwards with a high-strength, non-shrink mortar.

Feistel

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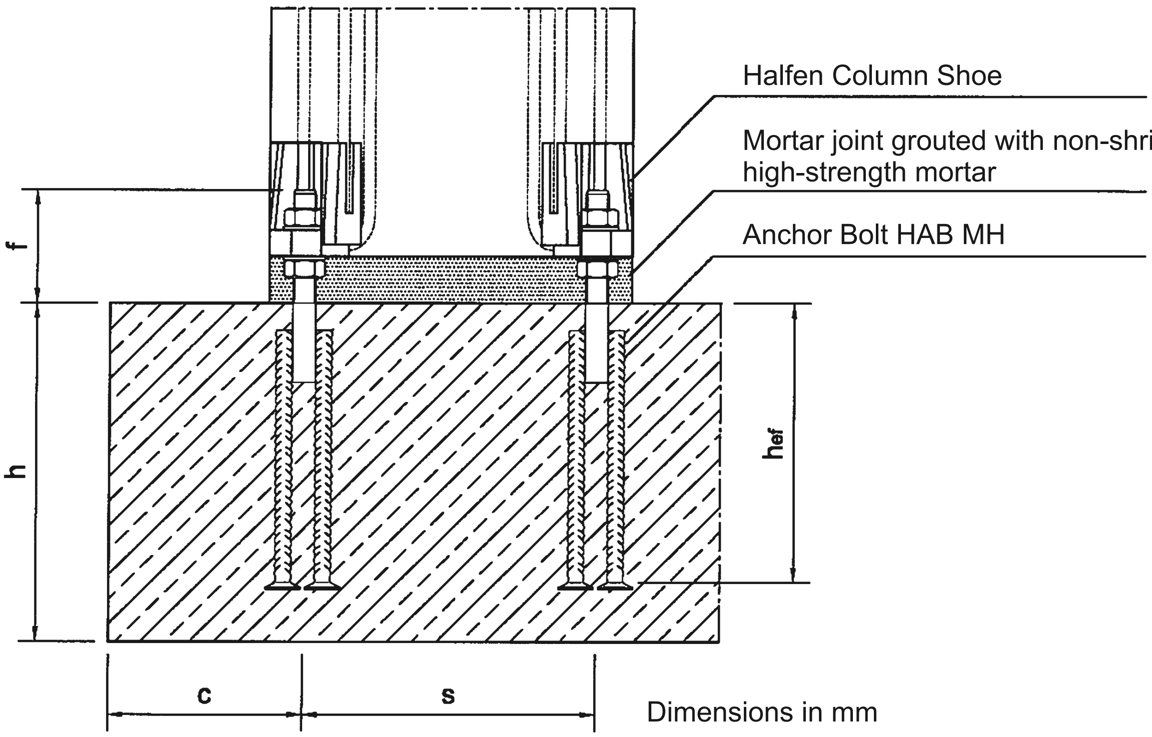
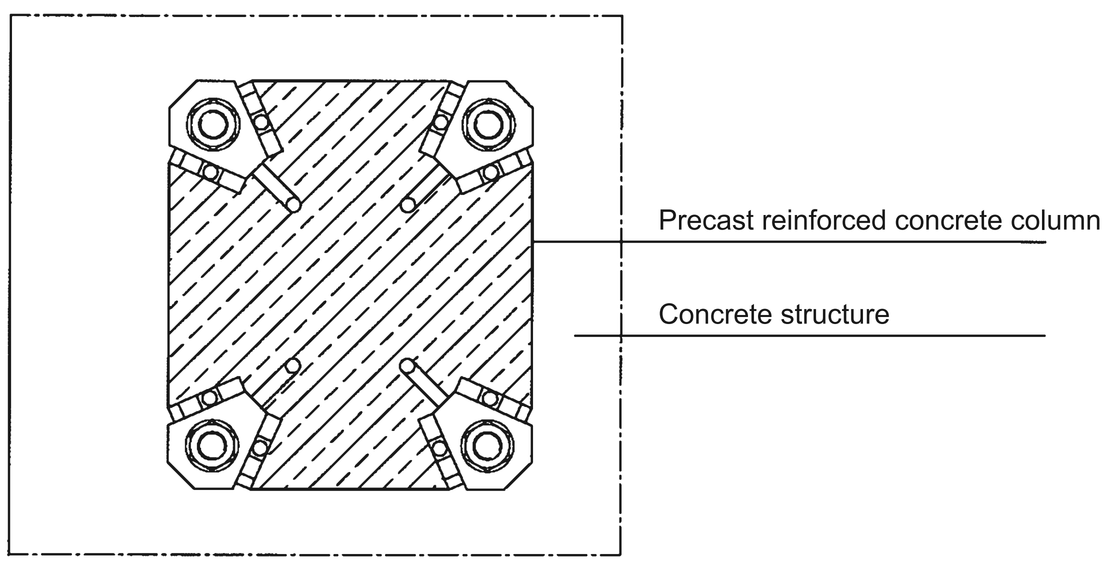
Vertical section



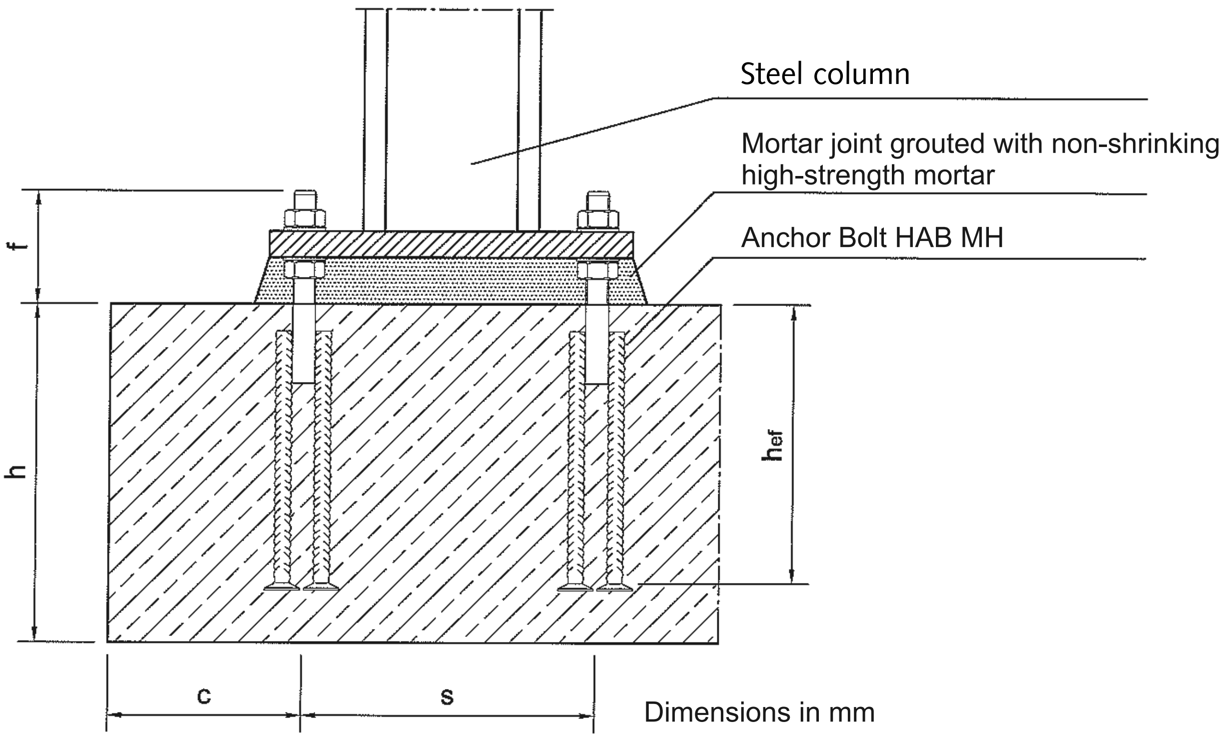
h	Thickness of concrete element
h_{ef}	Effective anchoring depth
c	Edge distance
s	Centre spacing
f	Projection of the Anchor Bolt from the concrete surface

Horizontal section



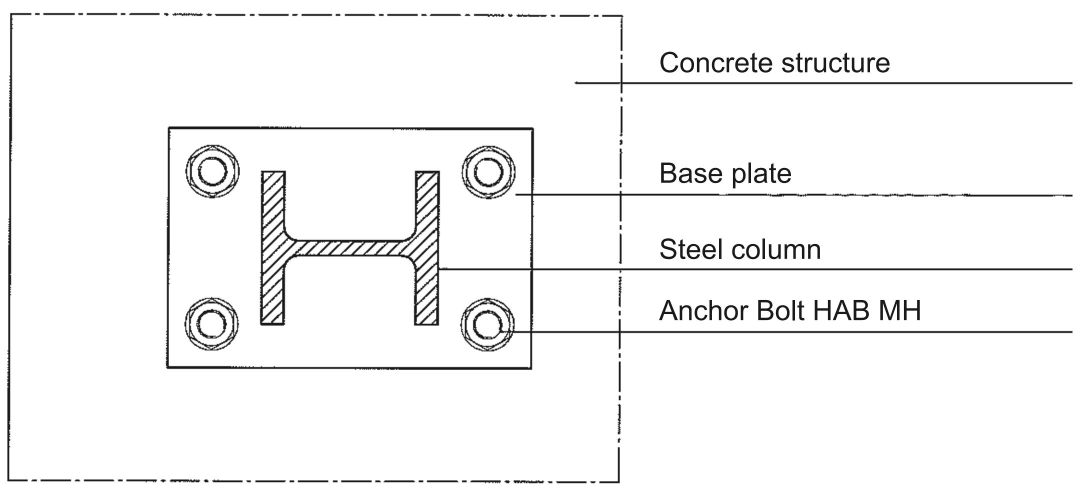
Halfen GmbH Liebigstr. 14 D - 40764 Langenfeld Phone +49-(0) 2173-970-0 Fax +49-(0) 2173-970-123	**Halfen Anchor Bolt HAB MH** Installed state Prefabricated column	Appendix 1

Vertical section



h	Thickness of concrete element
h_{ef}	Effective anchoring depth
c	Edge distance
s	Centre spacing
f	Projection of the Anchor Bolt from the concrete surface

Horizontal section



To be used in dry interior rooms only

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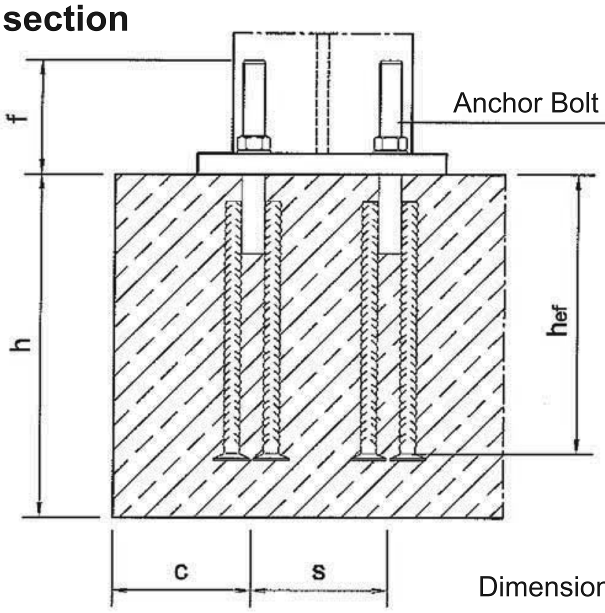
Halfen Anchor Bolt HAB MH

Installed state
steel column with counter nut screw connection

Appendix 2

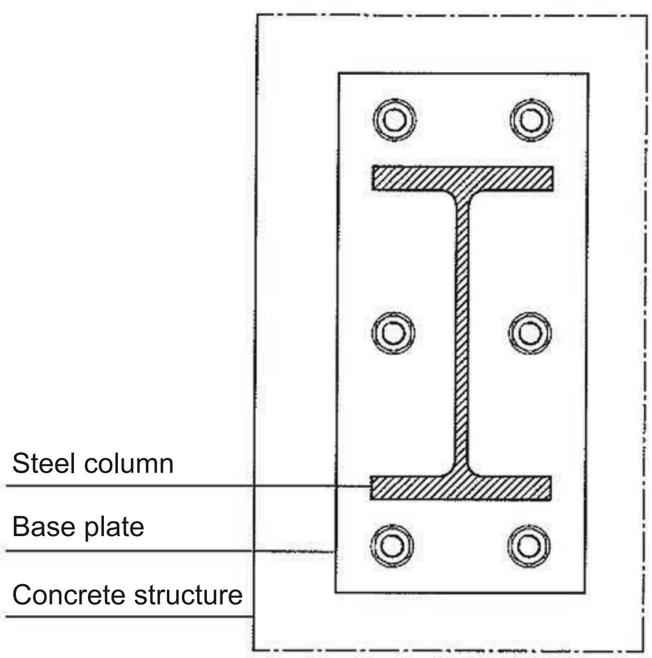
Vertical section



Dimensions in mm

h Thickness of concrete element
h_{ef} Effective anchoring depth
c Edge distance
s Centre spacing
f Projection of the Anchor Bolt from the concrete surface

Horizontal section



(Example)

To be used in dry interior rooms only

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Halfen Anchor Bolt HAB MH

Installed state
steel column without
nut screw connection

Appendix 3

Figure 1: Symbols used

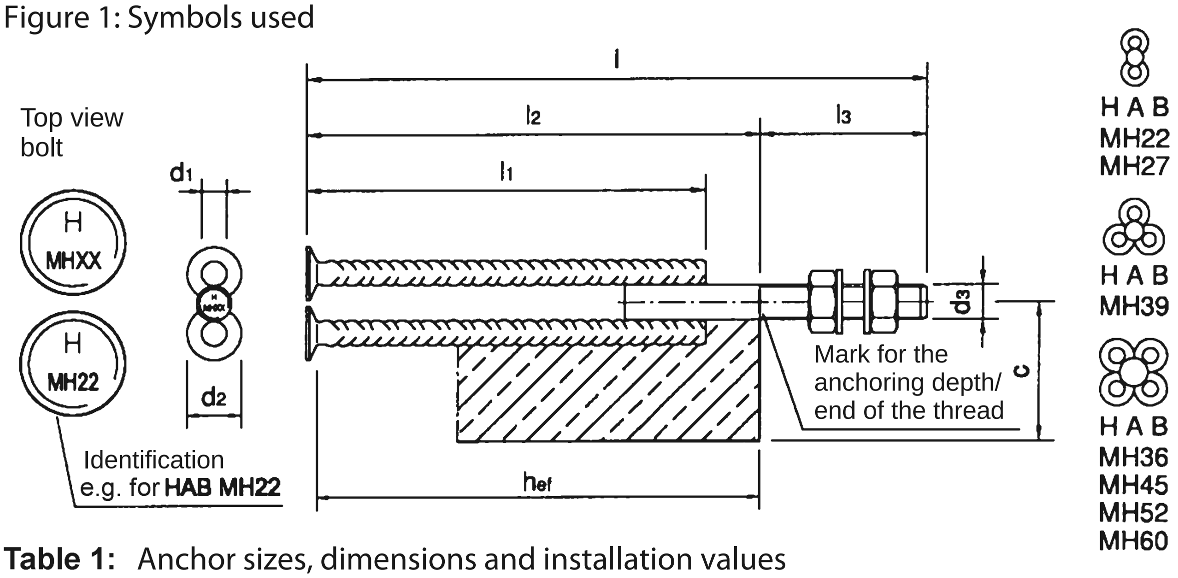


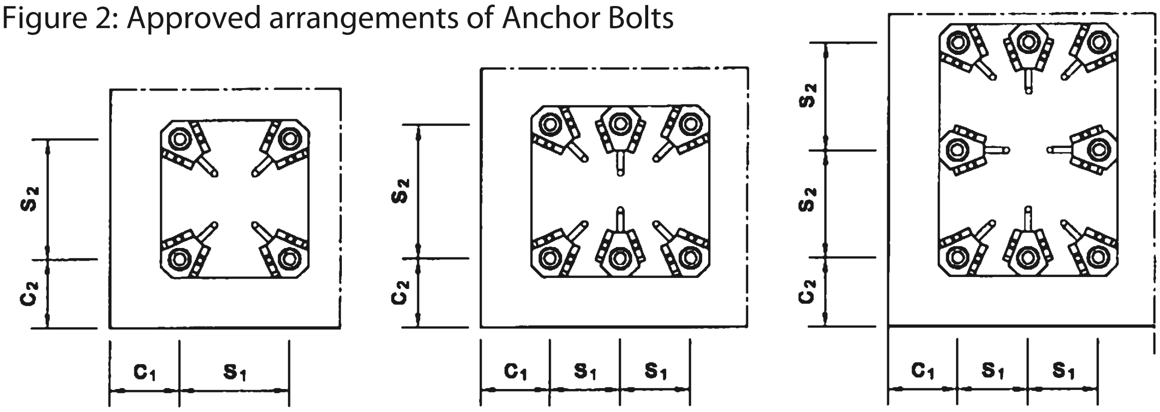
Table 1: Anchor sizes, dimensions and installation values

Anchor Bolt identification			HAB MH22	HAB MH27	HAB MH36	HAB MH39	HAB MH45	HAB MH52	HAB MH60
Total length	l	[mm]	510	650	740	880	980	1140	1330
Number of anchor studs	n		2	2	4	3	4	4	4
Installation depth	l_2	[mm]	380	500	575	695	785	900	1020
Bolt protrusion / thread length	l_3	[mm]	130	150	165	185	195	240	310
Minimum spacing	s_{min}	[mm]	130	130	160	180	200	280	280
Minimum edge distance	c_{min}	[mm]	100	120	140	150	160	180	180
Effective anchoring length	h_{ef}	[mm]	368	487	563	682	772	885	1000
Anchoring length	l_1	[mm]	320	450	520	640	730	860	1000
Diameter anchor bars	d_1	[mm]	20	25	20	25	25	32	32
Diameter headed stud	$d_2 \geq$	[mm]	46	55	46	55	55	70	70
Diameter thread	d_3	[mm]	22	27	36	39	45	52	60
Bolt tensional area	A_{sp}	[mm²]	303	459	817	976	1306	1758	2362
Base area	A_h	[mm²]	2695	3770	5391	5655	7540	12177	12177
max. installation torque	T_{inst}	[Nm]	250	550	1200	1400	2000	3300	3800

Table 2: Materials

Concr.reinf.steel	Headed stud diam.20 to 25mm: B 500 B, DIN 488-2:2009-08, diam.32: B 500 B according to General Certificate of Approval
Threaded part	S690, DIN EN 10025 -6:2005-02 or Imacro M
Washers	DIN EN ISO 7089:2000-11, S355J0 acc. to DIN EN 10025-2:2005-04
Hex-head nuts	Strength grade 8 acc. to DIN EN ISO 4032:2001-03 and DIN EN 20898-2:1994-02

Figure 2: Approved arrangements of Anchor Bolts



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Indices

S	=	Stress
R	=	Resistance
k	=	Characteristic value
d	=	Design value
s	=	Steel
c	=	Concrete
cb	=	Local concrete blow-out (blow-out failure)
cp	=	Concrete blow-out on the side facing away from the load (pryout failure)
p	=	Pull-out failure

Effects and resistances

F	=	Force (resultant force)
N	=	Normal force (positive tensile force)
V	=	Transverse force
M	=	Bending moment

F_{Sk} (N_{Sk}; V_{Sk}; M_{Sk})	=	Characteristic value of the stress (normal force, transverse force, bending moment)
F_{Sd} (N_{Sd}; V_{Sd}; M_{Sd})	=	Design value of the stress (normal force, transverse force, bending moment)
F_{Rk} (N_{Rk}; V_{Rk}; M_{Rk})	=	Characteristic value of the resistance (load bearing capacity: normal force, transverse force, bending moment)
F_{Rd} (N_{Rd}; V_{Rd}; M_{Rd})	=	Design value of the resistance (load bearing capacity: normal force, transverse force, bending moment)
N^h_{Sd} (V^h_{Sd})	=	Design value of the effective tensile force (transverse force) of the Anchor Bolt with the highest stress
N^g_{Sd} (V^g_{Sd})	=	Design value of the effective resulting force of all tensile stressed (transverse stressed) bolts

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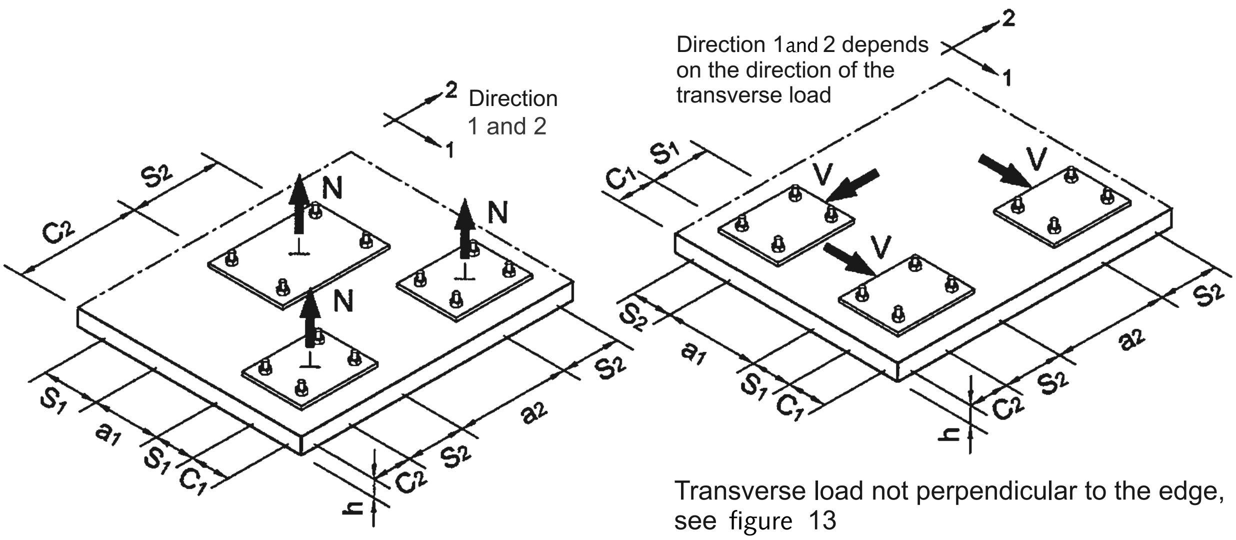
Halfen Anchor Bolt HAB MH

Terms and symbols

Anchor Bolt connection characteristics

a_1	=	Distance between the outer Anchor Bolts of neighbouring groups of bolts in direction 1
a_2	=	Distance between the outer Anchor Bolts of neighbouring groups of bolts in direction 2
b	=	Width of the concrete structural component
c_1	=	Distance from the edge in direction 1, with anchor connections under transverse stress, c_1 is the distance from the edge in the direction of the load (see fig. 3)
c_2	=	Distance from the edge in direction 2, direction 2 is perpendicular to direction 1
c_{min}	=	Minimum permitted distance from the edge
s_1	=	Centre spacing within a group of Anchor Bolts in direction 1
s_2	=	Centre spacing within a group of Anchor Bolts in direction 2
s_{min}	=	Minimum permitted centre spacing
d_1	=	Diameter of the shaft of the anchor stud
d_2	=	Diameter of the head of the anchor stud
d_3	=	Diameter of the thread of the central anchor rod
h_{ef}	=	Effective anchoring depth
h	=	Thickness of the concrete structural component
h_{min}	=	Minimum thickness of the concrete structural component
l_2	=	Length of the Anchor Bolt in the concrete structural element

Figure 3: Concrete element, centre spacing and distances from the edge



Transverse load not perpendicular to the edge, see figure 13

a) Anchor Bolts under tensile load

b) Anchor Bolts under transverse load in an anchor connection near to the edge

Characteristic resistance values for the proof of the load bearing capacity under tensile stress

Table 3: Characteristic tensile load bearing capacity $N_{Rk,s}$ of an anchor bolt at steel failure in kN

Anchor Bolt size	HAB MH22	HAB MH27	HAB MH36	HAB MH39	HAB MH45	HAB MH52	HAB MH60
Characteristic tensile load bearing capacity $N_{Rk,s}$ [kN]	242	367	654	781	1045	1406	1769

Table 4: Characteristic tensile load bearing capacity $N_{Rk,p}$ of an anchor bolt at pull-out failure in kN

Anchor Bolt size	HAB MH22	HAB MH27	HAB MH36	HAB MH39	HAB MH45	HAB MH52	HAB MH60
Characteristic tensile load bearing capacity in concrete grade C20/25 at pull-out $N_{Rk,s}$ [kN]	404	565	809	848	1131	1827	1827

Table 5: Factor Ψ of the tensile load bearing capacity $N_{Rk,p}$ at pull-out failure depending from the concrete strength

Concrete grade	C12/15	C20/25	C30/37	C40/50	C50/60
Increasing factor Ψ	0.60	1.00	1.48	2.00	2.40

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Characteristic tensile load bearing capacity with steel failure and at pull-out

Local concrete blow-out with anchor connections near the edge

The characteristic tensile load capacity of an Anchor Bolt or an Anchor Bolt group with local concrete blow-out near the edge is

$$N_{Rk,cb} = N^0_{Rk,cb} \cdot \frac{A_{c,Nb}}{A^0_{c,Nb}} \cdot \Psi_{s,Nb} \cdot \Psi_{g,Nb} \cdot \Psi_{ec,Nb} \quad [N] \qquad (3.7)$$

The proof for local concrete blow-out near the edge of the structural element must always be carried out, if the actual edge distance is $c \leq 0.5\ h_{ef}$ in one direction. In the following the individual factors of the equation (3.7) are specified:

a) The initial value of the characteristic load capacity of a bolt is:

$$N^0_{Rk,cb} = 8 \cdot c_1 \cdot \sqrt{A_h} \cdot \sqrt{f_{ck,cube}} \quad [N] \text{ with} \qquad (3.7a)$$

c_1 [mm] Distance to the edge
A_h [mm²] Base area of the anchor heads of an Anchor Bolt, see table 1
$f_{ck,cube}$ [N/mm²], for $f_{ck,cube}$ may be assessed at max. 60 N/mm²

b) The influence of the centre spacings and edge distances on the characteristic load capacity is considered with the ratio $A_{c,Nb}/A^0_{c,Nb}$

$A^0_{c,Nb}$ = $16c_1^2$; projected area of an Anchor Bolt (on one lateral side of the concrete). Thereby the blow-out body is assumed as a pyramid with the peak at the centre of the bolt head, with a height c_1 and a length of one side of the base 4 c_1 (see figure 4).

$A_{c,Nb}$ = actual projected area (on the lateral side of the concrete).

When calculating, the blow-out body of the Anchor Bolt is to be idealised as described above, and the interference of the projected areas must be considered. Example for the calculation of the projected area: see figure 5).

c) The factor of influence $\Psi_{s,Nb}$ takes into account the disruption of the tensile state in the concrete at the corner of the structural element.

$$\Psi_{s,Nb} = 0.7 + 0.3 \cdot \frac{c_2}{c_1} \leq 1 \qquad (3.7b)$$

For securing the corner of the structural element a corner reinforcement must be provided, which must be dimensioned for the tensile load of the bolt.

d) The factor of influence $\Psi_{g,Nb}$ takes into account the influence of the base areas of the individual anchoring devices within an anchoring group.

$$\Psi_{g,Nb} = \sqrt{n} + \left(1 - \sqrt{n}\right) \cdot \frac{s_1}{4c_1} \geq 1 \quad (s_1 \leq 4c_1) \qquad (3.7c)$$

n = number of Anchor Bolts under tensile load, arranged in a line parallel to the edge of the structural eleman anchoring group.

e) The factor of influence $\Psi_{ec,Nb}$ takes into account a non-centric tensile load on the anchoring arranged in a line.

$$\Psi_{ec,Nb} = \frac{1}{1 + 2e_N/(4c_1)} \leq 1 \qquad (3.7d)$$

e_n = „inner“ non-centricity of the bolts under tensile load
(see also equation (3.8c))

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Halfen Anchor Bolt
HAB MH

Characteristic tensile load bearing capacity with local concrete failure at the edge

Figure 4: Idealised concrete blow-out

$$A^{0}_{c,Nb} = 16 \cdot c_1^{\,2}$$

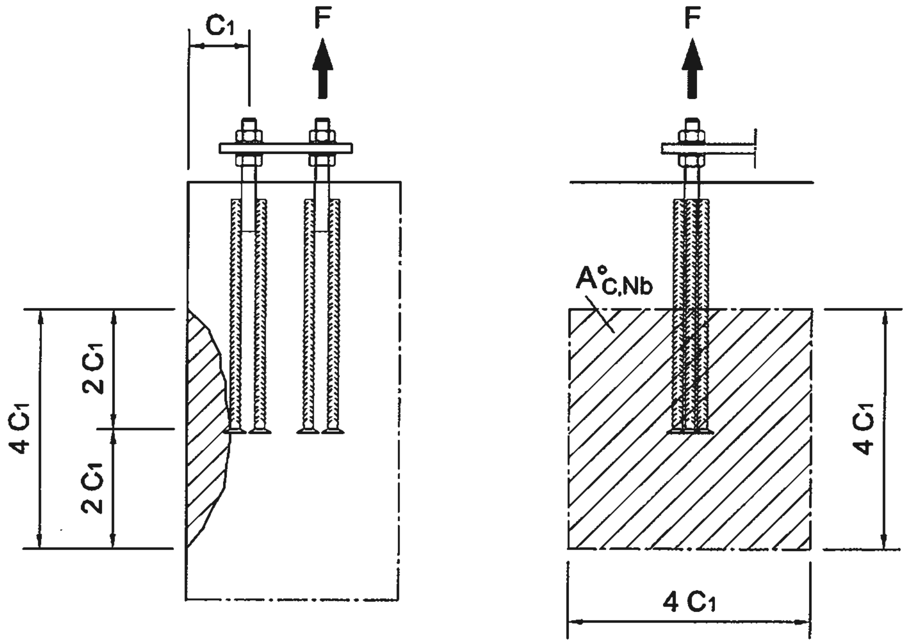
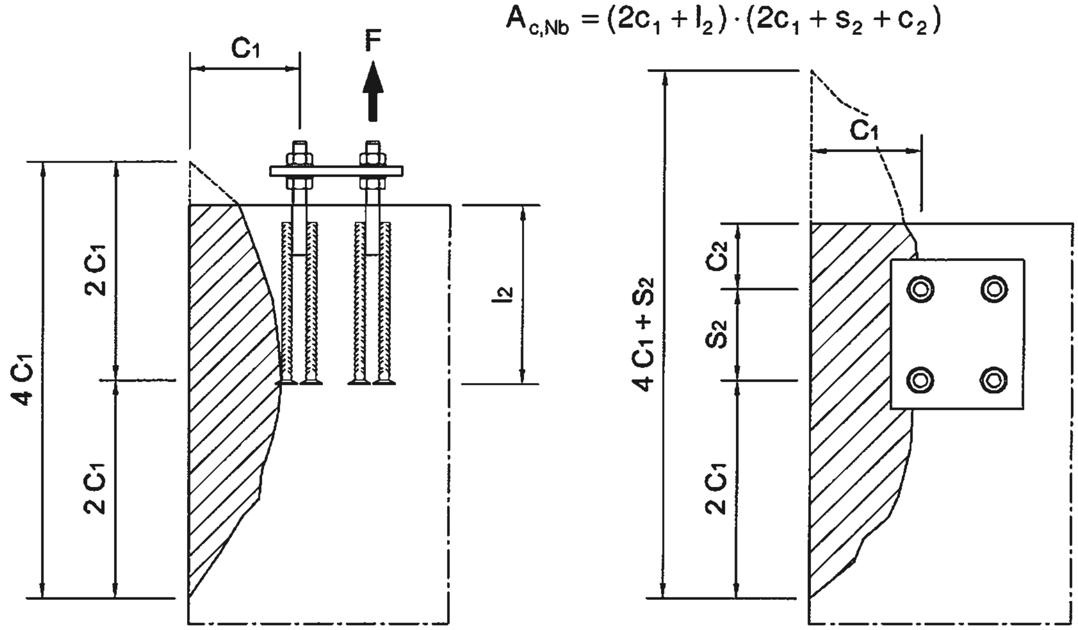


Figure 5: Example for a local concrete blow-out at the edge

$$A_{c,Nb} = (2c_1 + l_2) \cdot (2c_1 + s_2 + c_2)$$



Section

Plan view

Halfen GmbH Liebigstr. 14 D - 40764 Langenfeld Phone +49-(0) 2173-970-0 Fax +49-(0) 2173-970-123	**Halfen Anchor Bolt HAB MH** Characteristic tensile load bearing capacity with local concrete failure at the edge	Appendix 9

Concrete blow-out

The characteristic tensile load capacity of an Anchor Bolt or an Anchor Bolt group with concrete blow-out is:

$$N_{Rk,c} = N^0_{Rk,c} \cdot \frac{A_{c,N}}{A^0_{c,N}} \cdot \Psi_{s,N} \cdot \Psi_{ec,N} \cdot \Psi_{re,N} \qquad [N] \qquad (3.8)$$

The individual factors of the equation (3.8) are shown in the following:

a) The initial value of the characteristic tensile load-bearing capacity of a bolt in the concrete is:

$$N^0_{Rk,c} = 8.5 \cdot \sqrt{f_{ck,cube}} \cdot h_{ef}^{1.5} \qquad [N] \text{ with} \qquad (3.8a)$$

$f_{ck,cube}$ [N/mm²], for $f_{ck,cube}$ can be set as a maximum of 60 N/mm²

h_{ef} [mm]

b) The effect of the centre spacings and edge distances on the characteristic load-bearing capacity is taken into account by the ratio $A_{c,N}/A^0_{c,N}$:

$A^0_{c,N}$ = area of the blow-out body of a single bolt with large centre spacing and distance from the edge on the concrete surface. The blow-out body is idealised as a pyramid of height h_{ef} and length of side of base $3h_{ef}$ (see fig. 6

$A_{c,N}$ = available area of the blow-out body of the anchor connection on the concrete surface. It is limited by the overlapping of the individual blow-out bodies of neighbouring anchorings ($s \leq 3h_{ef}$) and by the edges of the structural elements ($c \leq 1.5h_{ef}$).
Example for the calculation of $A_{c,N}$: fig. 6

c) The factor of influence $\Psi_{s,N}$ takes into account the disruption of the rotationally symmetric state of stress in the concrete due to the edges of the structural element. With several edges of the structural element (e.g. with anchor connections at the corner of the structural element or in a narrow structural element), the smallest distance to the edge c must be used in equation (3.8b).

$$\Psi_{s,N} = 0.7 + 0.3 \cdot \frac{c}{1.5h_{ef}} \leq 1 \qquad (3.8b)$$

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Figure 6: Idealised concrete blow-out body and area $A^0_{c,N}$ of the concrete blow-out body of an Anchor Bolt

$$A^0_{c,N} = 9 \cdot h_{ef}^2$$

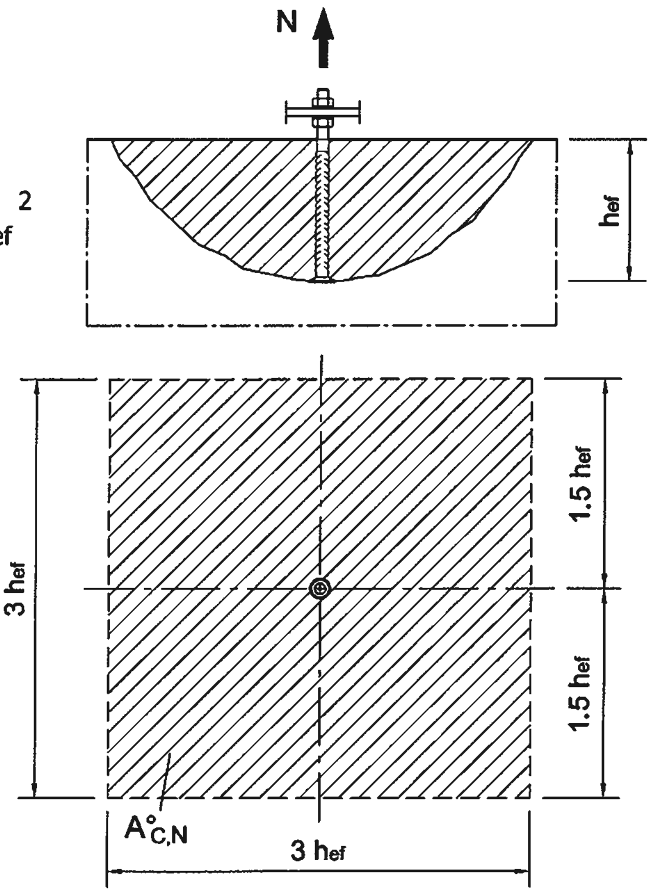
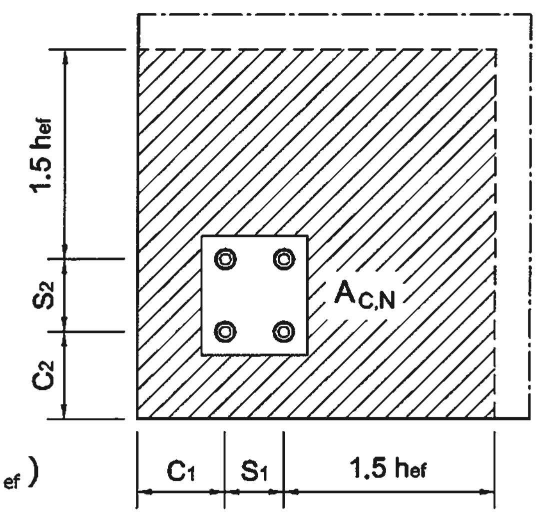


Figure 7: Example for the available area of the idealised concrete blow-out body under tensile stress from the Anchor Bolts



$$A_{c,N} = (c_1 + s_1 + 1.5h_{ef}) \cdot (c_2 + s_2 + 1.5h_{ef})$$

d) The factor of influence $\Psi_{ec,N}$ takes non-centric tensile stress from a group of Anchor Bolts into account.

$$\Psi_{ec,N} = \frac{1}{1 + 2e_N / (3h_{ef})} \leq 1 \qquad (3.8c)$$

e_N = non-centricity of the resulting tensile force of the Anchor Bolts.

This must be determined from the calculated tensile forces and be referenced to the geometrical centre of mass G of the tensile-stressed Anchor Bolts. In those cases where there is non-centricity in two directions, $\Psi_{ec,N}$ must be determined separately for each direction and the product of both factors used in equation (3.8c). If not all Anchor Bolts are tensile stressed, the group of Anchor Bolts may be considered as a rectangular grid for the determination of the geometrical centre of mass.

To be on the safe side, the factor of influence $\Psi_{ec,N}$ = 1.0 can be used, if the characteristic load-bearing capacity of the most highly stressed Anchor Bolt is calculated as

$$N^h_{Rk,c} = \frac{N_{Rk,c}}{n} \qquad (3.8d)$$

where n = number of Anchor Bolts under tensile stress

Then, instead of the proof according to table 3.2, line 4a,

the proof

$$N^h_{Sd} \leq N^h_{Rk,c} / \gamma_{Mc}$$

must be provided.

e) The surface blow-out factor $\Psi_{re,N}$ takes into account the effect of dense reinforcement.

$$\Psi_{re,N} = 0.5 + \frac{h_{ef}}{200} \leq 1 \qquad (3.8e)$$

h_{ef} [mm]

As long as reinforcement with a centre spacing of ≤ 15 cm is present in the area of the anchor connection, a surface blow-out factor of $\Psi_{re,N}$ = 1.0 can be used regardless of the anchoring depth.

Steel failure of the suspension reinforcement

The characteristic steel load capacity of the suspension reinforcement per bolt is:

$$N_{Rk,re} = n \cdot A_s \cdot f_{yk} \qquad [N]$$

with

- n = number of effective legs of the suspension reinforcement per bolt
- A_s = cross-sectional area of a leg of the suspension reinforcement [mm²]
- f_{yk} = characteristic value of the yield stress of the suspension reinforcement [N/mm²]

Failure of the anchoring of the suspension reinforcement

The design value of resistance of the anchoring of the suspension reinforcement in the blow-out cone is:

$$N_{Rd,a} = \sum_n \frac{l_n \cdot \pi \cdot d_s \cdot f_{bd}}{\alpha_a} \qquad [N]$$

with

- l_n = anchoring length of leg number n of the suspension reinforcement in the blow-out cone [mm]

$$\geq l_{b,min} = \begin{cases} 4 \cdot d_s & \text{(hook or loop)} \\ 10 \cdot d_s & \text{(straight bars)} \end{cases}$$

- $l_{b,min}$ = minimum anchoring length
- d_s = bar diameter of the suspension reinforcment [mm] ≤16 mm
- f_{bd} = design value of the bond stress depending on the concrete strength class acc. to DIN 1045-1:2008-08, sect. 12.5
- α_e = coefficient for considering the mode of anchoring 0.7 for hook
- n = number of effective link legs per bolt

The restraint reinforcement must be placed close to the bolts, they must have the same diameter and be anchored outside the blow out cone with an anchoring length $l_{b,net}$ acc. to DIN 1045-1:2008-08, paragraph 12.6.2 or $l_{b,d}$ according to DIN EN1992-1-1: 2011-01 with DIN EN 1992-1-1/NA: 2011-01, paragraph 8.4.3. Only links and hooks which are placed in a distance ≤ 0.75 h_{ef} from the bolt are suitable as restraint reinforcement. A bending roll diameter d_{br} must be observed for restraint reinforcement according to DIN 1045-1:2008-08, paragraph 12.3.1. or DIN EN 1992-1-1: 2011-01 with DIN EN 1992-1-1/NA: 2011-01, paragraph 8.3

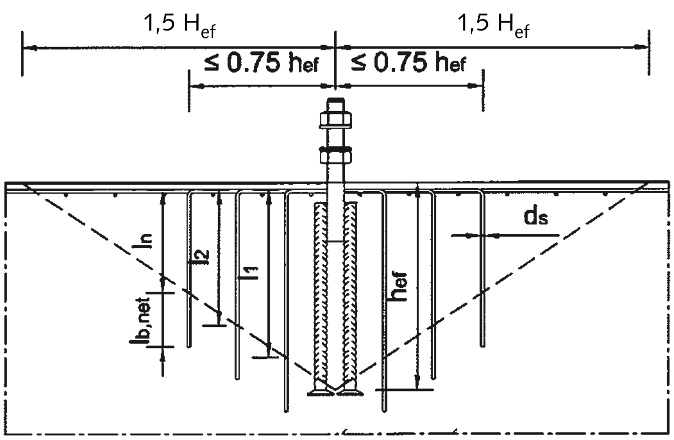


Fig. 8: Example for the arrangement of the suspension reinforcement, for which the dimensioning of a surface reinforcement is required

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Characteristic resistance values for the proof of the load capacity under transverse stress

Table 6: Characteristic resistance values of an Anchor Bolt under transverse load with and without lever arm at steel failure

Anchor Bolt size	HAB MH22	HAB MH27	HAB MH36	HAB MH39	HAB MH45	HAB MH52	HAB MH60
Characteristic resistance VRk,s [kN] under **transverse load without lever arm**	109	165	294	351	470	633	850
Characteristic resistance $M^0_{Rk,s}$ [Nm] under **transverse load with lever arm**	714	1330	3160	4130	6390	9980	15500

The following applies for transverse load with lever arm:

$V_{Rk,s}$ = $M_{Rk,s}/m$

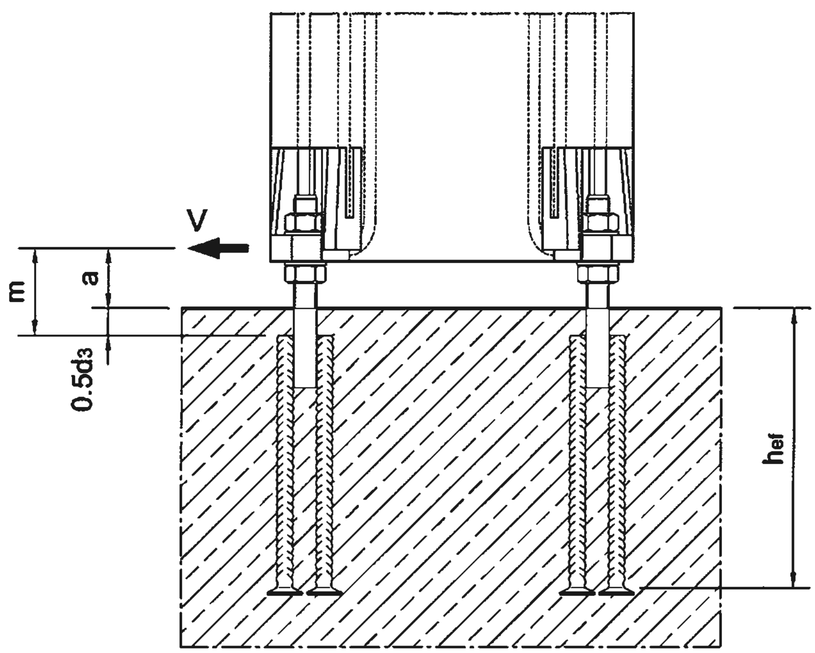
m = $a + 0.5\,d_3$ (lever arm, d_3 acc. to appendix 4)

a = Distance between transverse load and concrete surface

$M_{Rk,s}$ = $M^0_{Rk,s}\,(1 - N_{Sd}/N_{Rd,s})$

$N_{Rd,s}$ = $N_{Rk,s}/\gamma_{Ms}$

Fig. 9: Transverse load with lever arm, definitions



Concrete failure - concrete blow-out on the side facing away from the load

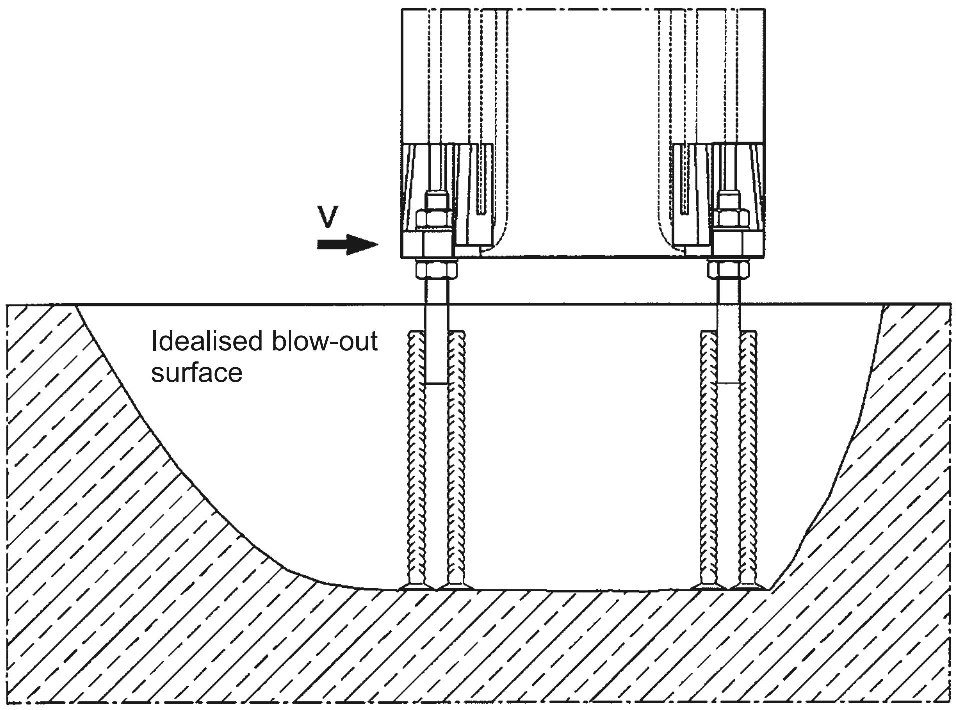
The associated characteristic transverse load capacity $V_{Rk,cp}$ is to be calculated from equation 3.9:

$$V_{Rk,cp} = 2.0^{1)} N_{Rk,c} \tag{3.9}$$

$N_{Rk,c}$ is to be calculated according to equation 3.8 (appendix 10). Thereby $N_{Rk,c}$ is to be determined for the Anchor Bolts under transverse stress.

1) For anchor connections with suspension reinforcement acc. to appendix 20 or 19 this factor is to be assessed with 1.5 .

Fig. 10: Concrete blow-out on the side facing away from the load



Concrete edge blow-out at anchor connections near the edge

The characteristic transverse load capacity of an Anchor Bolt or an Anchor Bolt group situated near the edge is as follows:

$$V_{Rk,c} = V^0_{Rk,c} \cdot \frac{A_{c,V}}{A^0_{c,V}} \cdot \Psi_{s,V} \cdot \Psi_{h,V} \cdot \Psi_{\alpha,V} \cdot \Psi_{ec,V} \quad [N] \qquad (3.10)$$

For the calculation of the characteristic transverse load capacity of Anchor Bolt groups only the most unfavorably positioned Anchor Bolt, or the Anchor Bolt with the most unfavorable position at the edge of the structural element may be used (see appendix 17, fig. 12)

In the following the individual factors of the Equation (3.10) are specified.

a) The initial value of the characteristic transverse load capacity of an Anchor Bolt with load in perpendicular direction relative to the edge of the structural element is:

$$V^0_{Rk,c} = 1.6 \cdot d_3^{\alpha} \cdot h_{ef}^{\beta} \cdot \sqrt{f_{ck,cube}} \cdot c_1^{1.5} \quad [N] \text{ with} \qquad (3.10a)$$

$$\alpha = 0.1 \cdot \left(\frac{h_{ef}}{c_1}\right)^{0.5} \quad ; \ \beta = 0.1 \cdot \left(\frac{d_3}{c_1}\right)^{0.2}$$

d_3, h_{ef}, c_1 [mm]; $f_{ck,cube}$ [N/mm²], for $f_{ck,cube}$ may be assessed with max. 60 N/mm²

$h_{ef} \leq 8 \cdot d_3$

For Anchor Bolts in the sizes HAB MH45, HAB MH52 and HAB MH60 the value is to be multiplied by the factor 0.8.

b) The influence of the centre spacings and further edge distances parallel to the load direction and of the thickness of the structural element on the characteristic load capacity is considered through the ratio $A_{c,V}/A^0_{c,V}$:

$A^0_{c,V}$ = Surface of the blow-out body of an Anchor Bolt on the lateral concrete surface without influence of edges parallel to the assumed load direction, of thickness of structural element or of adjacent Anchor Bolts. Thereby the blow-out body is assumed as a half pyramid with the height c_1 and the length of the base sides 1.5 c_1 and 3 c_1 (see figure 11).

$A_{c,V}$ = Present area of the blow-out body of the anchor connection on the lateral side of the concrete. It is limited by the overlappings of the individual blow-out bodies of adjacent anchor connections ($s \leq 3\ c_1$) and by the edges of the structural elements parallel to the assumed load direction ($c_2 \leq 1.5\ c_1$) and the thickness of the structural element ($h \leq 1.5\ c_1$).
Examples for the calculation of $A_{c,V}$: (see figure 12).

For the calculation of $A^0_{c,v}$ and $A_{c,v}$ it is assumed, that the transverse load is applied perpendicularly to the edge of the structural element.

For anchor connections in the corner of the structural element ($c_2 \leq 1.5\ c_1$) the proof must be carried out for both edges of the structural elements (see appendix 17, fig. 13)

Fig. 11: Idealised concrete blow-out body and surface $A^0_{c,v}$ of an Anchor Bolt

$$A^0_{c,V} = (2 \cdot 1.5c_1) \cdot 1.5c_1 = 4.5 \cdot c_1 \cdot c_1$$

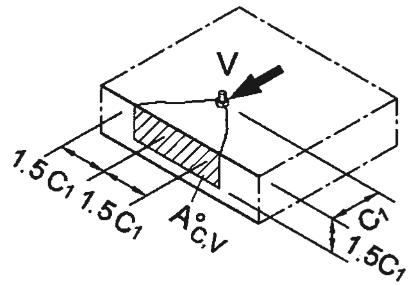
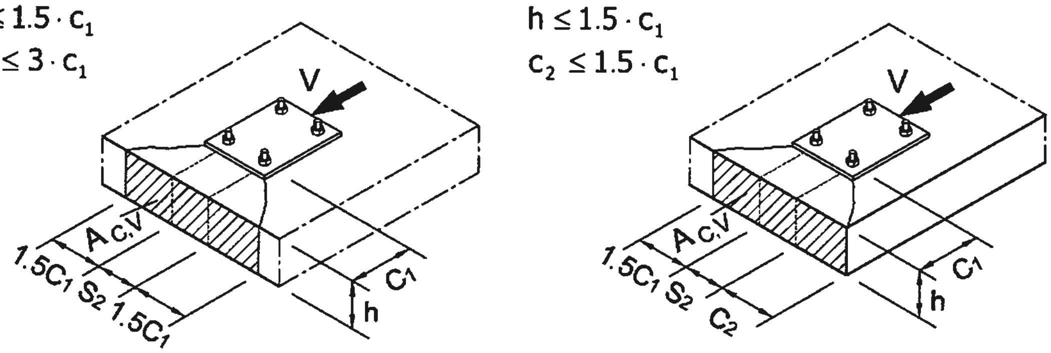


Fig. 12: Examples for present areas of the idealised concrete blow-out bodies for Anchor Bolt groups under transverse stress

$$A_{c,V} = (2 \cdot 1.5c_1 + s_2) \cdot h$$
$$h \leq 1.5 \cdot c_1$$
$$s_2 \leq 3 \cdot c_1$$

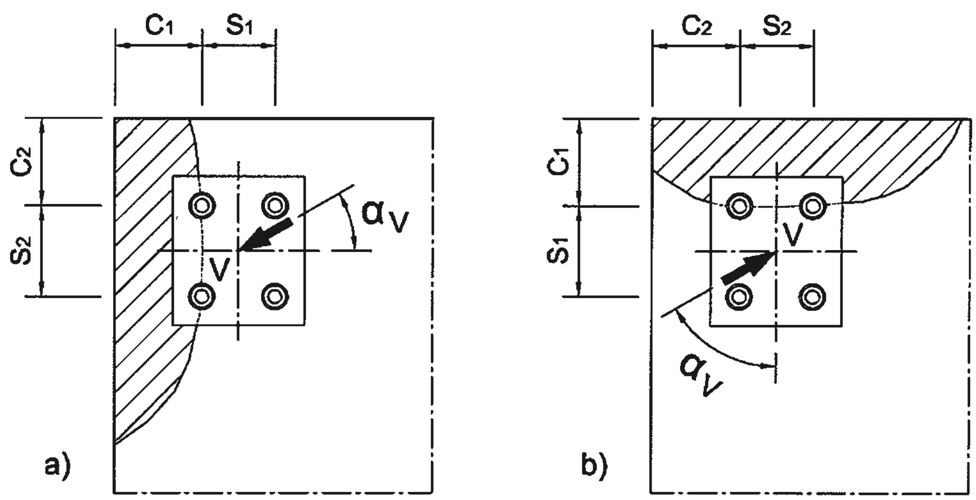
$$A_{c,V} = (1.5c_1 + s_2 + c_2) \cdot h$$
$$h \leq 1.5 \cdot c_1$$
$$c_2 \leq 1.5 \cdot c_1$$



a) Group of Anchor Bolts at the edge of a thin structural element

a) Group of Anchor Bolts at the corner of a thin structural element

Fig. 13: Examples for an Anchor Bolt group under transverse stress in the corner of the structural element (double proof required)



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Halfen Anchor Bolt HAB MH

Characteristic transverse load-bearing capacity in the case of concrete edge fracture

c) The factor of influence $\Psi_{s,V}$ takes into account the disruption of the state of stress in the concrete by further edges of the structural element. At anchor connections with two edge distances parallel to the load direction (e.g. in a slim structural element) the smaller edge distance has to be used in the equation (3.10b).

$$\Psi_{s,V} = 0.7 + 0.3 \cdot \frac{c_2}{1.5 c_1} \leq 1 \qquad (3.10b)$$

d) The factor $\Psi_{h,V}$ takes into account, that the transverse load capacity does not decrease proportionally with the thickness of the structural element.

$$\Psi_{h,V} = \left(\frac{1.5\, c_1}{h}\right)^{0.5} \geq 1 \qquad (3.10c)$$

e) With the factor $\Psi_{\alpha,V}$ the angle α between the acting load V and the direction perpendicular to the free edge of the structural element is considered (see fig. 14).

$$\Psi_{\alpha,V} = \sqrt{\frac{1}{(\cos\alpha_V)^2 + (0.4 \cdot \sin\alpha_V)^2}} \geq 1 \quad \text{for } 0° < \alpha_V \leq 90° \qquad (3.10d)$$

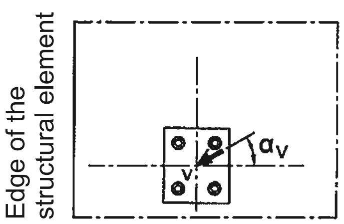

Fig. 14 Definition of the angle α_V

f) The factor of influence $\Psi_{ec,V}$ takes into account the non-centric transverse stress of a group of Anchor Bolts.

$$\Psi_{ec,V} = \frac{1}{1 + 2e_V/(3c_1)} \leq 1.0 \qquad (3.10e)$$

e_V = Non-centricity of the resulting transverse load of the Anchor Bolts. The non-centricity is to be determined from the calculated forces of the Anchor Bolts. It has to be related to the geometrical centre of mass G of the transverse-stressed Anchor Bolts.

To be on the safe side, the factor of influence may be set to $\Psi_{ec,V}$ = 1.0, when the characteristic load capacity of the Anchor Bolt with the highest load is calculated with

$$V^h_{Rk,c} = \frac{V_{Rk,c}}{n} \qquad (3.10f)$$

n = number of transverse-stressed Anchor Bolts

Then, instead of the proof acc. to table 3.3, line 4a, the proof

$V^h_{Sd} \leq V^h_{Rk,c} / \gamma_{Mc}$ must be carried out.

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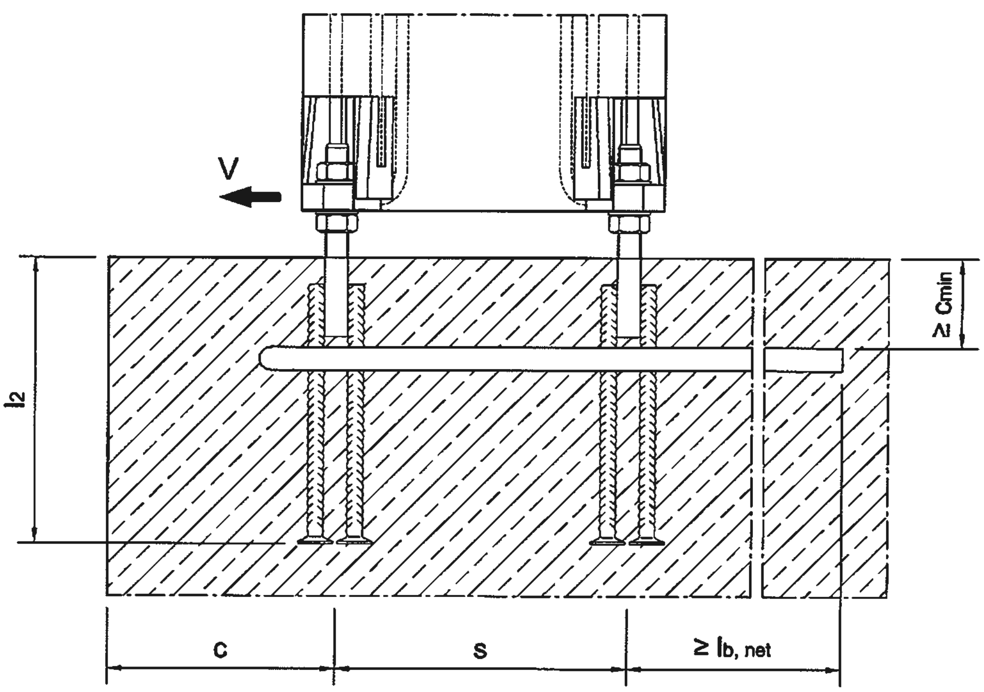
Table 7: Characteristic load capacity $V^0_{Rk,re}$ of one leg of the suspension reinforcement at anchor connections near the edge for supporting the transverse load.

Concrete reinforcm. steel BSt 500 S	∅ 8	∅ 10	∅ 12	∅ 14	∅ 16
Characteristic load bearing capacity of one leg $V^0_{Rk,re}$ [kN]	12	19	28	38	50

Only rings and stirrups in close contact with the Anchor Bolts may be used as restraint reinforcement. The minimal values required according to DIN 1045-1 for the concrete cover and the anchoring length must be maintained. Only the minimum bending roll diameter d_{br} according to DIN 1045-1 may be used.

Restraint reinforcement $V_{Rk,re} = V^0_{Rk,re}$

Fig. 15: Structual design of the restraint reinforcement



cmin, lb,net and dbr acc.to DIN 1045-1

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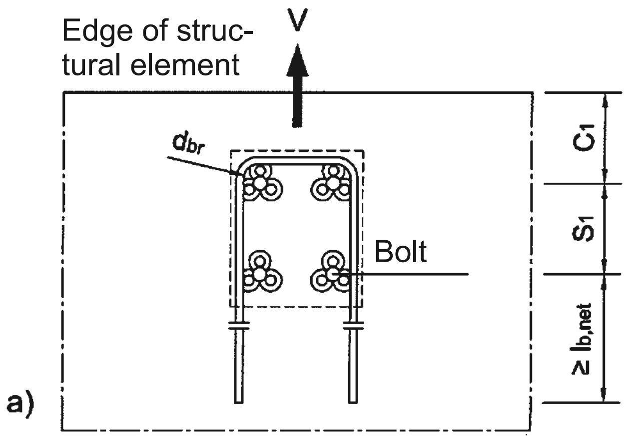
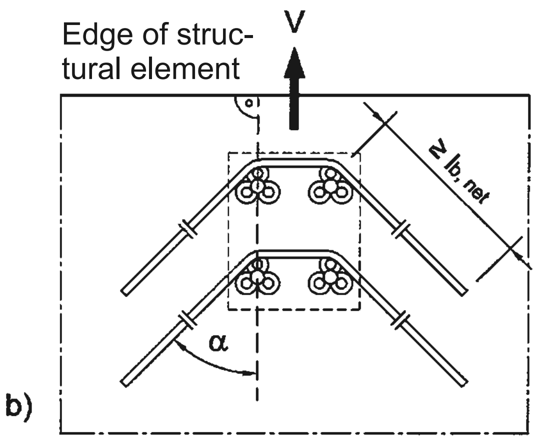
Fig. 16: Examples of restraint reinforcement for supporting the transverse load with close to the edge anchor connections



Restraint reinforcement

$$V_{Rk,re} = V^0_{Rk,re}$$



Restraint reinforcement

$$V_{Rk,re} = V^0_{Rk,re} \cdot \cos\alpha$$

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