TECHNICAL MANUAL

HPM® Rebar Anchor Bolt

Easy and fast bolted connections

Version PEIKKO GROUP 09/2022
European Technical Approval ETA-02/0006

HPM® Rebar Anchor Bolt

Easy and fast bolted connections

- Standardized and approved rebar anchor bolt system.
- Approved design parameters.
- Quick deliveries directly from stock.
- Certified production.
- Wide range of products for all anchoring purposes.
- Accessories for quick and easy installation.
- Easy to design with free Peikko Designer® software.
- Declared performances by CE marking via ETA (HPM® L).

HPM® Rebar Anchor Bolts are used to anchor concrete or steel structures and machinery into concrete base structures. The anchors are embedded into concrete and the structures are fastened to bolts by nuts and washers. The joint between two structures is then grouted.

The system consists of a wide range of headed and straight anchor bolts, installation accessories, and tools for designers. Headed bolts are used typically in shallow structures for end anchoring, whereas straight bolts are used for lap splices. In addition to plain finish bolts, the products are also available as ECO or Hot-Dip galvanized. Installation templates are provided to ensure easy and correct installation of the anchor bolts.

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About HPM® Rebar Anchor Bolt

1. Product properties

HPM® Rebar Anchor Bolts are cast-in-place anchors used to connect structural and non-structural elements to concrete in all types of buildings, warehouses, halls, bridges, dams, and power plants.

HPM® Rebar Anchor Bolts are available in several standard models that are suitable for different application solutions, loading conditions, and cross-sections. Anchor bolts are cast into concrete and transfer loads from the attachment to the base structure.

The product range consists of
- Headed anchor bolts, type HPM® L
- Straight anchor bolts, type HPM® P
- PPL Anchor Bolt Installation Template.

HPM® L Rebar Anchor Bolt

HPM® P Rebar Anchor Bolt

Type L bolt anchorage is achieved with a headed stud. Loads are transferred through the bearing of the head against hardened concrete. Due to their relatively short anchorage length, HPM® L Rebar Anchor bolts are particularly suitable for use in shallow structures (e.g. foundations, slabs, beams).

Type P bolt anchorage is achieved by splicing, whereby the bolt overlaps the main reinforcement. Loads are transferred through the bond of the ribbed bars. The primary use of HPM® P Rebar Anchor Bolts is in structures with sufficient depth (e.g. base columns, columns). Alternative usages are shown in Annex E.

HPM® Rebar Anchor Bolts are pre-designed to be compatible with HPKM® Column Shoes, SUMO® Wall Shoes, and Beam Shoes, providing a solution for most precast connections (e.g., column to foundation, column to base column, column to column, wall to foundation, wall to wall, beam to column, beam to wall), as well as to secure steel columns or even machine fixings. Anchor bolts can be equipped with debonding sleeve and closed-cell foam tube according to customer specifications.

Anchor bolts are cast into the base structure together with the main and supplementary reinforcement, as detailed in Annexes A, B, C, and D of this manual. The connection is achieved by fastening the anchor bolt to the base plate using nuts and washers. To finalize the connection, the joint is grouted with non-shrinking grouting material.

Peikko Bolted Connections can be designed to resist axial forces, bending moments, shear forces, combinations of the above, and fire exposure. The appropriate type and quantity of HPM® Rebar Anchor Bolts to be used in a connection may be selected and the resistance of the connection verified by using the Peikko Designer® software (download from www.peikko.com).

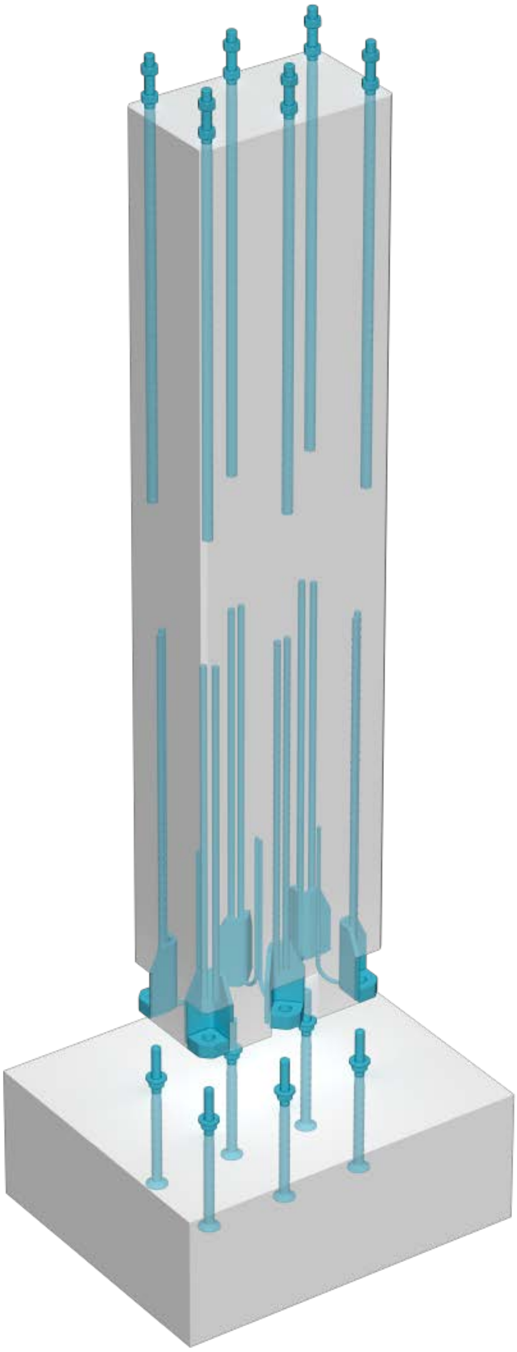


Figure 1. HPM® L Rebar Anchor Bolts in a concrete column to footing connection.

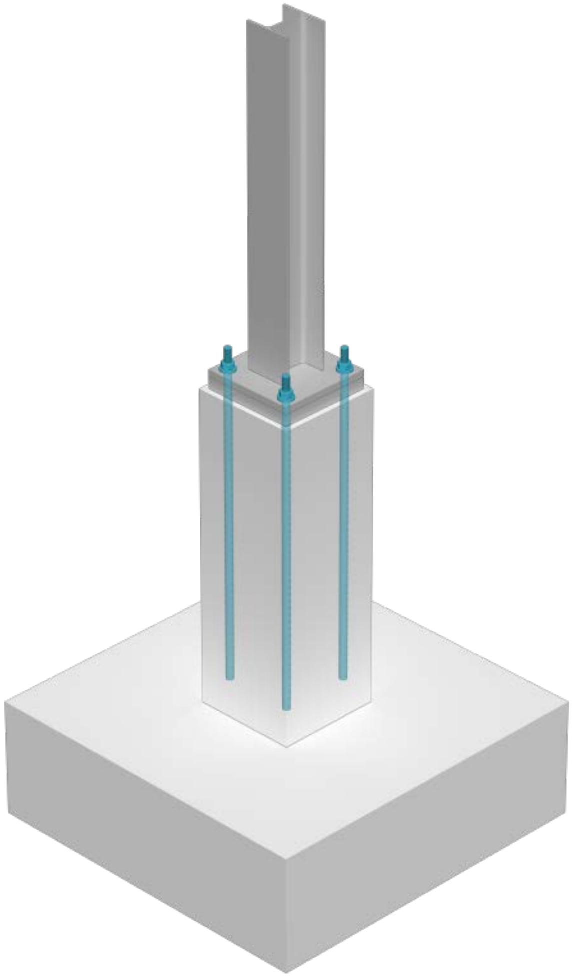


Figure 2. HPM® P Rebar Anchor Bolts in a steel column to base column connection.

1.1 Structural behavior

The loads on fixtures are transmitted to the anchor bolts as statically equivalent, tension, compression, and shear forces. Moment can be resisted by development of a force couple between tensile and compressive forces. The selected size and number of anchor bolts should be sufficient for the load.

1.1.1 Temporary conditions

In the erection stage, the forces acting on anchor bolts are caused principally by self-weight of the attachment as well as by the bending moment and shear force due to wind load. Since the joint is not grouted, all forces are carried solely by anchor bolts. In addition, bolts must be verified for buckling and bending. The open joint between the attachment and the base structure must be grouted with a non-shrink grouting material and the grout must harden before loads from other structures can be applied.

1.1.2 Final conditions

In the final stage, after the grout has reached the designed strength, the connection acts as a reinforced-concrete structure. The grout serves as the connection between the attachment and the base structure, transferring compression and shear loads. The grout must have a design compressive strength at least equal to the strength of the highest grade of concrete used in the connected elements.

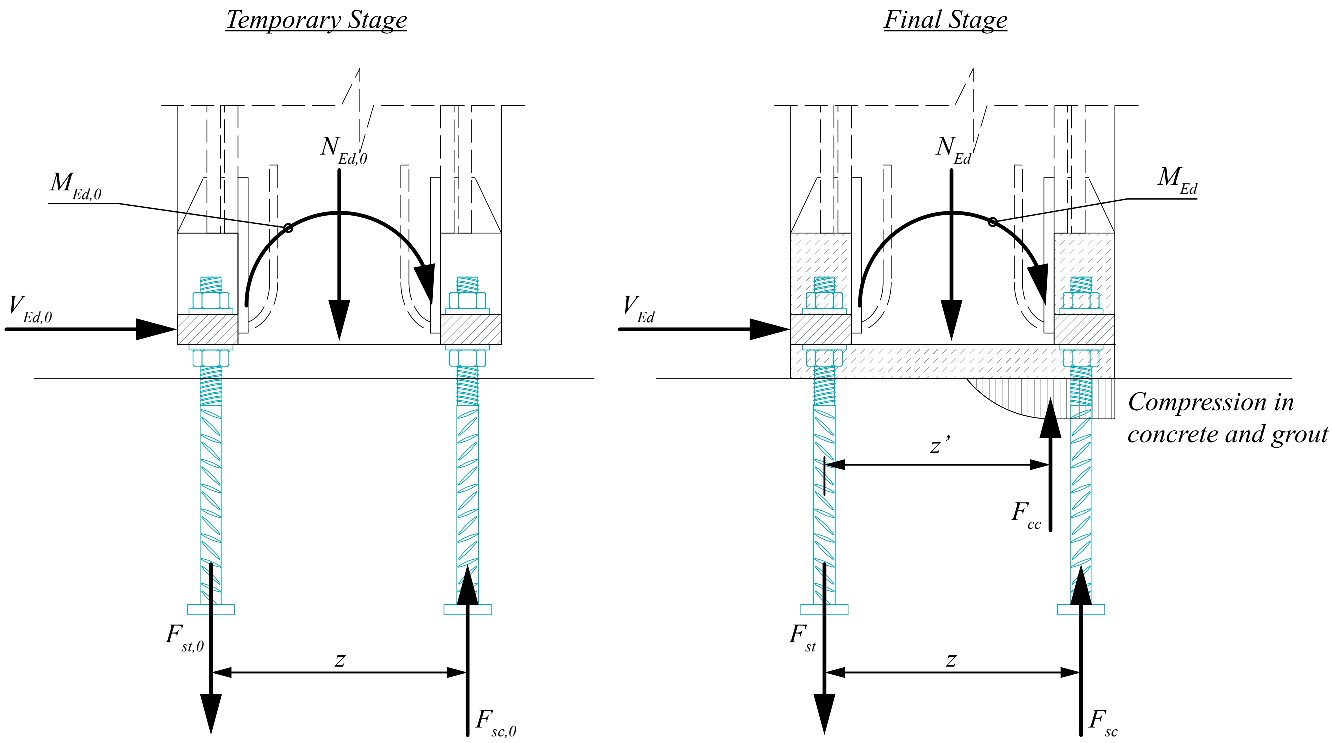


Figure 3. Structural behavior of the bolted connection under temporary and final conditions

1.2 Application conditions

The standard models of HPM® Rebar Anchor Bolts are pre-designed for use under the conditions mentioned in this section. If these conditions are not met, please contact Peikko Technical Support for custom-designed HPM® Rebar Anchor Bolts.

1.2.1 Loading and environmental conditions

HPM® Rebar Anchor Bolts are designed to carry static loads. To ensure resistance to corrosion the concrete cover of HPM® Rebar Anchor Bolts including washers and nuts must observe the minimum values determined according to the environmental exposure class and intended operating life. As an alternative to concrete cover, Peikko offers two standard surface coating options: ECO Galvanizing and Hot-Dip Galvanizing. Other anti-corrosion methods such as painting on site can also be utilized. For further information please contact Peikko Technical Support.

ECO Galvanizing is an economical, ecological, easy and quick way to protect bolts against corrosion, which allows anchor bolts to be galvanized partly or completely. The galvanizing method is a thermally sprayed zinc coating (according to EN ISO 2063). The minimum coating thickness is 100 µm, which corresponds to the performance of hot-dip galvanizing. The coating fulfills corrosion class C3 for a lifetime of minimum 50 years according to standard ISO 9223:2012. ECO Galvanizing is available for Anchor Bolt models: HPM24, HPM30, and HPM39.

Hot-Dip Galvanized bolts (according to EN ISO 1461) are dipped completely into galvanized material. Coating thickness average value is 55 µm, which fulfills corrosion class C3 for a lifetime of minimum 26 years according to of standard ISO 9223:2012.

Examples for ordering galvanized bolts:

- ECO Galvanized ⇨ Name: **HPM24P-ECO**
- Hot-Dip Galvanized ⇨ Name: **HPM30L-HDG**

Hot-dip galvanized oversize nuts and hot-dip galvanized washers are supplied if the bolt's thread is treated.

Figure 4. ECO Galvanized Bolt.

Table 1. Protection of anchor bolts against corrosion in different environmental conditions. Structural Class: S4, Allowance for deviation: $\Delta c_{dev} = 10\ mm$.

Exposure class	Required nominal concrete cover of anchor bolts according to EN 1992-1-1 c_{nom} [mm]
X0	20
XC1	25
XC2 / XC3	35
XC4	40
XD1 / XS1	45
XD2 / XS2	50
XD3 / XS3	55

1.2.2 Interaction with base structure

HPM® Rebar Anchor Bolts are pre-designed for use in reinforced base structures (e.g., foundations, slabs, base columns, columns, walls). The standard properties of HPM® Rebar Anchor Bolts are valid for reinforced normal weight concrete with a strength class in the range C20/25 to C50/60. The anchor bolt may be anchored in cracked and non-cracked concrete. In general, it is conservative to assume that the concrete will be cracked over its service life.

1.2.3 Positioning of the anchor bolt

HPM® Rebar Anchor Bolts are embedded in concrete up to the marking of the anchorage depth. Where possible, anchor bolts should be arranged symmetrically. The layout must also be coordinated with existing reinforcement and attached connectors like column shoes to ensure that the bolts can be installed in the intended location.

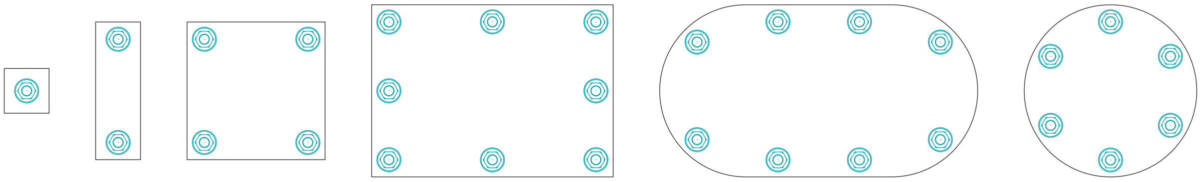


Figure 5. Examples with layout patterns of HPM® Rebar Anchor Bolts.

When placing HPM® L Rebar Anchor Bolts, the spacing (s_{min}), edge distance (c_{min}), and base structure thickness (h_{min}) must not fall below the minimum values shown in *Table 2*. It should be noted that the minimum thicknesses (h_{min}) in *Table 2* are for base structures cast directly against soil, $h_{min} = h_{ef} + k + c_{nom}$, hence $c_{nom} = 85\ mm$. Requirement of concrete cover to reinforcement based on environmental class could be also less than shown below. Punching resistance under studs and information shown in *Table 12* should be also considered when selecting thickness of structure and designing reinforcement.

Table 2. Positioning of HPM® L Rebar Anchor Bolts in base structure.

Anchor Bolt	c_{min} [mm]	s_{min} [mm]	h_{min} [mm]	h_{ef} [mm]	k [mm]
HPM 16 L	50	80	260	165	10
HPM 20 L	70	100	320	223	12
HPM 24 L	70	100	385	287	13
HPM 30 L	100	130	435	335	15
HPM 39 L	130	150	605	502	18

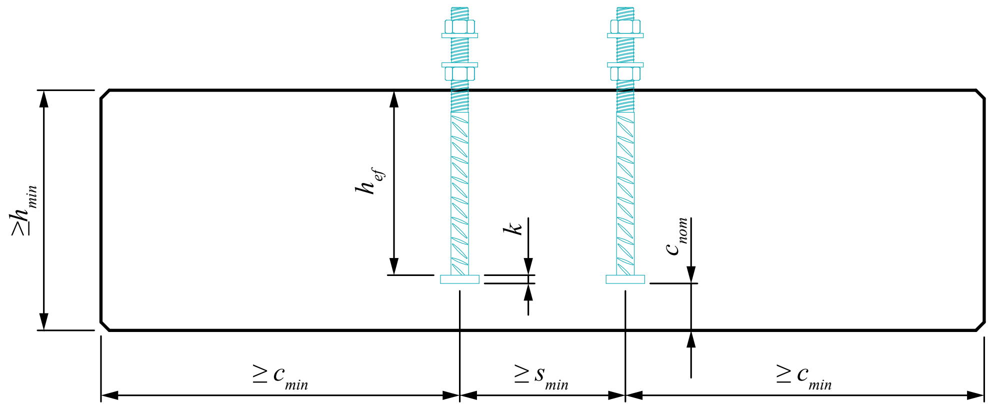


Figure 6. Installed HPM® L Rebar Anchor Bolt.

When placing HPM® P Rebar Anchor Bolts, the minimum edge distance should comply with the concrete cover thickness according to EN 1992-1-1, section 4. The bolts must be spaced to prevent bundles from forming and should fulfill the requirements for lapped bars, in EN 1992-1-1, sections 8.2 and 8.7.

1.3 Other properties

HPM® Rebar Anchor Bolts are fabricated of ribbed reinforcement steel bars with the following material properties:

Ribbed bars	B500B	EN 10080

Standard delivery for each anchor bolt includes two hexagonal nuts and two washers:

Washers	S355J2 + N	EN 10025-2
Nuts	Property class 8	EN ISO 4032 / EN ISO 898-2

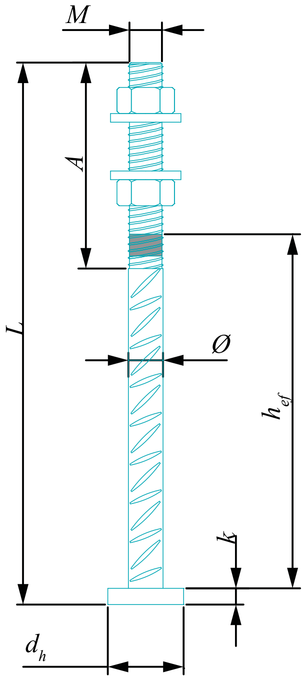
Peikko Group's production units are externally controlled and periodically audited on the basis of production certifications and product approvals by various independent organizations. HPM® L Anchor Bolts have European Technical Assessment ETA-02/0006 which will give CE marking provision.

Products are marked with the CE mark (HPM® L Anchor Bolts) and with the other applicable certification marks, the emblem of Peikko Group Oy, the type of product and place, year and week of manufacturing.

Manufacturing method	
Ribbed bars	Mechanical cutting
Threads	Rolling
Anchor head	Forging

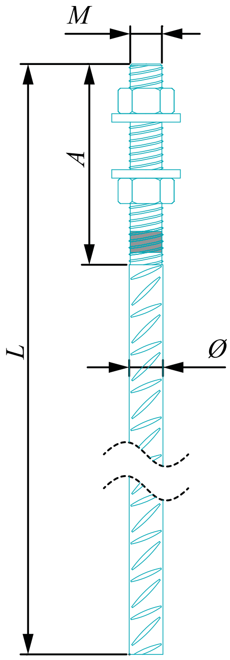
Manufacturing tolerances	
Length	± 10 mm
Thread length	+ 5, − 0 mm

Table 3. Dimensions [mm], weight [kg], and color codes of HPM® L Rebar Anchor Bolts



	HPM 16 L	HPM 20 L	HPM 24 L	HPM 30 L	HPM 39 L
M	M16	M20	M24	M30	M39
A	140	140	170	190	200
Stress area of the thread	157	245	352	561	976
Ø	16	20	25	32	40
L	280	350	430	500	700
Washer	Ø40-6	Ø44-6	Ø56-6	Ø65-8	Ø90-10
h_{ef}	165	223	287	335	502
d_h	38	46	55	70	90
k	10	12	13	15	18
Weight	0.7	1.2	2.2	4.1	9.2
Color code	Yellow	Blue	Grey	Green	Orange

Table 4. Dimensions [mm], weight [kg], and color codes of HPM® P Rebar Anchor Bolts.



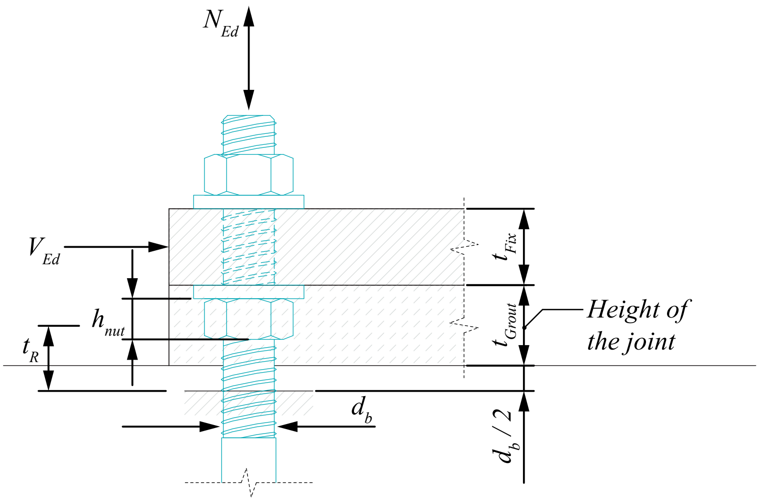
	HPM 16 P	HPM 20 P	HPM 24 P	HPM 30 P	HPM 39 P
M	M16	M20	M24	M30	M39
A	140	140	170	190	200
Stress area of the thread	157	245	352	561	976
Ø	16	20	25	32	40
L	810	1000	1160	1420	2000
Washer	Ø40-6	Ø44-6	Ø56-6	Ø65-8	Ø90-10
Weight	1.5	2.8	4.9	9.8	21.8
Color code	Yellow	Blue	Grey	Green	Orange

2. Resistances

2.1 Tensile, compressive, and shear resistances

The resistances of HPM® Rebar Anchor Bolts are determined by a design concept that makes reference to the following standards and European Technical Assessments (ETA):

- EN 1992-4:2018
- EN 1992-1-1:2004/AC:2010
- EN 1993-1-1:2005/AC:2009
- EN 1993-1-8:2005/AC:2005
- ETA-02/0006: ETA-assessment
- ETA-18/0037: ETA-assessment.



d_b = Diameter of stress area in thread
h_{nut} = Thickness of nut
t_R = Equivalent span of anchor bolt
$= t_{Grout} - h_{nut} + d_b / 2$

Figure 7. Loads and parameters characterizing the joint.

The resistance of HPM® Rebar Anchor Bolt connections is defined by bolt steel or anchorage to concrete strength. The required verifications are summarized later in this section. If the anchor bolt's tensile or shear steel resistance cannot be fully developed due to concrete failure, then the supplementary reinforcement may be used to carry the forces from the anchor bolt. It is recommended that the resistance be calculated and the required reinforcement for the bolted connections be assigned using the Peikko Designer® software.

Table 5. Design values for tensile or compressive resistance of individual HPM® Rebar Anchor Bolt. (Steel strength).

		HPM 16	HPM 20	HPM 24	HPM 30	HPM 39
N_{Rd} $N_{Rd,0}$	[kN]	62	96	139	220	383

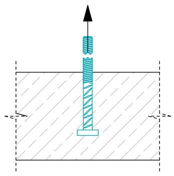
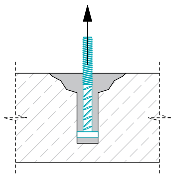
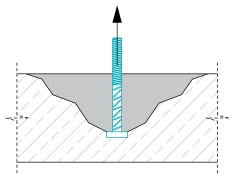
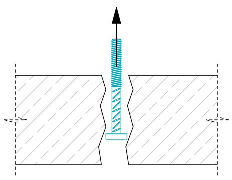
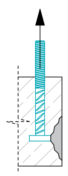
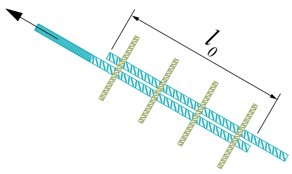
Table 6. Design values for shear resistance of individual HPM® Rebar Anchor Bolt. (Steel strength). The resistances are determined in accordance with ETA-18/0037.

Anchor Bolt	Final Stage V_{Rd} [kN]	Erection Stage $V_{Rd,0}$ [kN]	t_{Grout} [mm]
HPM 16	20	5	50
HPM 20	31	10	50
HPM 24	45	18	50
HPM 30	72	37	50
HPM 39	125	72	60

NOTE 1: Resistances V_{Rd} and $V_{Rd,0}$ in *Table 6* are valid for height of joint equal to t_{Grout}.
NOTE 2: Resistances shown in *Tables 5* and *6* are without simultaneous action of axial and shear load. For combined resistance, see section 2.2 of this manual.

The use of Peikko Designer® software is recommended to prove the resistance of the following verifications

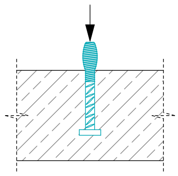
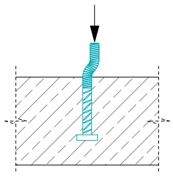
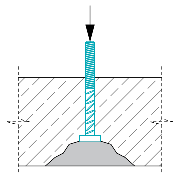
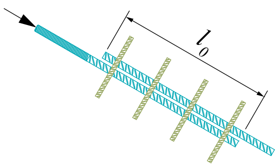
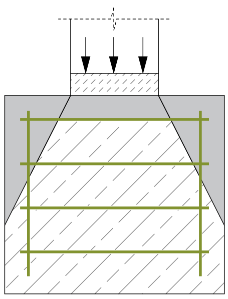
Table 7. Required verification for HPM® Rebar Anchor Bolts loaded in tension.

Failure mode	Example	HPM® L Rebar Anchor Bolts	HPM® P Rebar Anchor Bolts
Steel strength		Required (for most loaded bolt)	Required (for most loaded bolt)
Pull-out strength		Required (for most loaded bolt)	Not applicable
Concrete cone strength [1]		Required (for anchor group)	Not applicable
Splitting strength [2]		Required (for anchor group)	Not applicable
Blow-out strength [3]		Required (for anchor group)	Not applicable
Splicing length [4]		Not applicable	Required (for most loaded bolt)

1) Not required if supplementary reinforcement is provided according to Annex A1.
2) Not required if the edge distance in all directions $c \geq 1.5h_{ef}$ for one bolt and $c \geq 1.8h_{ef}$ for groups of bolts and the member thickness is $h \geq h_{min}$ in both cases. Or if supplementary reinforcement is provided according to Annex A2.
3) Not required if the edge distance in all directions $c \geq 0.5h_{ef}$
4) See Annex D for required transverse reinforcement in the lap zone.

The use of Peikko Designer® software is recommended to prove the resistance of the following verifications

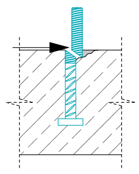
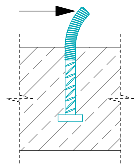
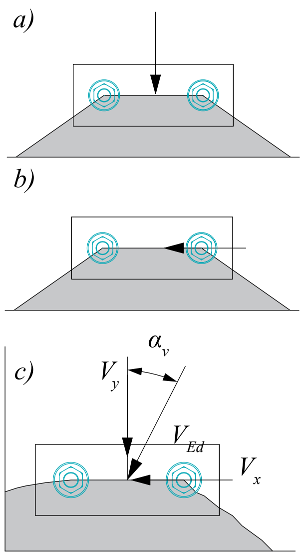
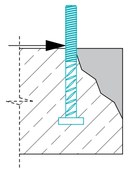
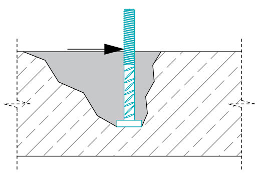
Table 8. Required verification for HPM® Rebar Anchor Bolts loaded in compression.

Failure mode	Example	HPM® L Rebar Anchor Bolts	HPM® P Rebar Anchor Bolts
Steel strength		Required (for most loaded bolt)	Required (for most loaded bolt)
Buckling strength [1]		Required (for most loaded bolt)	Required (for most loaded bolt)
Punching strength under the anchor head [2]		Required (for anchor group)	Not applicable
Splicing length [3]		Not applicable	Required (for most loaded bolt)
Partially loaded areas [4] • Local crushing • Transverse tension forces		Required only in the final stage (for the base structure)	Required only in the final stage (for the base structure)

1) Not required (according to ETA-18/0037) if the height of the joint does not exceed the grouting thicknesses stated in the installation instructions of this manual. See *Table 6* for t_{Grout}.
2) Not required if the thickness of the base structure ensures a sufficient concrete layer under the anchor head or if supplementary reinforcement is provided. Details can be found from Annex C1.
3) See Annex D for the required transverse reinforcement in the lap zone.
4) See Annex C2 for design guidelines and the required splitting reinforcement.

The use of Peikko Designer® software is recommended to prove the resistance of the following verifications

Table 9. Required verification for HPM® Rebar Anchor Bolts loaded in shear.

Failure mode	Example	HPM® L Rebar Anchor Bolts	HPM® P Rebar Anchor Bolts
Steel strength		Required (for most loaded bolt)	Required (for most loaded bolt)
Steel strength with lever arm [1)]		Required (for most loaded bolt)	Required (for most loaded bolt)
Concrete edge strength a) Shear perpendicular to the edge b) Shear parallel to the edge c) Inclined shear		Required (for anchor group)	Required (for anchor group)
Concrete pry-out strength		Required (for anchor group)	Not applicable

1) Not required (according to ETA-18/0037) in the final stage if the height of the joint does not exceed the grouting thicknesses stated in the installation instructions of this manual. See *Table 6* for t_{Grout}. It should be noted that the check always applies in the erection stage.

2.2 Combined axial and shear load

When axial and shear forces strain the bolt simultaneously the interaction should be checked by satisfying the following equations for different failure modes and design stages.

WITH RESPECT TO STEEL VERIFICATIONS

Bolts in Erection Stage

The simultaneous **axial** force and **shear** force in each bolt shall satisfy the condition:

$$\frac{|N^1_{Ed,0}|}{N_{Rd,0}} + \frac{|V^1_{Ed,0}|}{V_{Rd,0}} \leq 1$$ EOTA-TR-068, Eq. (1)

Bolts in Final Stage

The simultaneous **tensile** force and **shear** force in each bolt shall satisfy the condition:

$$\frac{|N^1_{Ed}|}{1.4N_{Rd}} + \frac{|V^1_{Ed}|}{V_{Rd}} \leq 1$$ EOTA-TR-068, Eq. (10)

$$\frac{|N^1_{Ed}|}{N_{Rd}} \leq 1$$ EOTA-TR-068, Eq. (11)

Where

$V_{Rd,0}$ = Shear resistance of bolt, Erection Stage
V_{Rd} = Shear resistance of bolt, Final Stage
$N_{Rd,0}$ = Axial resistance of bolt, Erection Stage
N_{Rd} = Axial resistance of bolt, Final Stage
$V^1_{Ed,0}$ = Shear load on a single bolt, Erection Stage
V^1_{Ed} = Shear load on a single bolt, Final Stage
$N^1_{Ed,0}$ = Axial load on a single bolt, Erection Stage
N^1_{Ed} = Axial load on a single bolt, Final Stage

WITH RESPECT TO CONCRETE VERIFICATIONS (applies only for HPM® L Rebar Anchor Bolts)

Bolts without reinforcement or with supplementary reinforcement for both tension and shear:

The simultaneous **tensile** force and **shear** force shall satisfy the condition:

$$\left(\frac{N_{Ed}}{N_{Rd,i}}\right)^{1.5} + \left(\frac{V_{Ed}}{V_{Rd,i}}\right)^{1.5} \leq 1$$ EN 1992-4, Eq. (7.55)

or

$$\left(\frac{N_{Ed}}{N_{Rd,i}}\right) + \left(\frac{V_{Ed}}{V_{Rd,i}}\right) \leq 1.2$$ EN 1992-4, Eq. (7.56)

with $N_{Ed}/N_{Rd,i} \leq 1$ and $V_{Ed}/V_{Rd,i} \leq 1$.

The largest value of $N_{Ed}/N_{Rd,i}$ and $V_{Ed}/V_{Rd,i}$ for different failure modes shall be taken.

Bolts with supplementary reinforcement for tension or shear only:

The simultaneous **tensile** force and **shear** force shall satisfy the condition:

$$\left(\frac{N_{Ed}}{N_{Rd,i}}\right)^{2/3} + \left(\frac{V_{Ed}}{V_{Rd,i}}\right)^{2/3} \leq 1$$

EN 1992-4, Eq. (7.57)

where N_{Ed} and V_{Ed} are resultant design tension and shear force of the fastener, and $N_{Rd,i}$ and $V_{Rd,i}$ represent the design resistances for the different applicable failure modes.

NOTE 1: If there is supplementary reinforcement for shear and/or tension, coefficient of utilization for cone and/or edge failure must be substituted by coefficient of utilization for their corresponding supplementary reinforcement.

NOTE 2: If splitting supplementary reinforcement is provided, then splitting failure shall not be included in combined verification.

2.3 Fire resistance

The fire resistance of bolted connection should be verified in accordance with EN 1992-1-2. The fire design of column connections is implemented into Peikko Designer® to enable quick and easy proof of load-bearing function for concrete column connections with HPM® Rebar Anchor Bolts when exposed to fire. If the fire resistance of the connection is insufficient, the concrete cover must be increased, or alternative means used to reach the intended fire resistance class. Please contact Peikko Technical Support for custom designs.

Selecting HPM® Rebar Anchor Bolt

The following aspects must be considered when selecting an appropriate type of HPM® Rebar Anchor Bolt to be used in bolted connections:

- Resistances
- Properties of the grouting
- Properties of the base structure
- Position and arrangement of the anchor bolts in the base structure
- Design value of actions.

The resistance of Peikko Bolted Connections should be verified for the following design situations:

- Erection stage
- Final stage
- Fire situation
- Environmental exposure conditions
- if necessary, the accident situation.

Peikko Designer® Column Connection software

Peikko Designer® is software to be used for designing column connections with Peikko's products. It can be downloaded free of charge from www.peikko.com. The Column Connection module enables the user to design connections to resist actual loadings and optimize the connections to meet the requirements of the entire project. The software's output reports can also be used to verify the design and output drawings as details of the connection. The summary of the products in the project helps to plan material flow during construction.

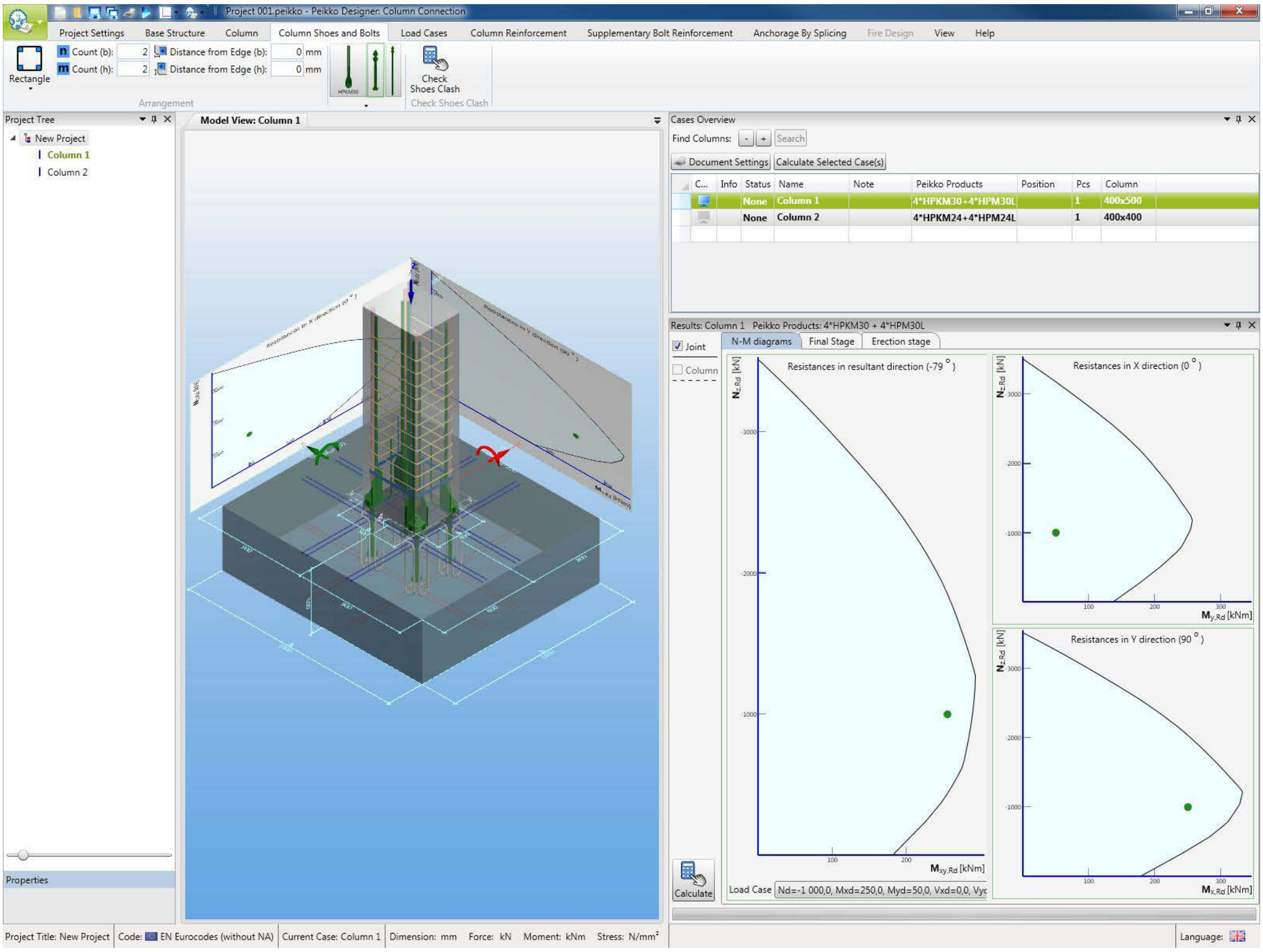


Figure 8. Peikko Designer® Column Connection user interface.

Typically, the following steps are used for the selection procedure:

USER INPUT

- Materials for column, structure under column, and grouting
- Geometries of the column and structure under column
- Design values of the actions – erection, final, and fire stages
- NOTE: Second order effects should be included in the load cases
- Type of column shoes and anchor bolts
- Column shoe arrangement
- Column reinforcement (optional).

PEIKKO DESIGNER OUTPUT

- N-M interaction diagram (axial force-bending moment diagram) of joint in final and fire stage
- N-M interaction diagram of reinforced column
- Calculation results for column connection in final stage
- Calculation results for column connection in erection stage
- Supplementary reinforcement details
- Summary of products in the project.

Annex A – Supplementary reinforcement to resist tension load

A1: Concrete cone reinforcement

If the concrete cone resistance is exceeded, supplementary reinforcement for the tension load should be provided. Detailing of hanger reinforcement for HPM® L Rebar Anchor Bolts is shown in the following figure. The required quantities of stirrups and surface bars are given in *Table 10*. Alternative reinforcement arrangements can be calculated using the Peikko Designer® Column Connection software in accordance with EN 1992-4.

Table 10. Concrete cone reinforcement (B500B).

Anchor Bolt	Stirrups (per bolt) ①	Surface bars ②	c_{nom} [mm]	$R_{1,max}$ [mm]	h_{ef} [mm]	Width of stirrup b [mm]
HPM 16 L	4 Ø 8	Ø 8	35	75	165	85
HPM 20 L	4 Ø 8	Ø 8	35	85	223	90
HPM 24 L	4 Ø 8	Ø 8	35	100	287	105
HPM 30 L	4 Ø 10	Ø 8	35	100	335	125
HPM 39 L	4 Ø 12	Ø 8	35	200	502	150

The reinforcement from *Table 10* can be directly applied under the following conditions:

- The concrete strength class of the base structure is equal to or greater than C25/30 (good bond).
- The nominal concrete cover is equal to or smaller than 35 [mm].
- The minimum clear distance (***a***) between adjacent legs of stirrups should not be less than 21 [mm], requirement according to EN 1992-1-1, section 8.2 (maximum size of aggregate = 16 mm)
- Minimum concrete cover of the stirrups measured towards parallel edge is $3Ø\ (\alpha_1 \cdot \alpha_2 = 0.7 \cdot 1 = 0.7)$.

NOTE 1: If concrete cover is bigger than 3Ø reinforcement can be further optimized by applying equation from EN 1992-1-1, 8.4.4(2), Table 8.2.

To ensure force continuity the assigned supplementary reinforcement outside the assumed failure cone shall be detailed in one of the following ways:

- *Figure 9*, Alternative 1. Stirrups enclose bottom reinforcement of concrete member
- *Figure 9*, Alternative 2. Creating lap-splices (load transfer to structural reinforcement)
- *Figure 9*, Alternative 3. Providing design anchorage length l_{bd} (load transfer to surrounding concrete)

NOTE 2: If the force transmission is achieved by means of anchorage (*Figure 9*, Alternative 3), then the total capacity of the assigned supplementary reinforcement shall be limited to the concrete cone resistance $N_{Rd,c}$ that is calculated using Formula (7.1) of EN 1992-4, where the different factors of Formula (7.1) are now obtained by substituting h_{ef} with $h_{ef}^{hairpins}$ hence assuming an embedment length corresponding to the end of U-bars.

NOTE 3: The reinforcement quantities presented in *Table 10* are calculated for load corresponding to tensile steel resistance N_{Rd} (see Table 5) of a single bolt. Given quantities do not account for possible reduction in the resulting capacity that could be caused by anchorage (load transfer) outside the assumed failure cone.

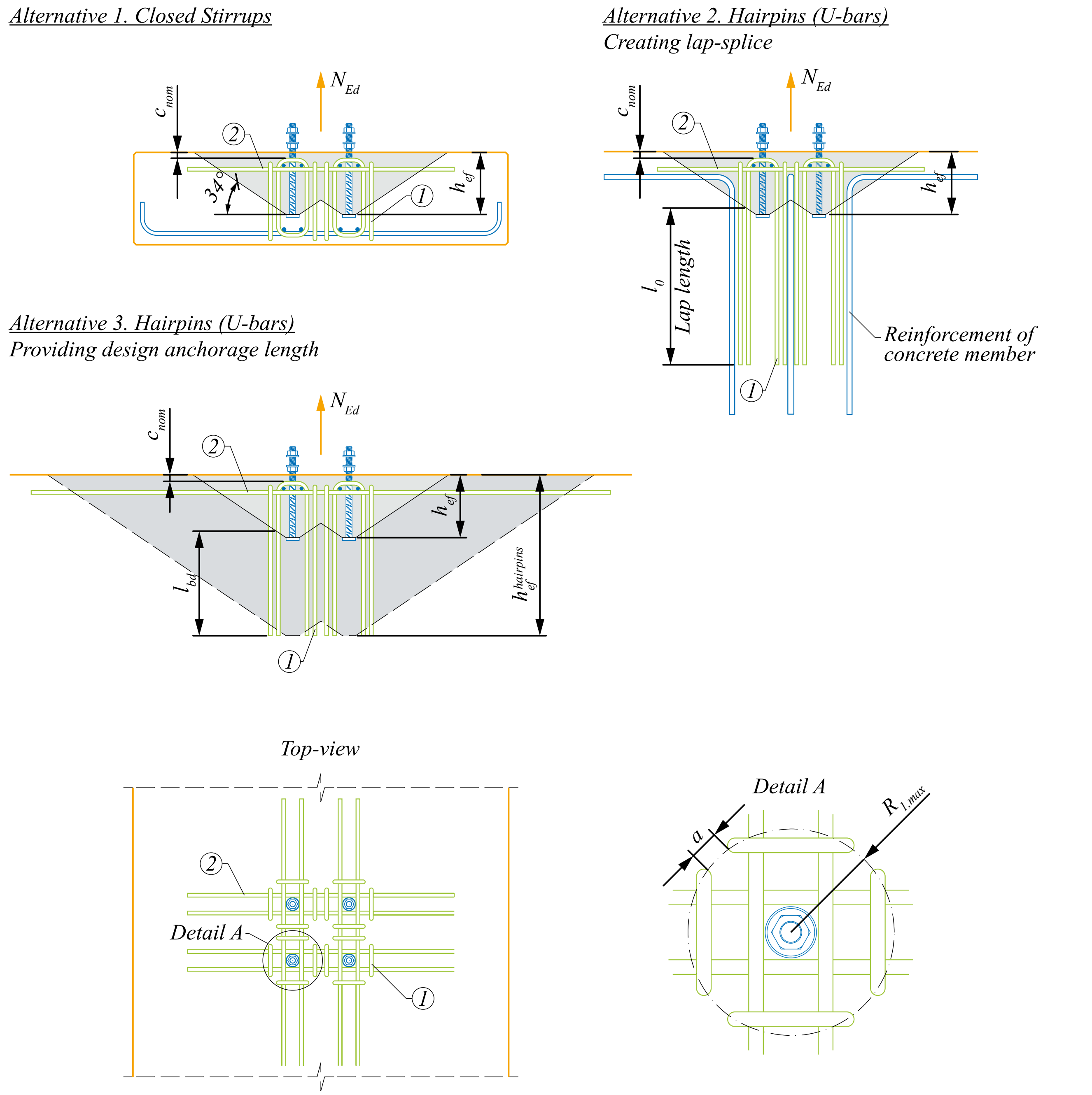


Figure 9. Illustration of detailing of the supplementary reinforcement in the form of stirrups and hairpins.

A2: Splitting reinforcement

If the splitting resistance is exceeded, supplementary side and top face reinforcement near the concrete surface should be provided to resist the splitting forces and to limit splitting cracks. Detailing of reinforcement for HPM® L Rebar Anchor Bolts is shown in the following figure. The required quantities of reinforcement bars are given in *Table 11*. Alternative reinforcement arrangements can be calculated using the Peikko Designer® Column Connection software in accordance with EN 1992-4.

The required cross-section A_s of the splitting reinforcement may be determined as follows

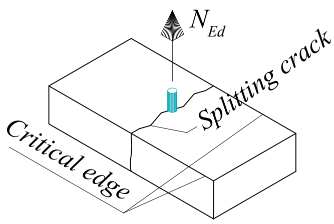
$$A_s = 0.5 \frac{\sum N_{Ed}}{f_{yk} / \gamma_{Ms,re}} [mm^2]$$ EN 1992-4, Eq. (7.22)

where

$\sum N_{Ed}$ = sum of the design tensile forces of the bolts in tension under the design value of the actions
f_{yk} = nominal yield strength of the reinforcing steel ≤ 500 N/mm²
$\gamma_{Ms,re}$ = partial safety factor for steel failure of supplementary reinforcement = 1.15

Table 11. Minimum recommended splitting reinforcement (B500B) per fully loaded anchor bolt.

Anchor Bolt	A_s ① + ② $[mm^2]$	Selected reinforcement
HPM 16 L	71	3 Ø 6
HPM 20 L	111	4 Ø 6
HPM 24 L	159	4 Ø 8
HPM 30 L	253	4 Ø 10
HPM 39 L	441	4 Ø 12



Placement of reinforcement

- Splitting reinforcement must be evenly placed along the **critical edge(s)*** on the side and top faces of concrete member.
  *** The distance from the edge of the concrete surface to the center of the nearest bolt in tension smaller than $1.8h_{ef}$.**
- Bars against splitting must be located inside effective reinforcement zone, i.e., area of cross-section (close to side/top faces) between critical edge(s) and resultant tensile force vector $\overrightarrow{N_{Ed}}$.
- Position ① is the **side-face reinforcement** of the critical edge or edges of the same direction.
- Position ② is the **top-face reinforcement** of the critical edge or edges of the same direction.
- **NOTE 1:** Perpendicular edges should be considered independently (i.e., splitting reinforcement A_s in each direction).
- **NOTE 2:** In a case of only one critical edge in examined direction (e.g., *Figure 10*), the required amount of splitting reinforcement A_s for that direction can be reduced by half.
- **NOTE 3:** The recommended spacing between splitting bars ≤ 150 mm
- **NOTE 4:** Deepest effective splitting reinforcement bar placed along the side face of concrete member is located not more than 100 mm below anchor bolt.

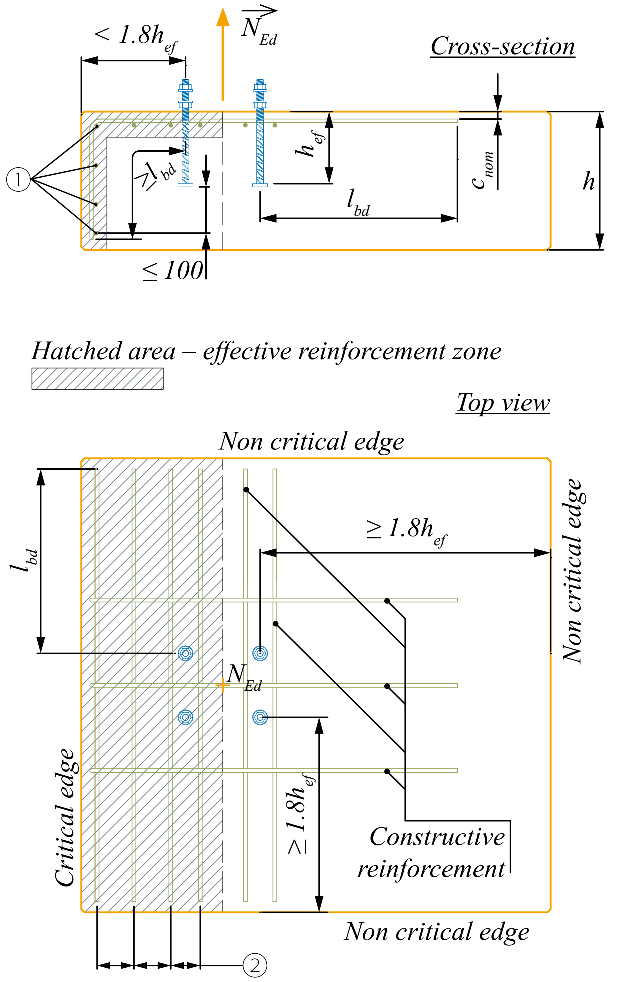


Figure 10. Detail for splitting reinforcement. Example case with one critical edge.

Annex B – Supplementary reinforcement to resist shear load

B1: Edge reinforcement

If the edge cone resistance is exceeded, supplementary reinforcement should be provided based on the corresponding magnitude of the shear force for this edge. The shear force magnitude for the edge under consideration depends on the orientation of the applied load. The requirement and amount of supplementary shear reinforcement for each edge of the concrete member should be checked independently. Detailing of edge reinforcement for HPM® L and P Rebar Anchor Bolts is shown in the following figure. The required quantities of U-bars are given in *Table 12*. Alternative reinforcement arrangements can be calculated using the Peikko Designer® Column Connection software in accordance with EN 1992-4.

Table 12. Concrete edge reinforcement (B500B) per fully loaded anchor bolt in shear.

Anchor Bolt	U-bars (per bolt) ①	c_1 [mm]	c_{nom} [mm]	e_s [mm]
HPM 16	1 Ø 12	50	35	100...120
HPM 20	1 Ø 14	70	35	105...135
HPM 24	1 Ø 16	70	35	110
HPM 30	2 Ø 14	100	35	125...145
HPM 39	3 Ø 16	130	35	145...240

The reinforcement from *Table 12* can be directly applied under the following conditions:

- The distance e_s between gravity axis of reinforcement and shear force shall be in a range between $e_{s,min}$ and $e_{s,max}$. Preferably placed as close as possible to the top surface of foundation, (see *Figure 11* sectional view A-A). The assumed concrete cover for calculated $e_{s,min}$ is $c_{nom} = 35\ mm$
- The edge distance of Anchor Bolt is equal to or greater than c_1.

It should be noted that the supplementary reinforcement shown in *Table 12* is selected for the edge perpendicular to the applied load, which is the least favorable case ($\alpha_V = 0°$).

If applied load acts inclined against the considered edge ($0° < \alpha_V \leq 90°$), then the force in the supplementary reinforcement $N_{Ed,re}$ can be reduced by utilizing coefficient $\psi_{\alpha,V}$.

Coefficient $\psi_{\alpha,V}$ shall be calculated for each edge individually:

$$\psi_{\alpha,V} = \sqrt{\frac{1}{(\cos\alpha_V)^2 + (0.5 \cdot \sin\alpha_V)^2}} \geq 1 \qquad \text{EN 1992-4:2018, Eq. (7.48)}$$

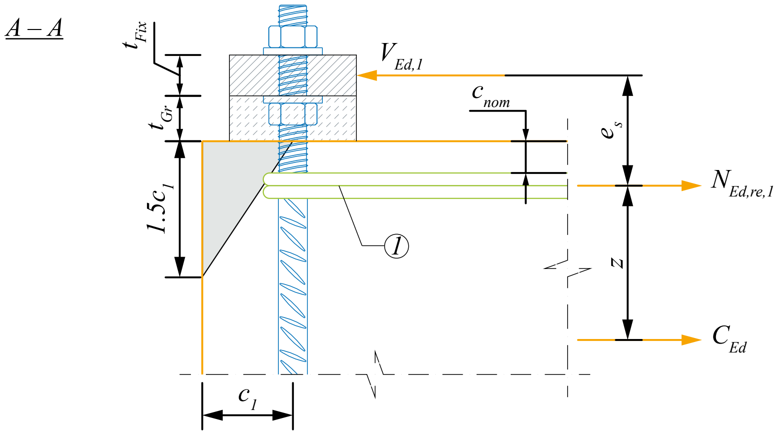
Reduced force to be covered with reinforcement:

$$N_{Ed,re}^{Reduced} = N_{Ed,re} \cdot \frac{1}{\psi_{a,V}} = \left(\frac{es}{z} + 1\right) \cdot V_{Ed} \cdot \frac{1}{\psi_{a,V}}$$

where

α_V = angle between design shear load V_{Ed} and the line perpendicular to the edge (see also *Table 9*)

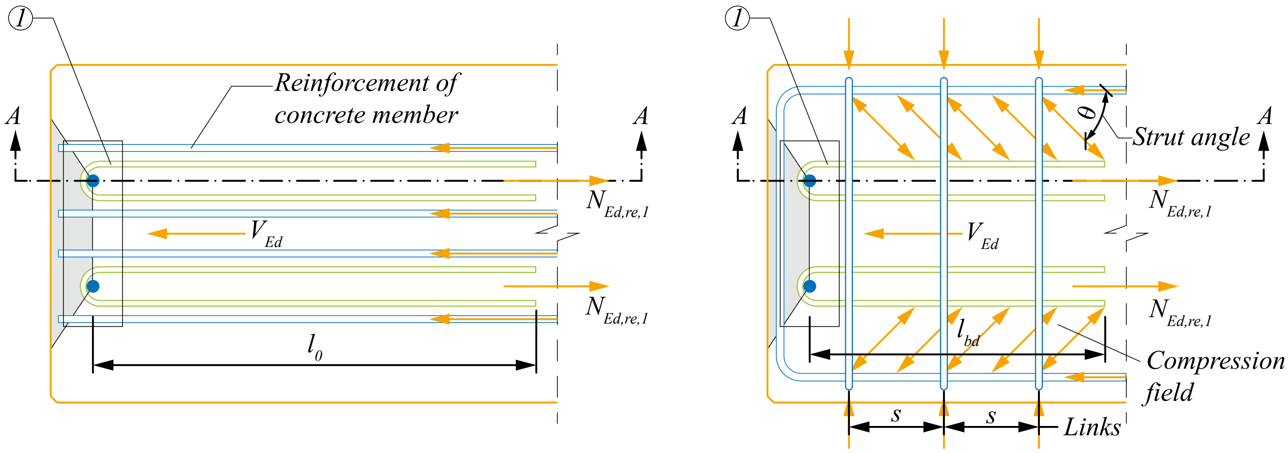
$N_{Ed,re}$ = the design tension force in the supplementary reinforcement caused by the design shear force acting on a fixture. Origin of $N_{Ed,re}$ is gravity axis of U-bar group



To ensure force continuity the assigned supplementary reinforcement outside the assumed failure body shall be either ***a) spliced with reinforcement of concrete member by adequate lapping*** *or* ***b) anchored into structural concrete member.***

Top view

a) Load transfer by lap slices *b) Load transfer by achorage Strut and tie model*



Transverse reinforcement in the lap zone shall be considered acc. to EN 1992-1-1, 8.7.4.1

The vertical links are the transverse tension members in presented strut and tie system

Figure 11. Illustration of detailing of the supplementary reinforcement in the form of U-bars.

where

$V_{Ed,1}$ = shear force acting per anchor bolt (in *Table 12* it is assumed that $V_{Ed,1} = V_{Rd,s}$)

C_{Ed} = reaction compressive force in the concrete induced by bending

z = internal lever arm of the concrete member

NOTE 1: In *Figure 11* it is assumed that the edges of the concrete member parallel to the applied load have sufficient resistance without supplementary reinforcement.

NOTE 2: The reinforcement quantities presented in *Table 12* are calculated for load corresponding to shear steel resistance V_{Rd} (see *Table 6*) of a single bolt. Given quantities do not account for possible reduction in the resulting capacity that could be caused by anchorage (load transfer) outside the assumed failure cone.

Annex C – Supplementary reinforcement to resist compression load

C1: Concrete cone reinforcement for punching

If the punching resistance under the head of the anchor bolt is exceeded, supplementary reinforcement should be provided. Detailing of supplementary reinforcement for HPM® L Rebar Anchor Bolts is shown in following figure. The required quantities of stirrups are given in *Table 13*. Reinforcement may be omitted if the concrete thickness h under the bolt's head is equal to or greater than h_{req} (see *Figure 12*).

Table 13. Concrete cone reinforcement (B500B).

Anchor Bolt	h_{req} [mm]	A_s [mm]	Stirrups (per bolt) ①
HPM 16 L	80	98	2 Ø 6
HPM 20 L	100	140	2 Ø 8
HPM 24 L	115	193	2 Ø 8
HPM 30 L	145	314	2 Ø 10
HPM 39 L	190	523	2 Ø 14

NOTE: Pre-calculated h_{req} thicknesses are relevant only for cases where the punching cone under the bolt's head is not limited by adjacent cones or the edges of the base structure (see Figure 12). The inclination angle of stress cone is 45°.

The reinforcement from *Table 13* can be directly applied under the following conditions:

- The concrete strength class of base structure is equal to or greater than C25/30 (good bond).
- Stirrups are located inside the stress cone and anchored according to EN 1992-1-1.

It should be noted that punching reinforcement, if in form of closed stirrups, may be used as hanger reinforcement for tension.

NOTE 2: In addition, concrete layer thickness under the bolt's head shall always meet requirement of concrete cover based on environmental class ($h_{req} \geq c_{nom}$), see section 1.2.3 of this manual.

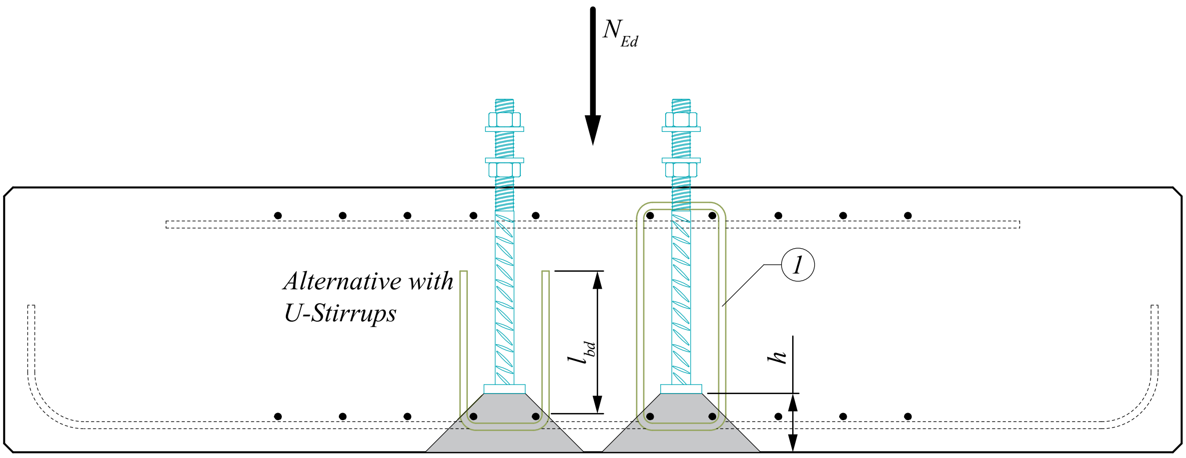


Figure 12. Reinforcing the conical fracture under the bolt.

C2: Partially loaded areas, Splitting reinforcement

In column-to-column connections, the concrete strength class of the lower column should be at least the same as that used in the upper column. If that is not the case, local crushing of the lower column should be considered. Local crushing can be prevented by expanding the base structure by dimension Δ (see *Figure 13*). In addition, splitting reinforcement should be provided to resist transverse tension forces in the base structure. The stirrups should be distributed uniformly in the direction of the tension force over the height h, where compression trajectories are curved. In the absence of better information, height h can be taken as 2Δ.

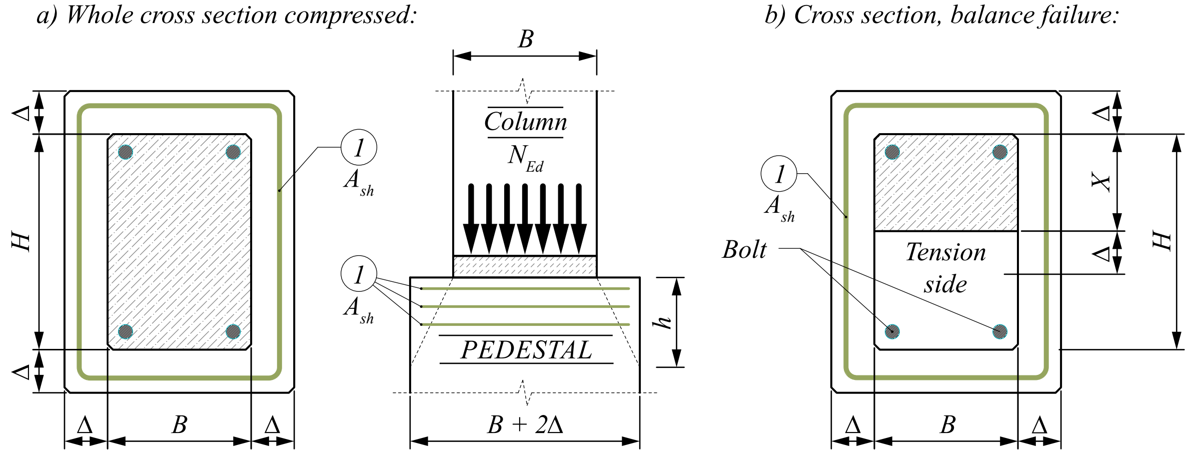


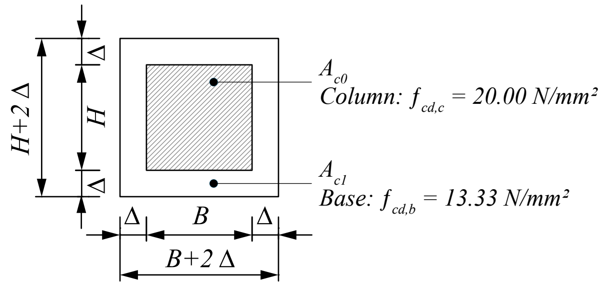
Figure 13. Column connection with two different size sections. Splitting reinforcement in base column.

Table 14. The expansion Δ of base structure and required splitting stirrups (B500B).

Concrete Grade (Column)	Concrete Grade (Base Column)	a) Whole cross section compressed Δ [mm]	b) The bolts of the tension side yield (balance failure) Δ [mm]	Required reinforcement area Stirrups with 2-cuts ① A_{sh} [mm²]
C30/37	C25/30	$\Delta = 0.10 \times H$	$\Delta = 0.06 \times H$	$A_{sh} = B \times H/933$
C35/45	C25/30	$\Delta = 0.20 \times H$	$\Delta = 0.12 \times H$	$A_{sh} = B \times H/474$
C40/50	C25/30	$\Delta = 0.30 \times H$	$\Delta = 0.18 \times H$	$A_{sh} = B \times H/320$
C50/60	C35/45	$\Delta = 0.21 \times H$	$\Delta = 0.13 \times H$	$A_{sh} = B \times H/317$
C60/75	C35/45	$\Delta = 0.36 \times H$	$\Delta = 0.22 \times H$	$A_{sh} = B \times H/193$

DESIGN EXAMPLE

A concrete 400 [mm] × 400 [mm] column (C30/37) bears on a base column (C20/25). Determine the minimum cross section and required splitting reinforcement of the base structure to resist the maximum compression force applied from the supported column. Loading Situation: Column under uniaxial compression without bending moment.
(Material factor for Concrete $\gamma_c = 1.5$ and coefficient of long term effects on the strength $\alpha_{cc} = 1.0$)



The concentrated resistance force of the partially loaded area:

$$F_{Rdu} = \sqrt{\frac{A_{c1}}{A_{c0}}} \cdot A_{c0} \cdot f_{cd,1} \leq 3.0 \cdot f_{cd,1} \cdot A_{c0}$$ EN 1992-1-1, Eq. (6.63)

where
A_{c0} = is the loaded area
A_{c1} = is the maximum design distribution area with a similar shape to A_{c0}
$f_{cd,1}$ = is the design compressive strength of base structure

Substituting in Eq. (6.63):
A_{c0} = $B \cdot H = 400 \cdot 400 = 160000\ mm^2$
A_{c1} = $(B + 2 \cdot \Delta) \cdot (H + 2 \cdot \Delta) = (400 + 2 \cdot \Delta) \cdot (400 + 2 \cdot \Delta) = (400 + 2 \cdot \Delta)^2$
F_{Rdu} = maximum applied force (i.e. ultimate strength of an axially loaded column)
For simplification, F_{Rdu} is defined here without reinforcements
F_{Rdu} = $A_{c0} \cdot f_{cd,0} = B \cdot H \cdot f_{cd,0} = 160000 \cdot 20 = 3200000\ N = 3200\ kN$

where
$f_{cd,0}$ = is the design compressive strength of column

Solving this quadratic equation:

$$\cancel{B} \cdot \cancel{H} \cdot f_{cd,c} = \cancel{B} \cdot \cancel{H} \cdot f_{cd,b} \cdot \sqrt{\frac{(B+2\cdot\Delta)\cdot(H+2\cdot\Delta)}{B \cdot H}}$$

$$\Delta = 100\ mm$$

Minimum cross-section of base column:

$$(B+2\cdot\Delta)\cdot(H+2\cdot\Delta) = 600\ [mm] \times 600\ [mm]$$

Splitting force (according to EN 1992-1-1, section 6.5):

$$F_{sp} = 0.25 \cdot F_{Rdu} \cdot \left(1 - \frac{B}{B+2\cdot\Delta}\right) = 0.25 \cdot 3200 \cdot \left(1 - \frac{400}{600}\right) = 266.7\ kN$$

Required splitting reinforcement area (2-cuts, B500B):

$$A_{sp} = \frac{F_{sp}}{2 \cdot \frac{f_{yk}}{\gamma_s}} = \frac{266700}{2 \cdot \frac{500}{1.15}} = 306.7\ mm^2$$

where
f_{yk} = characteristic yield strength of reinforcement
γ_s = partial safety factor for reinforcement

Selected stirrups: 7Ø8 ($A_s = 352\ mm^2$) or 4Ø10 ($A_s = 314\ mm^2$)

Annex D – Transverse reinforcement in the lap zone

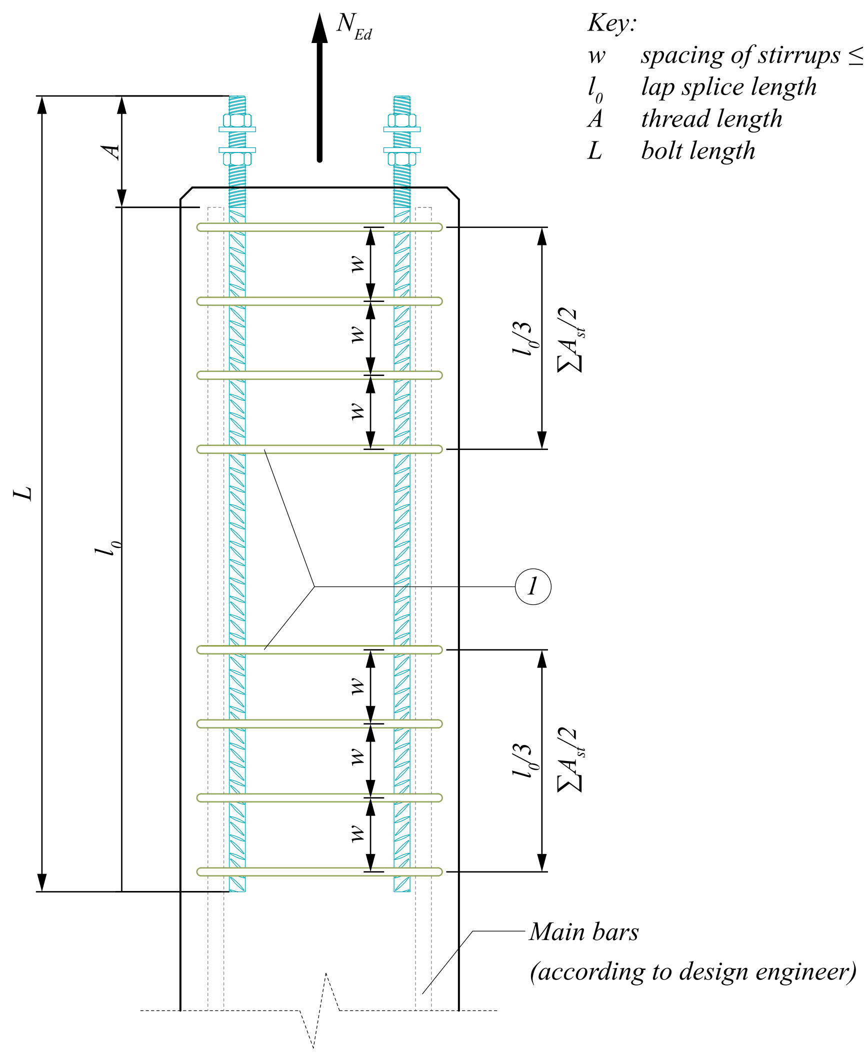
Long HPM® P Rebar Anchor Bolts are designed for use in lap splices with the main reinforcement of the base structure. The base structure must be reinforced with at least the same cross section area of longitudinal bars corresponding to the bolts. Adequate transverse reinforcement $\sum A_{st}$ should be provided in the lap zone (see *Figure 14*). The required quantities of stirrups are given in *Table 15*. Alternative reinforcement arrangements can be calculated using the Peikko Designer® Column Connection software.

Table 15. Reinforcement for lap splices, (B500B).

Anchor Bolt	Total amount of stirrups ①	l_0 [mm]
HPM 16 P	4 + 4 Ø 6	670
HPM 20 P	3 + 3 Ø 8	860
HPM 24 P	4 + 4 Ø 8	990
HPM 30 P	4 + 4 Ø 10	1230
HPM 39 P	6 + 6 Ø 12	1800

The reinforcement from *Table 15* can be directly applied under the following conditions:

- The concrete strength class of base structure is equal to or greater than C25/30 (good bond).
- The bolts are loaded in tension.



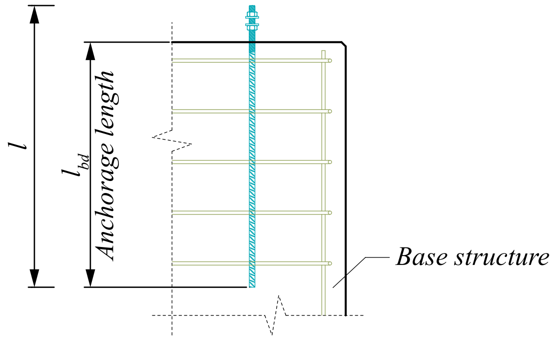
Key:
w *spacing of stirrups ≤ 150 mm*
l_0 *lap splice length*
A *thread length*
L *bolt length*

Figure 14. Transverse reinforcement for lapped splices. Detail of reinforcement when bars in tension. Other transverse reinforcement or stirrups according to EN 1992-1-1.

Annex E – Alternative use of HPM® P Rebar Anchor Bolts

1\.

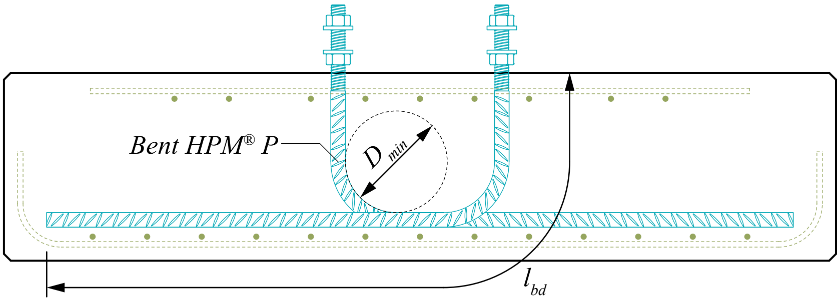
HPM® P Rebar Anchor Bolts as alternative to lap splices can be anchored as longitudinal reinforcement by providing sufficient tension/compression development length. It should be noted that this solution might require additional verifications and reinforcement for the base structure. The design anchorage length l_{bd} to anchor the force N_{Ed} acting on a bolt must be checked in accordance with EN 1992-1-1, section 8.4.



2\.

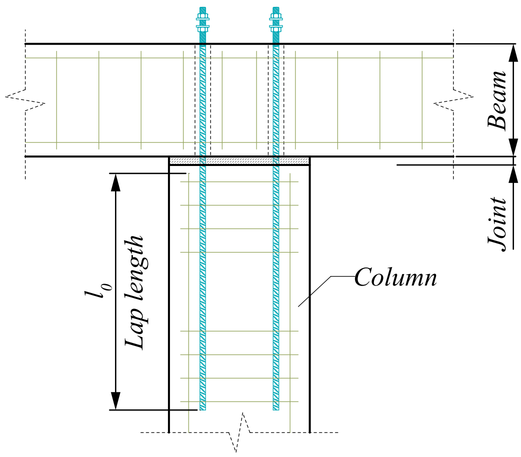
HPM® P Rebar Anchor Bolts can be also installed in shallow structures with limited thickness by bending them. The minimum mandrel diameter $Ø_{m,min}$ must be checked for each individual case (according to EN 1992-1-1, section 8.3) to avoid bending cracks in the anchor bolt and to avoid failure of the concrete inside the bend.

Bent anchor bolts can be manufactured and delivered according to specification.



3\.

If requested, extra-long HPM® P Rebar Anchor Bolts are available for structural solutions such as column-to-column connections through the beam. Where l_0 is the design lap length in accordance with EN 1992-1-1, section 8.7.3.

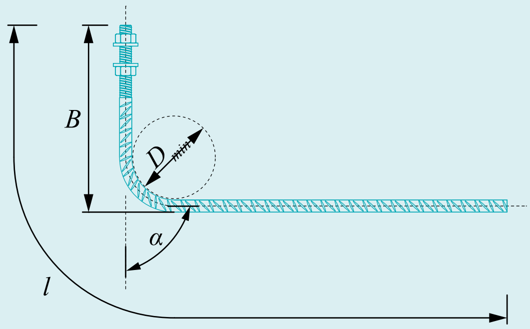


<u>**Ordering non-standard HPM® P Rebar Anchor Bolts:**</u>
All dimensions in [mm]

1. Straight HPM® P Rebar Anchor Bolt ⇨ **HPM(*)P – *l***
   Example 1) **HPM30P – 2000**
2. Bent HPM® P Rebar Anchor Bolt ⇨ **HPM(*)P – *l* – Bent*α* – *B***
   Example 2) **HPM30P – 2000 – Bent90 – 500**
   Example 3) **HPM30P – 2500 – Bent45 – 700**

where

*	is the size of the bolt
l	is the total length of the bolt
α	is the angle of bend [degrees]
B	is the position of bend



Annex F – Alternative means to transfer shear load

There are two principal ways of transferring shear force from columns into the base structure:

- By anchor bolt shear resistance (see *Table 6*)
- By friction resistance between the base plate and grout:

$$F_{f,Rd} = \mu \cdot N_{Ed}$$

where

μ = is the friction coefficient between the base plate and grout = 0.20 (without additional tests)

N_{Ed} = is the design value of the total axial force

NOTE: If the column is loaded with tensile axial force, $\mu \cdot N_{Ed} = 0$.

Alternative ways used in resisting large shear forces:

- Shear dowel (see *Figure 15a*)
- Embedding the column in the base structure (see *Figure 15b*)
- Transferring the force to the floor slab using hairpin bars (see *Figure 15c*)

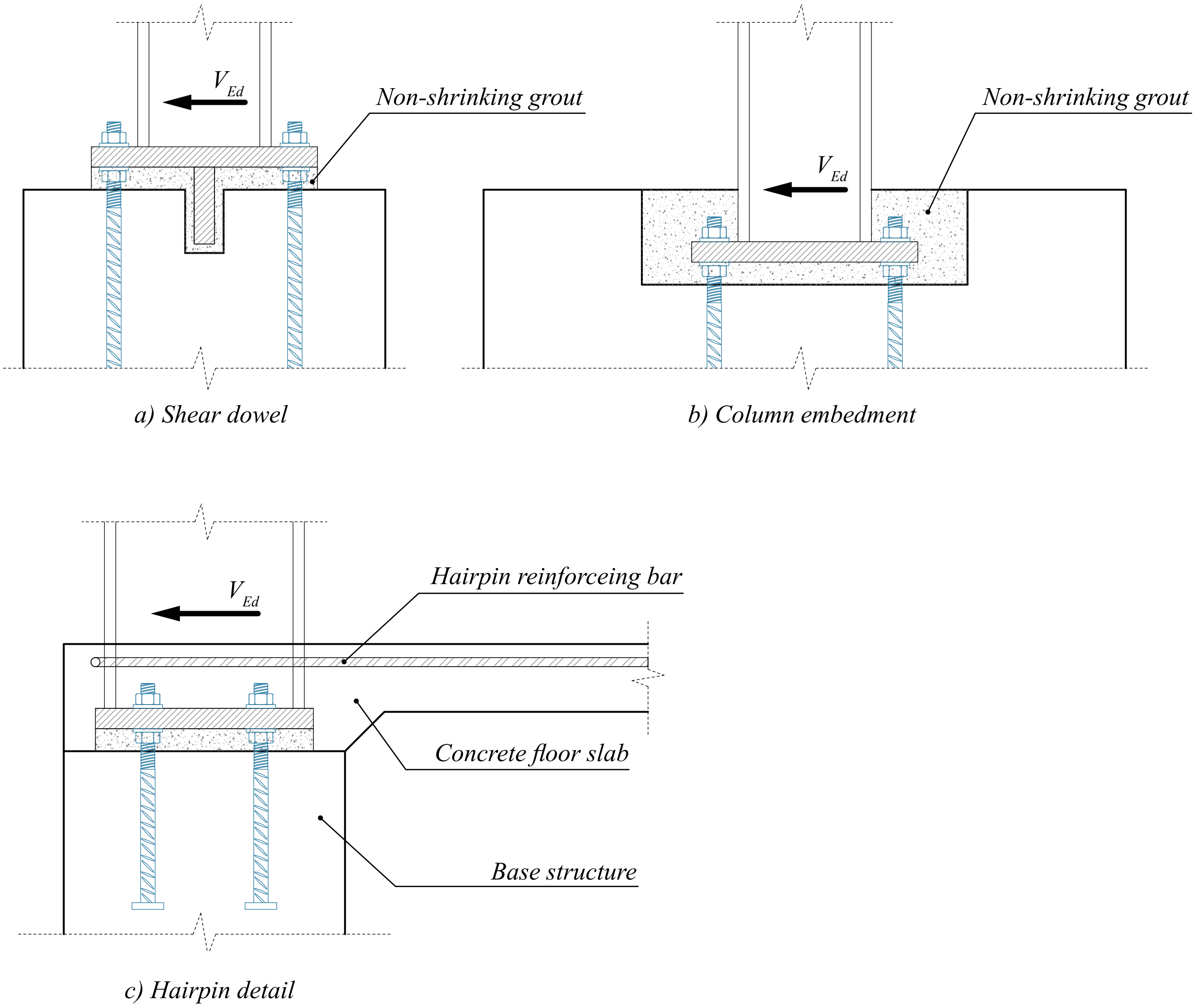


Figure 15. Details of alternative means of transferring shear load.

Installing HPM® Rebar Anchor Bolts

Identification of the product

HPM® Rebar Anchor Bolts are available in standard models (16, 20, 24, 30, and 39) analogous to the M-thread diameter of the bolt. The model of anchor bolt can be identified by the name in the label on the product and the color of the product.

Forming a bolt group

Bolts are collected into bolt groups using the PPL Installation Template. The installation template enables bolt groups to be centralized on the horizontal plane in exactly the right place and easily adjusted to the correct casting level.

HPM® Rebar Anchor Bolt color identification.

Anchor Bolt	Thread diameter [mm]	Color code	Installation Template
HPM 16	16	Yellow	PPL 16
HPM 20	20	Blue	PPL 20
HPM 24	24	Grey	PPL 24
HPM 30	30	Green	PPL 30
HPM 39	39	Orange	PPL 39

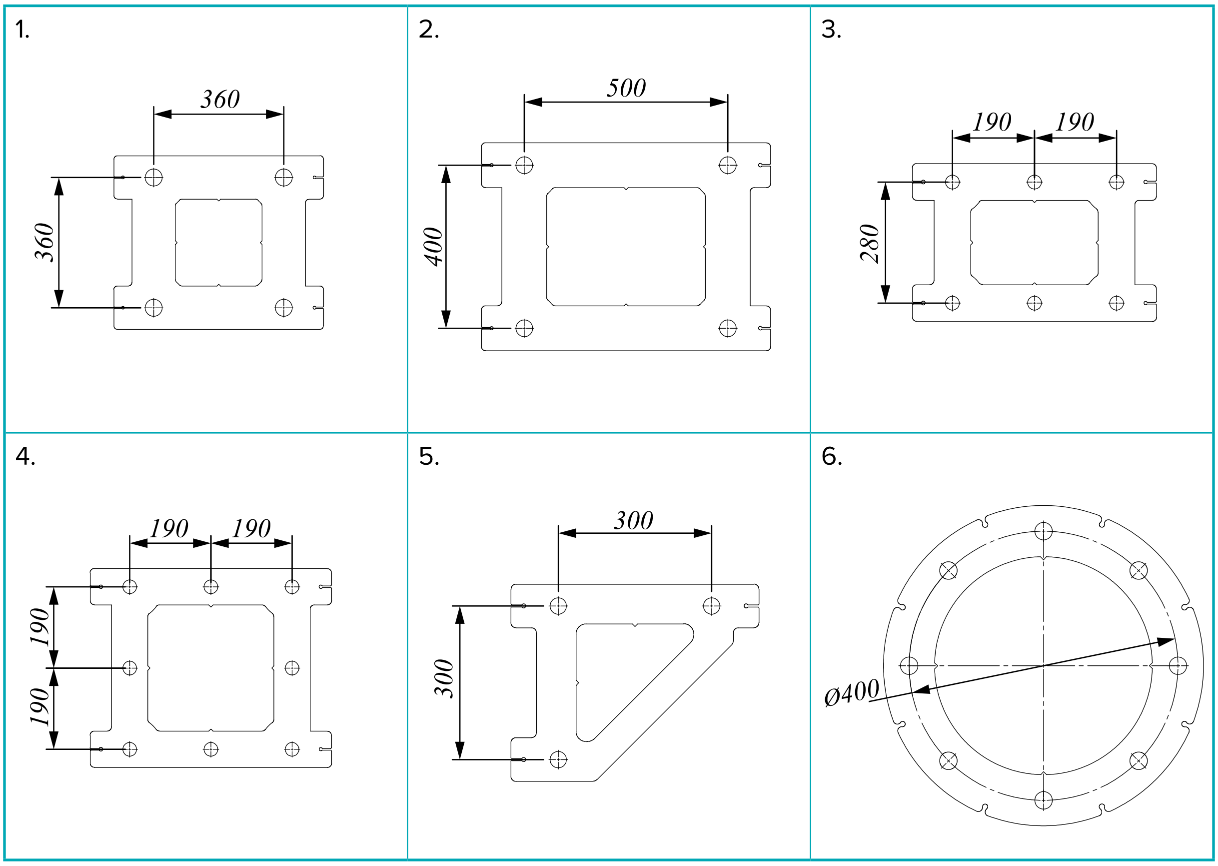
The PPL Installation Template is a steel plate. Anchor Bolts are fixed through the holes on the template with nuts and washers. The PPL installation plate has alignment marks for accurate positioning of the anchor bolt group. To prevent displacement during the concreting process, the template should be fixed securely to the supporting base by its fixing recesses at the sides. Concrete can be poured easily through the hole in the middle of the template. After casting, the installation template is detached and can be reused.

Ordering PPL Installation Templates

When PPL Installation Templates are ordered the thread diameter of bolts, the number of bolts and the center-to-center dimensions must be specified.

<u>Examples of installation plates:</u>

1. **PPL39-4** 360 × 360: 4 pieces M39 bolts in square form.
2. **PPL39-4** 500 × 400: 4 pieces M39 bolts in rectangular form.
3. **PPL30-6** 280 × (190 + 190): 6 pieces M30 bolts rectangular form.
4. **PPL30-8** (190 + 190) × (190 + 190): 8 pieces M30 bolts in the form of a square.
5. **PPL30-3** 300 × 300: 3 pieces M30 bolts in the form of rectangular triangles.
6. **PPL24-8** D400: 8 pieces M24 bolts in the form of circles with diameter of 400 mm.

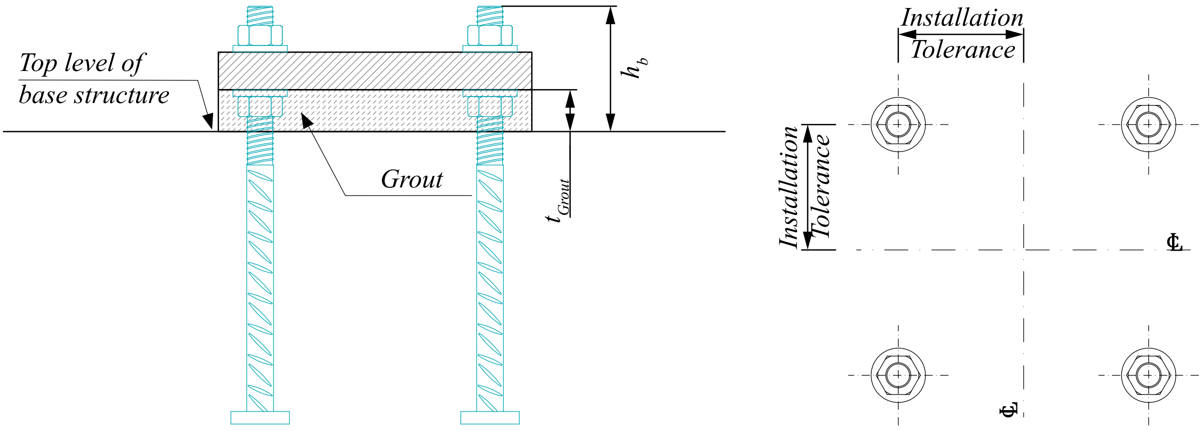


PPL Installation Templates can also be manufactured according to drawings that present the location of the bolts and thread diameters.

Bolt installation and installation tolerances

The bolts are installed to the height level according to dimension h_b given in table below. The height level is measured from the surface of concrete, and the level tolerance is ±20 mm. Each anchor bolt includes a marking of the anchorage depth.

Installation tolerances and the anchor bolt`s protrusion from the concrete.



Anchor Bolt	HPM 16	HPM 20	HPM 24	HPM 30	HPM 39
Thickness of grouting t_{Grout} [mm]	50	50	50	50	60
Protrusion of the bolt h_b [mm]	105	115	130	150	180
Installation tolerance for the bolt [mm]	±3	±3	±3	±3	±3

Bending the bolts

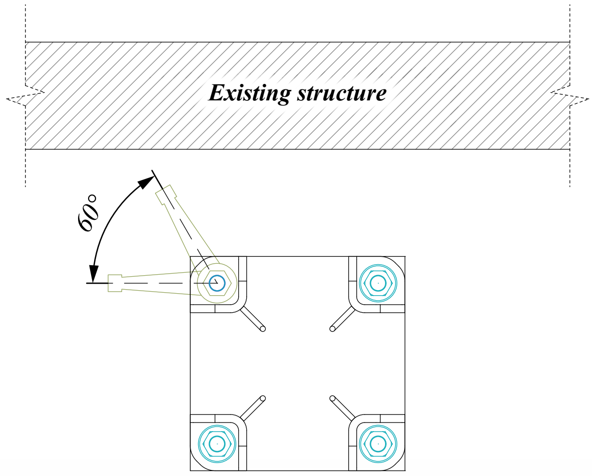
HPM® Rebar Anchor Bolts are made of B500B ribbed reinforcement steel. Bending must be done in accordance with EN 1992-1-1. See Annex E of this manual with application examples.

Welding the bolts

Welding of the bolts should be avoided, although all materials used in HPM® Rebar Anchor Bolts are weldable (except the nuts). Requirements and instructions of standard EN 17660-1: Welding of reinforcing steel, Part 1: load bearing welding joints shall be taken into account when welding rebars.

Existing buildings

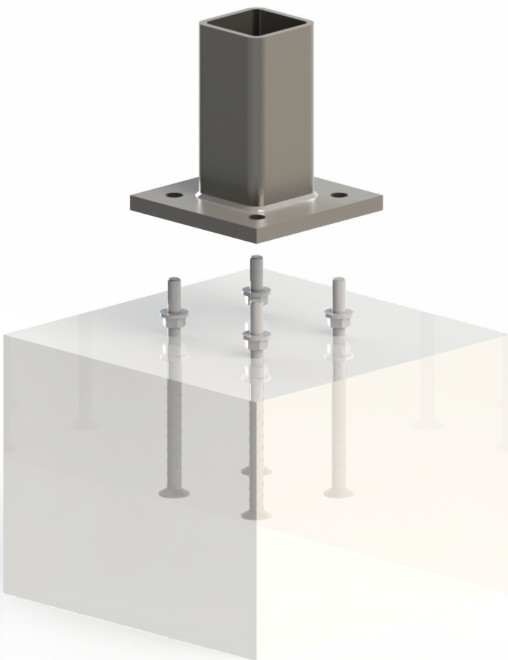
Where placing anchor bolts adjacent to walls or other obstructions, construction sequences should be considered. It is necessary to check that the erector will have enough access to tighten the nuts. If special setting is required, please contact Peikko Technical Support.



Erection of the attachment

Before erecting the attachment, the upper nuts and washers are removed from the anchor bolts. The lower leveling nuts and washers are adjusted to the correct level. The attachment is erected directly on the pre-leveled washers and nuts.

An alternative method is to place shims between anchor bolts and adjust them to the proper level. The lower leveling nuts must be leveled at least 5 mm under the top level of shims to ensure that the attachment will rest first on the shims.



Securing the connection

The upper nuts and washers are screwed onto the bolts and the attachment is aligned in the vertical position using leveling nuts. It is practical to use two theodolites from different directions to ensure verticality. The nuts are tightened at least to the minimum torque given in the table below. Adequate torque can be achieved typically by 10 – 15 impacts of a slogging ring wrench (DIN 7444) or open-ended slogging wrench (DIN 133) and a 1.5 kg sledgehammer.

Recommended minimum T_{min} torque values of nuts.

Anchor Bolt	T_{min} [Nm]	Size of the slogging wrench
HPM 16	120	24 mm
HPM 20	150	30 mm
HPM 24	200	36 mm
HPM 30	250	46 mm
HPM 39	350	60 mm

Grouting the joint and recess boxes

Before loading the attachment with any other structures, the joint and recess boxes must be grouted following the grout supplier's instructions. The grouting must be non-shrinking and have a strength according to the plans. To avoid air being trapped in the joint, it is recommended that grout be poured from one side only. Grouting formwork is made so that adequate concrete cover for anchor bolts is achieved.

Instructions for controlling bolt installation

Before casting:

- Ensure that the right PPL Installation Template is being used (axial distances, thread size).
- Verify the location of the bolt group.
- Ensure that the reinforcement required by the bolts has been installed.
- Ensure that the bolts are at the correct level.
- Ensure that the installation plate is in a horizontal position
- Ensure that the installation plate and bolt group are not rotated.
- Ensure that the bolt group is fixed in such a way that no movement can occur during casting.

After casting:

- Ensure that the location of the bolt group is within the allowance for tolerance. Greater variations must be reported to the structural designer.
- Protect the thread until the erection of the attachment (tape, plastic tube, etc.).

Instructions for controlling attachment installation

The joints must be made according to the installation plan drafted by the structural designer. If needed, Peikko's technical support can provide advice.

Check the following:

- The installation order.
- Supports and bracing during installation.
- Instructions for tightening the nuts.
- Instructions for joint and recess boxes casting.

NOTES

Technical Manual Revisions

Version: PEIKKO GROUP 09/2022. Revision: 002

- Correction made in Table 4.
- Correction made in Annex D, Table 15.

Version: PEIKKO GROUP 01/2022. Revision: 002

- Update in accordance with EN 1992-4.

Version: PEIKKO GROUP 01/2015. Revision: 001*

- New cover design for 2018 added.

Resources

DESIGN TOOLS

Use our powerful software every day to make your work faster, easier, and more reliable. Peikko design tools include design software, 3D components for modeling programs, installation instructions, technical manuals, and product approvals of Peikko's products.

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TECHNICAL SUPPORT

Our technical support teams around the world are available to assist you with all of your questions regarding design, installation etc.

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APPROVALS

Approvals, certificates, and documents related to CE-marking (DoP, DoC) can be found on our websites under each products' product page.

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Environmental Product Declarations and management system certificates can be found at the quality section of our websites.

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