TECHNICAL MANUAL

HPM® Rebar Anchor Bolts

Easy and Fast Bolted Connections

Version: PEIKKO GROUP ACI-M 03/2016
Designed according to ACI 318M-11

peikko®

HPM Rebar Anchor Bolt

For bolted connections

System benefits

- 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

HPM Rebar Anchor Bolts are intended to anchor concrete or steel structures and machinery into concrete base structures. HPM Rebar Anchor Bolts can be used with HPKM® Column Shoes, SUMO Wall Shoes or even with steel columns and machine fixings.
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 and also installation accessories. Headed bolts are used typically in shallow structures for end anchoring, whereas straight bolts are used for lap splices. Anchor Bolts are suitable for different environmental conditions, and available in black steel, ECO & Hot-Dip Galvanized versions. Installation templates are provided to ensure easy and correct installation of the anchor bolts.
The HPM Rebar Anchor Bolt as a steel part cast into concrete is designed according to Eurocodes or ACI 318M-11.
Headed HPM/L Anchor Bolts have been ETA approved (ETA-02/0006).

Contents

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. It can be used also in communication and transmission towers.
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
- Installation templates

HPM L Anchor Bolt

HPM P 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 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 Anchor Bolts is in structures with sufficient depth (e.g. pedestals, columns). Alternative usages are shown in Annex E.

HPM Rebar Anchor Bolts are pre-designed to be compatible with HPKM® Column Shoes and SUMO Wall Shoes, providing a solution for most precast connections (e.g. column to foundation, column to pedestal, column to column, wall to foundation and wall to wall), as well as to secure steel columns or even machine fixings.

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-shrink grout 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 Anchor Bolts in a concrete column to footing connection

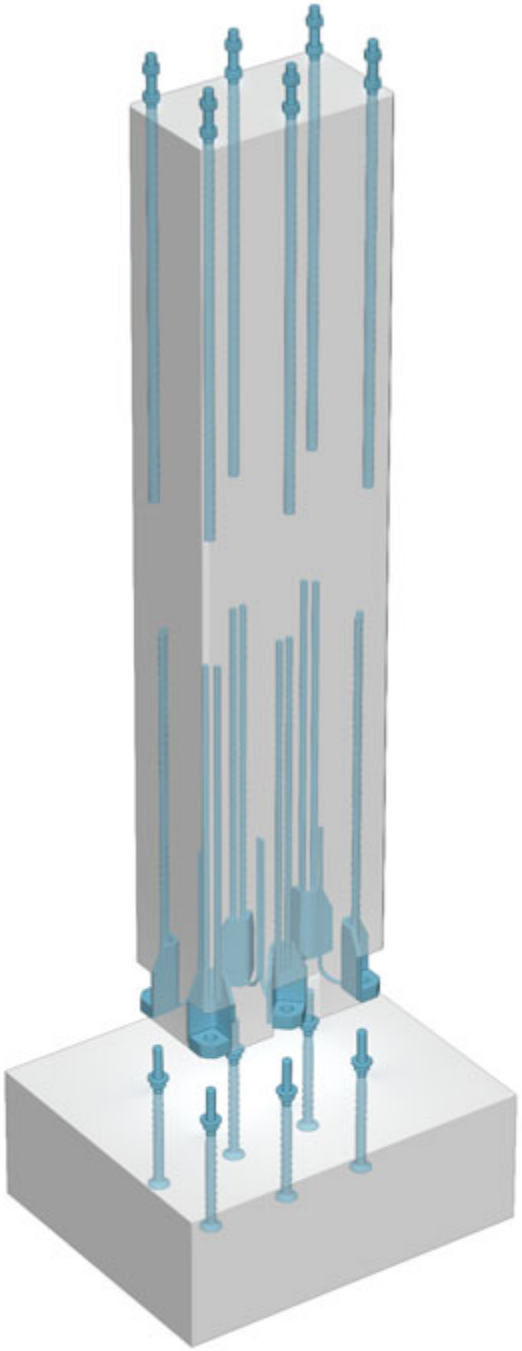
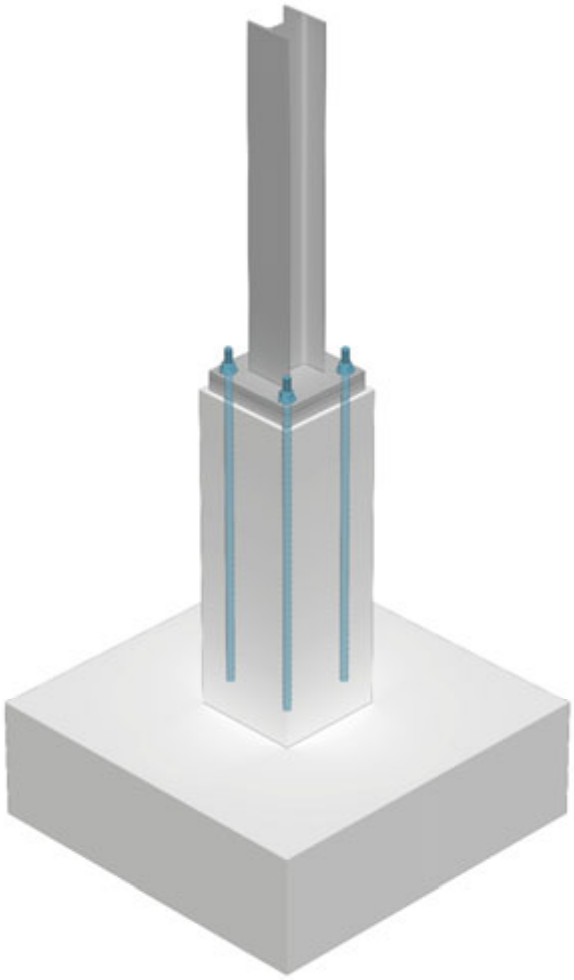


Figure 2. HPM P Anchor Bolts in a steel column to pedestal connection.



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.

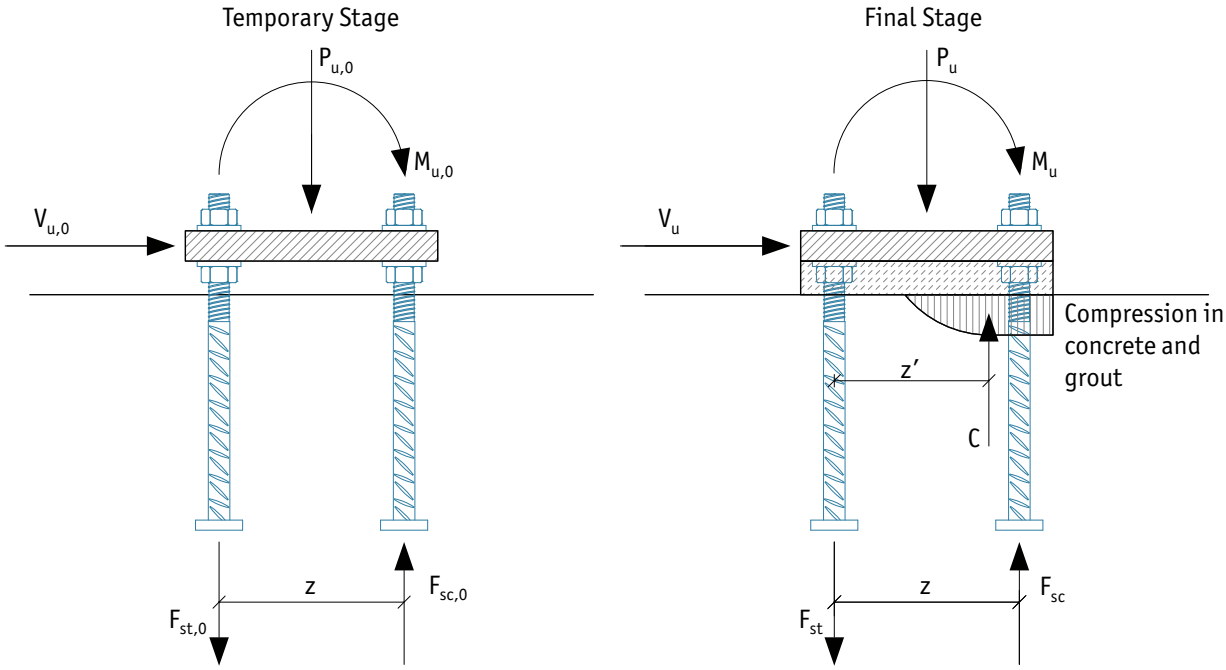
1.1.1 Temporary conditions

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 of the 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 grout 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 Customer Engineering Service 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. The required concrete cover is defined by structural designer. As an alternative to concrete cover, Peikko offers coating options: Hot-Dip Galvanizing. Other anti-corrosion methods such as painting on site can also be utilized. For further information please contact Peikko Customer Engineering Service.

Hot-Dip Galvanized bolts (according to ASTM A153/A153M) are dipped completely into galvanized material. The minimum coating thickness is 53 µm, which fulfills material class C.

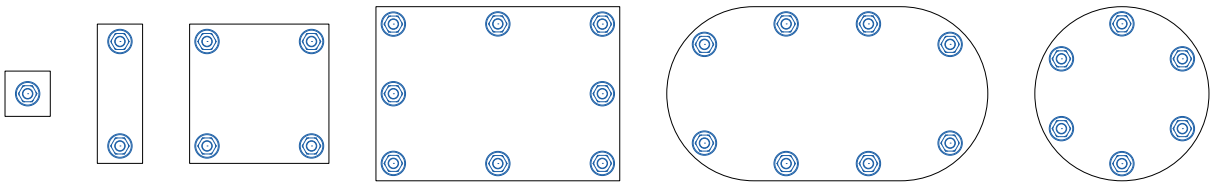
1.2.2 Interaction with base structure

HPM Rebar Anchor Bolts are pre-designed for use in reinforced base structures (e.g. foundations, slabs, pedestals, columns, walls). The standard properties of HPM Rebar Anchor Bolts are valid for reinforced normal weight concrete with a strength 25 to 70 MPa cylinder strength. 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 bolts

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 to ensure that the bolts can be installed in the intended location.

Figure 4. Examples with layout patterns of HPM Rebar Anchor Bolts.

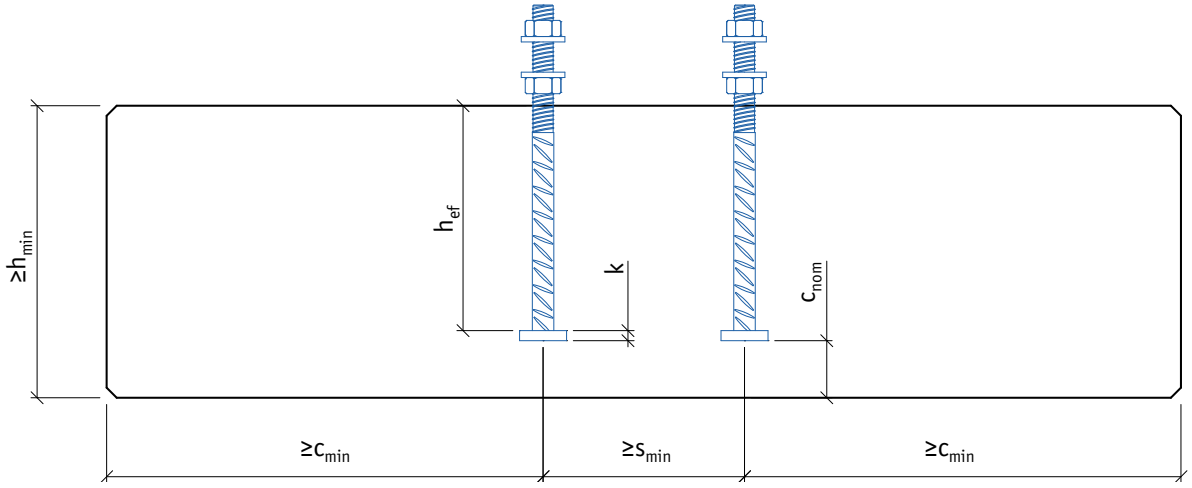


When placing HPM L Anchor Bolts, the spacing (s_{min}), edge distance (c_{min}), and base structure thickness (h_{min}) must not fall below the minimum values shown in *Table 1*. It should be noted that the minimum thicknesses (h_{min}) in *Table 1* are for base structures cast directly against soil, $h_{min} = h_{ef} + k + c_{nom}$, hence $c_{nom} = 75$ mm (concrete cover for concrete cast against and permanently exposed to earth according to ACI 318M-11, section 7.7.1). While edge distance (c_{min}) is calculated by using concrete cover for concrete exposed to earth or weather according to ACI 318M-11, section 7.7.1.

Table 1. Positioning of HPM L Anchor Bolts in base structure.

Anchor Bolt	c_{min} [mm]	s_{min} [mm]	h_{min} [mm]	h_{ef} [mm]	k [mm]
HPM 16 L ACI	60	65	250	165	10
HPM 20 L ACI	75	80	310	223	12
HPM 24 L ACI	80	100	375	287	13
HPM 30 L ACI	85	130	425	335	15
HPM 39 L ACI	95	160	595	502	18

Figure 5. Installed HPM L Anchor Bolt.



When placing HPM P Anchor Bolts, the minimum edge distance should comply with the concrete cover thickness according to ACI 318M-11, chapter 7. The bolts must be spaced to prevent bundles from forming and should fulfill the requirements for lapped bars, ACI 318M-11, chapters 7 and 12.

1.3 Other properties

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

Alternatives of ribbed bars	Grade 60	ASTM A615M
	B500B	EN 10080
	HRB 500	GB 1499

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

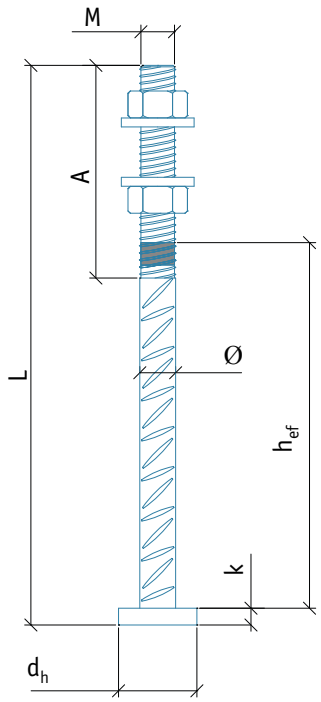
NOTE: Alternative materials of washers and nuts can be supplied on request.

Peikko Group's production units are externally controlled and periodically audited on the basis of production certifications and product approvals by various organizations.

Manufacturing method	
Ribbed bars	Mechanical cutting
Threads	Rolling
Anchor head	Forging

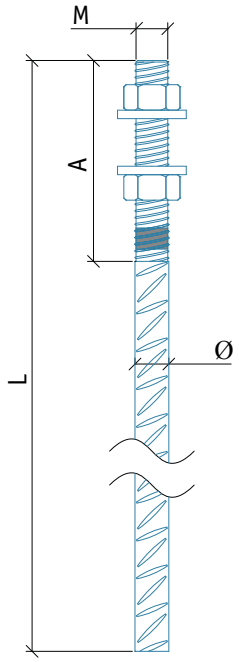
Manufacturing tolerances	
Length	± 10 mm
Thread length	+ 5, -0 mm

Table 2. Dimensions [mm], weight [kg], and color codes of HPM L Anchor Bolts.



	HPM 16 L ACI	HPM 20 L ACI	HPM 24 L ACI	HPM 30 L ACI	HPM 39 L ACI
M	M16	M20	M24	M30	M39
A	140	140	170	190	200
Stress area of the thread	155	241	349	555	968
Ø	16	20	25	32	40
L	280	350	430	500	700
Washer	Ø 40-6	Ø 44-6	Ø 56-6	Ø 65-8	Ø 90-10
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 3. Dimensions [mm], weight [kg], and color codes of HPM P Anchor Bolts.



	HPM 16 P ACI	HPM 20 P ACI	HPM 24 P ACI	HPM 30 P ACI	HPM 39 P ACI
M	M16	M20	M24	M30	M39
A	140	140	170	190	200
Stress area of the thread	155	241	349	555	968
Ø	16	20	25	32	40
L	810	1000	1160	1420	2000
Washer	Ø 40-6	Ø 44-6	Ø 56-6	Ø 65-8	Ø 90-10
Weight	1.5	2.8	4.9	9.8	21.8
Color code	Yellow	Blue	Grey	Green	Orange

Lap lengths of HPM P Anchor bolt for HPM 16, 20 and 24 are defined according to concrete grade equal to or greater than 25 MPa cylinder strength.

Lap lengths of HPM P Anchor bolt for HPM 30 and 39 are defined according to concrete grade equal to or greater than 30 MPa cylinder strength.

Anchor bolt weight in *Table 2* and *Table 3* is theoretical, and is calculated from the values of the nominal cross-sectional area using density value of 7850 kg/m^3 .

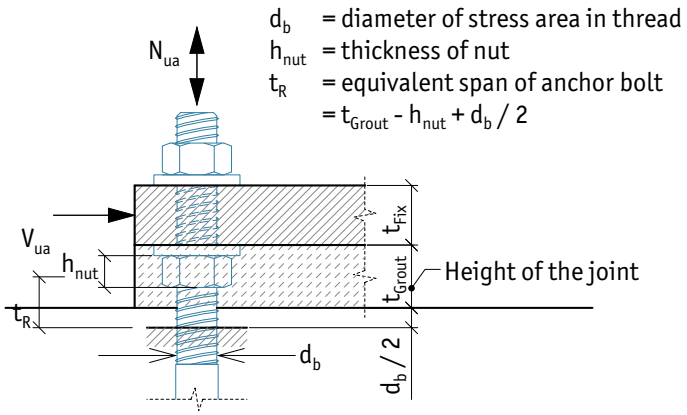
2. Resistances

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:

- ACI 318M-11
- AISC Steel Design Guide 1, Base Plate and Anchor Rod Design, Second edition

Figure 6. 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. The resistances of HPM Rebar Anchor bolt in this manual are calculated by using strength reduction factors according to loading combination of 9.2 in ACI318M-11. Also these resistances are without interaction of axial and shear load. For combined resistance, see section 2.2 of this manual.

Table 4. Design values for tensile or compressive resistance of individual HPM Rebar Anchor Bolt. (Steel strength). Anchor bolt material grade 60 according to standard ASTM A615M.

		HPM 16 ACI ASTM	HPM 20 ACI ASTM	HPM 24 ACI ASTM	HPM 30 ACI ASTM	HPM 39 ACI ASTM
ϕN_{sa} $\phi N_{sa,0}$	[kN]	63	97	141	224	390

Table 5. Design values for tensile or compressive resistance of individual HPM Rebar Anchor Bolt. (Steel strength). Anchor bolt material B500B according to standard EN 10080.

		HPM 16 ACI EN	HPM 20 ACI EN	HPM 24 ACI EN	HPM 30 ACI EN	HPM 39 ACI EN
ϕN_{sa} $\phi N_{sa,0}$	[kN]	55	86	125	199	346

Table 6. Design values for tensile or compressive resistance of individual HPM Rebar Anchor Bolt. (Steel strength). Anchor bolt material HRB500 according to standard GB 1499.

		HPM 16 ACI GB	HPM 20 ACI GB	HPM 24 ACI GB	HPM 30 ACI GB	HPM 39 ACI GB
ϕN_{sa} $\phi N_{sa,0}$	[kN]	63	97	141	224	390

The resistances of shear are determined in reference to ACI 318M-11 for final stage and AISC Steel Design Guide 1, Base Plate and Anchor Rod Design, Second edition for erection stage.

Table 7. Design values for shear resistance of individual HPM Rebar Anchor Bolt. (Steel strength). Anchor bolt material grade 60 according to standard ASTM A615M.

Anchor Bolt	ϕV_{sa} [kN] Final Stage	$\phi V_{sa,0}$ [kN] Erection Stage	t_{Grout} [mm]
HPM 16 ACI ASTM	28	5	50
HPM 20 ACI ASTM	43	11	50
HPM 24 ACI ASTM	62	19	50
HPM 30 ACI ASTM	99	40	50
HPM 39 ACI ASTM	173	72	60

Table 8. Design values for shear resistance of individual HPM Rebar Anchor Bolt. (Steel strength). Anchor bolt material B500B according to standard EN 10080.

Anchor Bolt	ϕV_{sa} [kN] Final Stage	$\phi V_{sa,0}$ [kN] Erection Stage	t_{Grout} [mm]
HPM 16 ACI EN	25	5	50
HPM 20 ACI EN	38	10	50
HPM 24 ACI EN	55	17	50
HPM 30 ACI EN	88	35	50
HPM 39 ACI EN	153	64	60

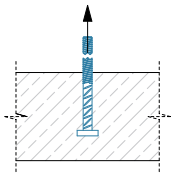
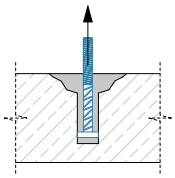
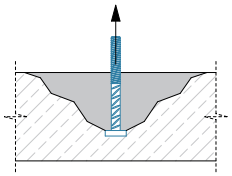
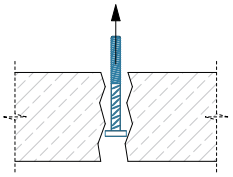
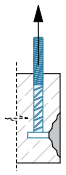
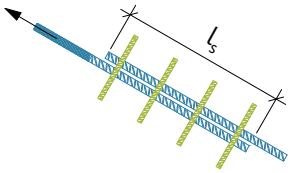
Table 9. Design values for shear resistance of individual HPM Rebar Anchor Bolt. (Steel strength). Anchor bolt material HRB500 according to standard GB 1499.

Anchor Bolt	ϕV_{sa} [kN] Final Stage	$\phi V_{sa,0}$ [kN] Erection Stage	t_{Grout} [mm]
HPM 16 ACI GB	28	5	50
HPM 20 ACI GB	43	11	50
HPM 24 ACI GB	62	19	50
HPM 30 ACI GB	99	40	50
HPM 39 ACI GB	173	72	60

NOTE: Resistances ϕV_{sa} and $\phi V_{sa,0}$ in Table 7-9 are valid for height of joint equal to t_{Grout}.

Table 10. Required verification for HPM Rebar Anchor Bolts loaded in tension.

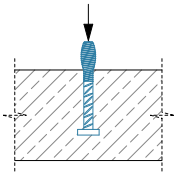
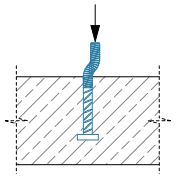
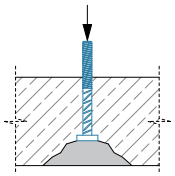
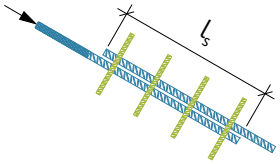
The use of Peikko Designer® software is recommended to prove the resistance of the following verifications

Failure mode	Example	HPM L ACI Anchor Bolts	HPM P ACI 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 breakout strength [1)]		Required (for anchor group)	Not applicable
Splitting strength [2)]		The requirements for splitting according to ACI 318M-11 section D.8	Not applicable
Concrete side face blowout 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) The splitting reinforcement is not required if the spacing (s_{min}), edge distance (c_{min}), and base structure thickness (h_{min}) do not fall below the minimum values shown in *Table 1*.
3) Not required if the edge distance in all directions $c \geq 0.4h_{ef}$.
4) See Annex D for required transverse reinforcement in the lap zone.

Table 11. Required verification for HPM Rebar Anchor Bolts loaded in compression.

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

Failure mode	Example	HPM L ACI Anchor Bolts	HPM P ACI 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)

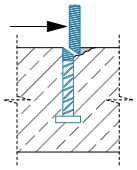
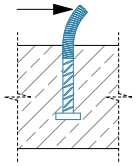
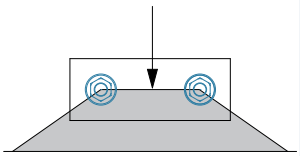
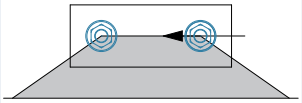
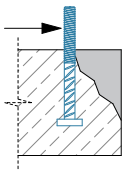
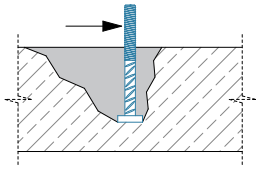
1) Not required if the height of the joint does not exceed the grouting thicknesses stated in the installation instructions of this manual. See *Table 7-9* for t_{Grout}. For custom design additional provisions can be found in AISC Steel Design Guide 1, Base Plate and Anchor Rod Design, Second Edition, Appendix A, Section A1.1

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.

Table 12. Required verification for HPM Rebar Anchor Bolts loaded in shear.

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

Failure mode	Example	HPM L ACI Anchor Bolts	HPM P ACI 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 breakout strength [2] • **Shear perpendicular to the edge** • **Shear parallel to the edge** • **Inclined shear**	  	Required (for anchor group)	Required (for anchor group)
Concrete pry-out strength		Required (for anchor group)	Not applicable

[1] Not required 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 7-9* for t_{Grout}. It should be noted that the check always applies in the erection stage.

[2] Not required if supplementary reinforcement is provided according to Annex B1.

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 **tension** force and **shear** force in each bolt shall satisfy the condition:

$$f_t \le \phi\, F'_{nt} = \phi \left[1.3F_{nt} - \frac{F_{nt}}{\phi\, F_{nv}} \cdot f_v \right] \le \phi\, F_{nt}$$

Where
f_t = tensile stress in anchor bolt = $f_{tb} + f_{ta}$
f_{tb} = stress due to bending = $\frac{M_l}{S} = \frac{V_{ua,0} \cdot t_R}{S}$
f_{ta} = axial stress = $N_{ua,0}/A_g$
F_{nt} = nominal tensile strength=0.75 f_{uta}
F_{nv} = nominal shear strength=0.40 f_{uta}
f_v = shear stress = $V_{ua,0}/A_g$
f_{uta} = specified tensile strength of anchor steel
$V_{ua,0}$ = factored shear load on a single bolt, Erection Stage
$N_{ua,0}$ = factored axial load on a single bolt, Erection Stage
M_l = bending moment due to shear force
t_R = span of anchor bolt (lever arm), (see *Figure 6*)
S = section modulus = $d^3 / 6$
d = basic major diameter of external thread (nominal diameter)
A_g = gross area based on the nominal diameter of the thread
ϕ = strength reduction factor for combined tension and shear forces = 0.75

NOTE: In cases of interaction between compression and shear, the formula above may be used by introducing limit for the nominal steel compressive strength and by adjusting strength reduction factor.

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

- If $V_{ua}/(\phi V_n) \le 0.2$ for the governing strength in shear, then full strength in tension shall be permitted $\phi N_n \ge N_{ua}$.
- If $N_{ua}/(\phi N_n) \le 0.2$ for the governing strength in tension, then full strength in shear shall be permitted $\phi V_n \ge V_{ua}$.
- If $V_{ua}/(\phi V_n) > 0.2$ for the governing strength in shear and $N_{ua}/(\phi N_n) > 0.2$ for the governing strength in tension, then

$$\frac{N_{ua}}{\phi N_n} + \frac{V_{ua}}{\phi V_n} \le 1.2$$

ACI 318M-11 Eq. (D-42)

Where
ϕV_n = governing strength in shear
ϕN_n = governing strength in tension
V_{ua} = factored shear load on a single bolt, Final Stage
N_{ua} = factored axial load on a single bolt, Final Stage

2.3 Fire resistance

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 Customer Engineering Service for custom designs.

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

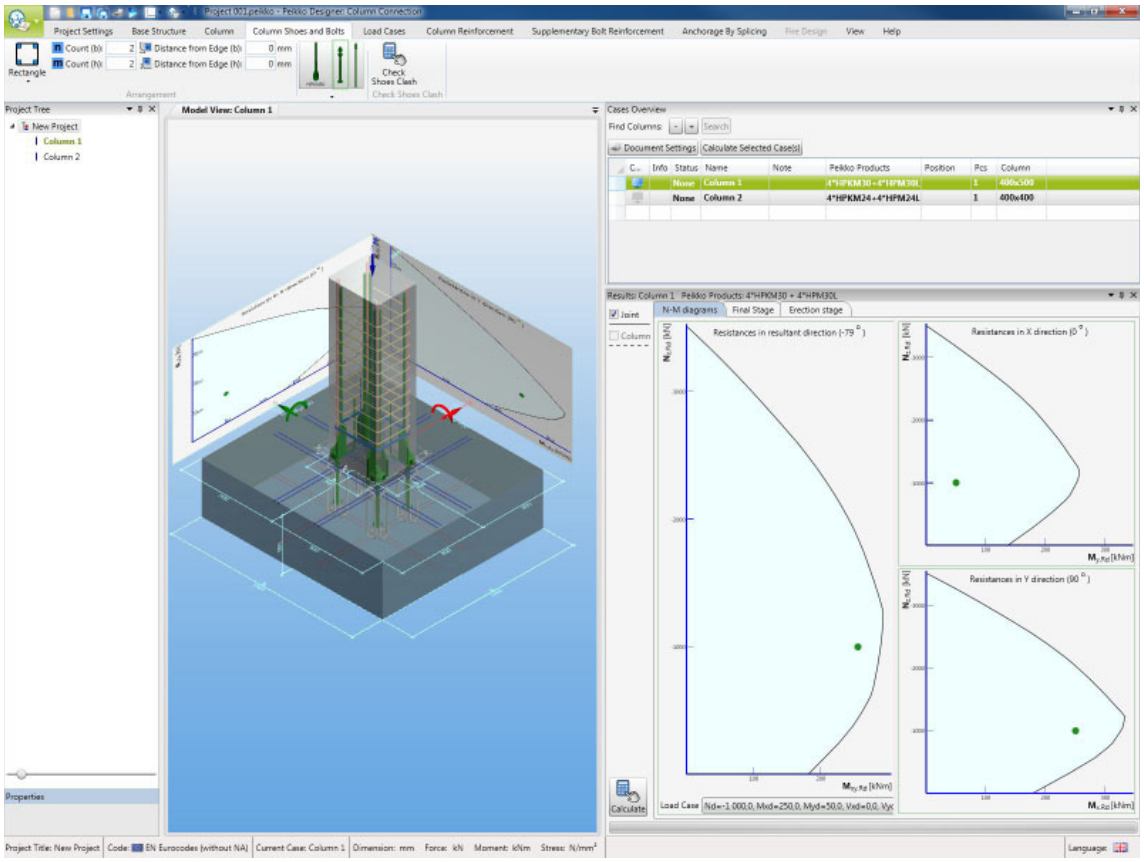
Examples for ordering HPM Rebar Anchor Bolt from specific material:

- **HPM ACI ASTM** = Anchor Bolt manufactured from material according to standard ASTM A615M
  Example: **HPM30P ACI ASTM**
- **HPM ACI EN** = Anchor Bolt manufactured from material according to standard EN 10080
  Example: **HPM30P ACI EN**
- **HPM ACI GB** = Anchor Bolt manufactured from material according to standard GB 1499
  Example: **HPM30P ACI GB**

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 7. User interface of Peikko Designer® Column Connection.



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 (P-Delta effect) should be included in the load case
- Type of column shoes and anchor bolts
- Column shoe arrangement
- Column reinforcement (optional)
- Reinforcement of structure under column (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

A1: Concrete breakout reinforcement

If the concrete breakout resistance is exceeded, supplementary reinforcement for the tension load should be provided. Detailing of hanger reinforcement for HPM L Anchor Bolts is shown in the following figure. The required quantities of stirrups and surface bars are given in *Table 13*. Alternative reinforcement arrangements can be calculated using the Peikko Designer® Column Connection software.

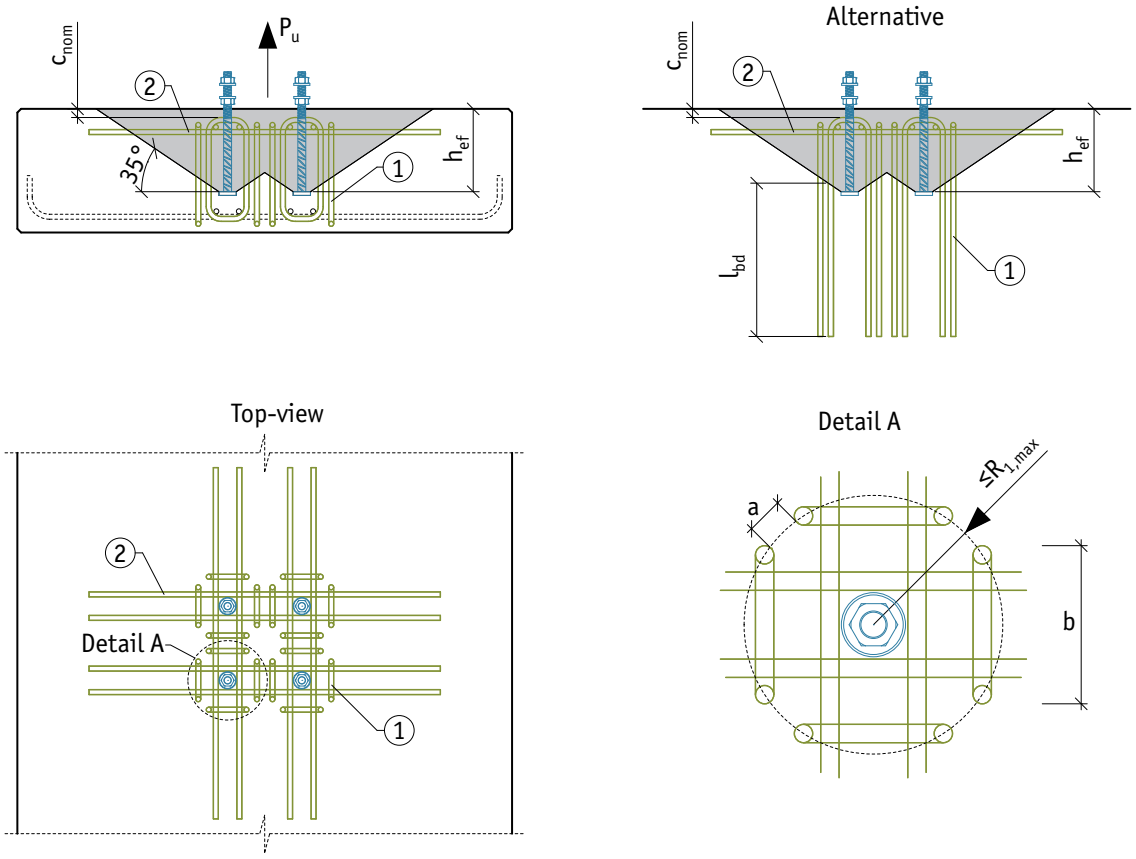
Table 13. Concrete breakout reinforcement (yield strength 420 MPa or higher).

Anchor Bolt	Stirrups (per bolt) ①	Surface bars ②	c_{nom} [mm]	$R_{1,max}$ [mm]	h_{ef} [mm]	b width of stirrup [mm]
HPM 16 L ACI	4 Ø 10	Ø 10	40	80	165	90
HPM 20 L ACI	4 Ø 10	Ø 10	40	110	223	100
HPM 24 L ACI	4 Ø 10	Ø 10	40	140	287	110
HPM 30 L ACI	4 Ø 12	Ø 10	40	165	335	130
HPM 39 L ACI	4 Ø 14	Ø 10	40	250	502	155

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

- The concrete strength class of the base structure is equal to or greater than 25 MPa cylinder strength.
- The nominal concrete cover is equal to or smaller than 40 [mm].
- The minimum clear distance **(a)** between adjacent legs of stirrups should not be less than 25 [mm], requirement according to ACI 318M-11, section 7.6.

Figure 8. Illustration of detailing of the supplementary reinforcement in the form of stirrups and hairpins.



B1: Edge reinforcement

If the edge breakout 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 Anchor Bolts is shown in the following figure. The required quantities of U-stirrups are given in *Table 14*. Alternative reinforcement arrangements can be calculated using the Peikko Designer® Column Connection software.

Table 14. Concrete breakout reinforcement (yield strength 420 MPa or higher) per fully loaded anchor bolt in shear.

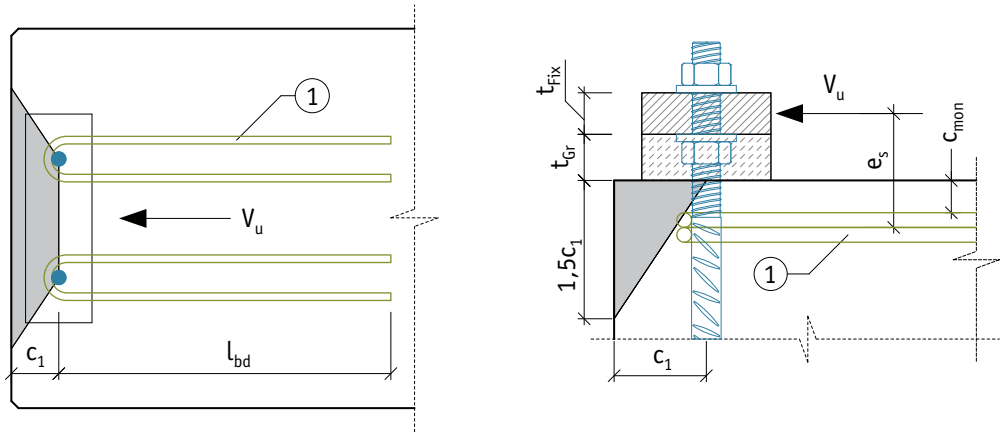
Anchor Bolt	U-Stirrups (per bolt) ①	c_1 [mm]	c_{nom} [mm]	e_s [mm]
HPM 16 L ACI	1 Ø 12	60	40	115
HPM 20 L ACI	1 Ø 14	75	40	120
HPM 24 L ACI	1 Ø 16	80	40	130
HPM 30 L ACI	2 Ø 16	85	40	155
HPM 39 L ACI	3 Ø 16	95	40	190

The reinforcement from *Table 14* can be directly applied under the following conditions:

- The distance between reinforcement and shear force equal to or smaller than e_s
- The edge distance is equal to or greater than c_1

It should be noted that the supplementary reinforcement shown in *Table 14* is selected for the edge perpendicular to the applied load, which is the least favorable case.

Figure 9. Illustration of detailing of the supplementary reinforcement in the form of loops.



NOTE: In Fig*ure 9* it is assumed that the edges of the concrete member parallel to the applied load have sufficient resistance without supplementary reinforcement.

C1: Concrete breakout 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 Anchor Bolts is shown in following figure. The required quantities of stirrups are given in *Table 15*. Reinforcement may be omitted if the concrete thickness *h* under the bolt's head is equal to or greater than h_{req} (see *Figure 10*).

Table 15. Concrete breakout reinforcement (yield strength 420 MPa or higher).

Anchor Bolt	h_{req} [mm]	A_s [mm²]	Stirrups (per bolt) ①
HPM 16 L ACI	80	98	2 Ø 10
HPM 20 L ACI	100	140	2 Ø 10
HPM 24 L ACI	115	201	2 Ø 10
HPM 30 L ACI	145	358	2 Ø 12
HPM 39 L ACI	190	591	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 10*).

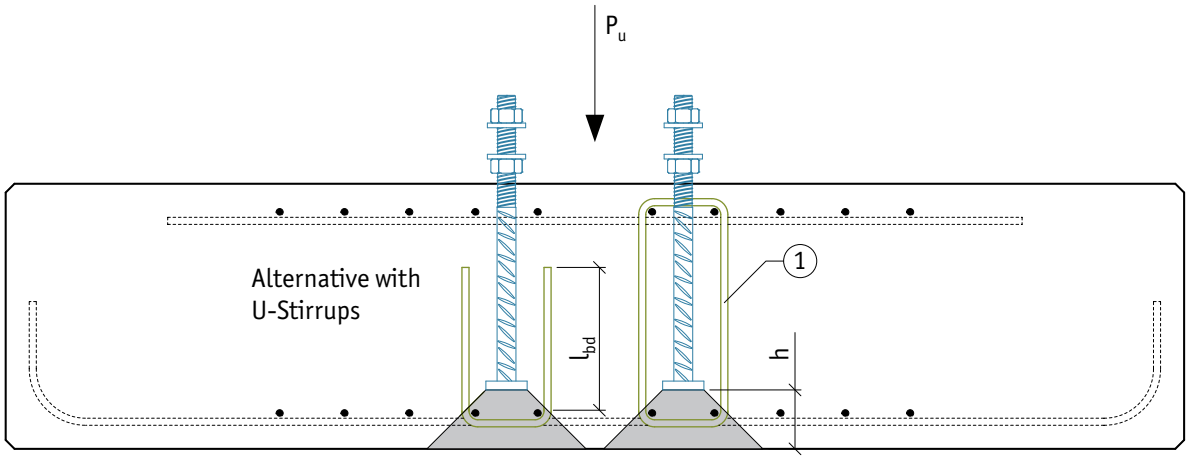
The inclination angle of stress cone is 45°.

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 25 *MPa cylinder strength*
- Stirrups are located inside the stress cone and anchored according to reinforced concrete standards

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

Figure 10. Reinforcing the conical fracture under the bolt.

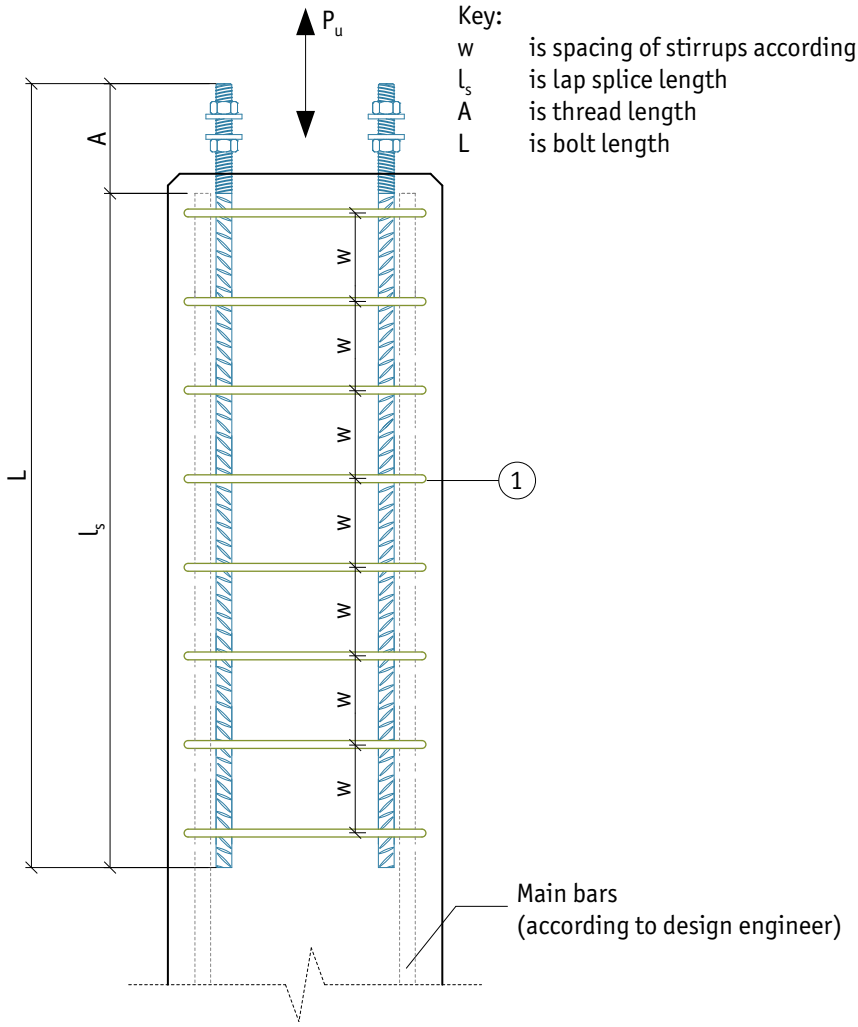


Long HPM P Anchor Bolts are designed for use in lap splices with the main reinforcement of the base structure. The base structure must be reinforced with at least the same cross section area of longitudinal bars corresponding to the bolts. Adequate transverse reinforcement $\sum A_{st}$ should be provided in the lap zone (see *Figure 11*). The recommended quantities of stirrups are given in *Table 16*. Alternative reinforcement arrangements can be calculated using the Peikko Designer® Column Connection software.

Table 16. Reinforcement for lap splices, (yield strength 420 MPa or higher).

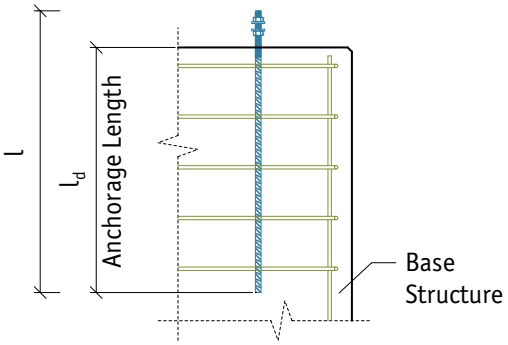
Anchor Bolt	Recommended amount of stirrups ①	l_s [mm]
HPM 16 P ACI	4 Ø 10	670
HPM 20 P ACI	4 Ø 10	860
HPM 24 P ACI	4 Ø 12	990
HPM 30 P ACI	8 Ø 10	1230
HPM 39 P ACI	12 Ø 10	1800

Figure 11. Transverse reinforcement for lapped splices.



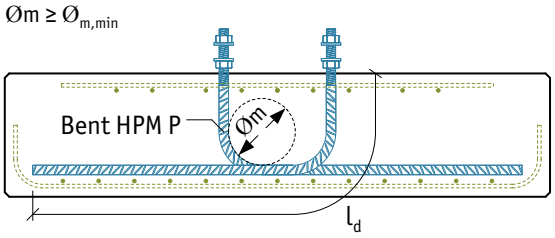
Key:
w is spacing of stirrups according to ACI318M-11, section 7.10.5
l_s is lap splice length
A is thread length
L is bolt length

1. HPM P 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_d to anchor the force P_u acting on a bolt must be checked in accordance with ACI 318M-11, chapter 12.

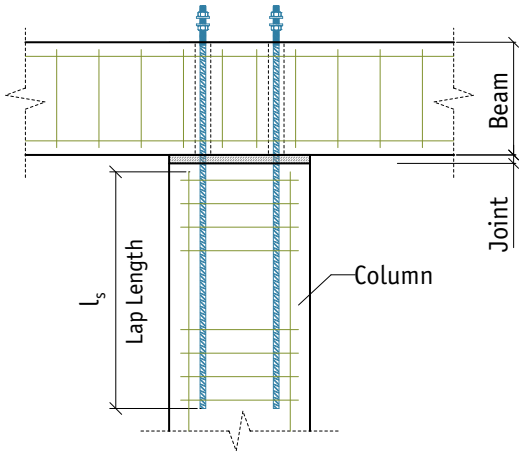


2. HPM P Anchor Bolts can be also installed in shallow structures with limited thickness by bending them. The minimum mandrel diameter $Ø_{m,min}$ must be checked for each individual case (according to ACI 318M-11, section 7.2 for black anchor bolt and according to ASTM A767/A767M for galvanized anchor bolt) 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 Anchor Bolts are available for structural solutions such as column-to-column connections through the beam. Where l_s is the design lap length in accordance with ACI 318M-11, chapter 12.



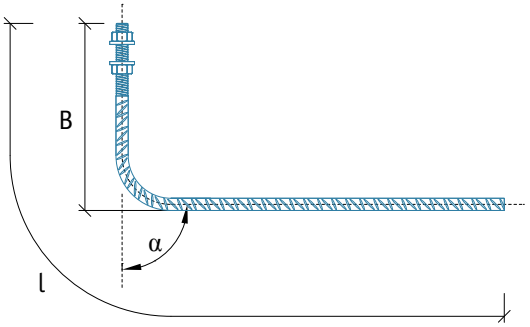
Ordering non-standard HPM P Anchor Bolts:

All dimensions in [mm]

1. Straight HPM P Anchor Bolt => **HPM(*)P – l**
   Example 1: HPM30P – 2000
2. Bent HPM P Anchor Bolt => **HPM(*)P – l – Bent(α)- B**
   Example 2: HPM30P – 2000 – Bent 90 – 500
   Example 3: HPM30P – 2500 – Bent 45 – 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



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

- By anchor bolt shear resistance (see *Table 7-9*)
- By friction resistance between the base plate and grout:

$$\phi V_{n,f} = \phi \mu P_u \leq 0.2 f_c' A_c$$

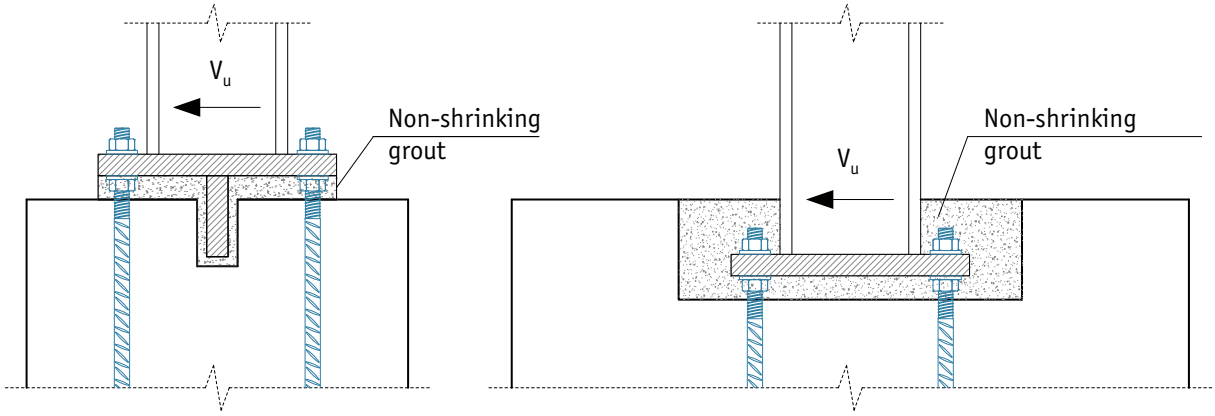
where

ϕ = strength reduction factor for friction
μ = friction coefficient is 0.55 for steel on grout, and 0.7 for steel on concrete
P_u = factored compressive load in the column that is consistent with the lateral force being evaluated
f_c' = specified compressive strength of concrete
A_c = area of concrete section resisting shear transfer

Alternative ways used in resisting large shear forces:

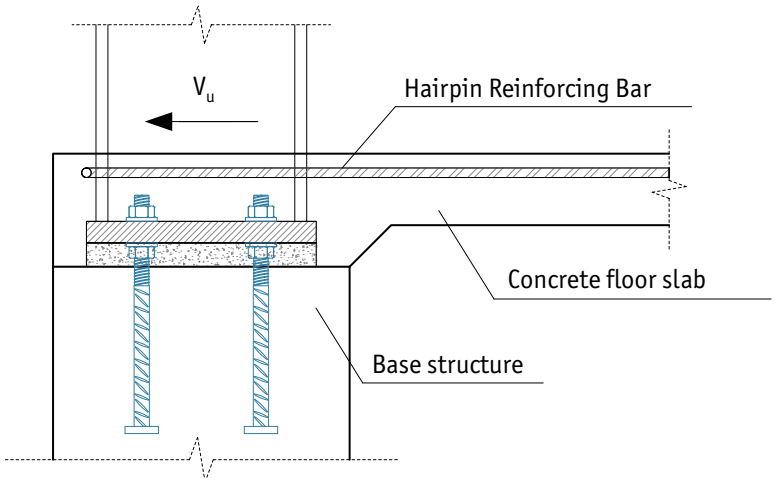
- Shear dowel (see *Figure 12a*)
- Embedding the column in the base structure (see *Figure 12b*)
- Transferring the force to the floor slab using hairpin bars (see *Figure 12c*)

Figure 12. Details of alternative means of transferring shear load.



a) Shear Dowel

b) Column Embedment



c) Hairpin detail

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.

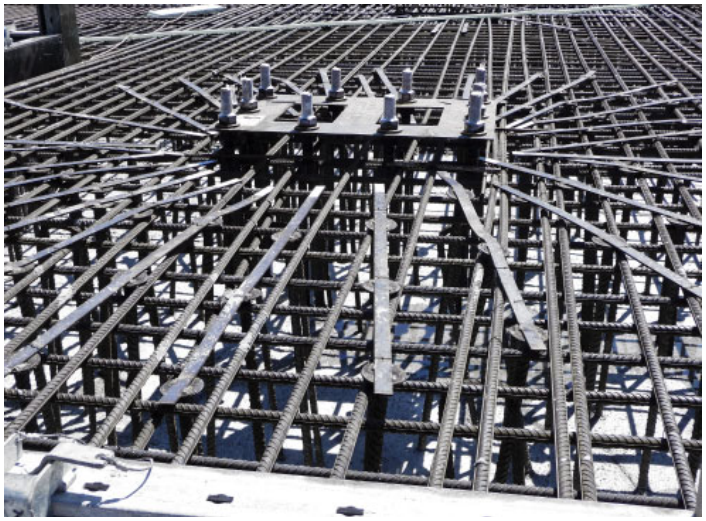
Forming a bolt group

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 ACI	16	Yellow	PPL 16
HPM 20 ACI	20	Blue	PPL 20
HPM 24 ACI	24	Grey	PPL 24
HPM 30 ACI	30	Green	PPL 30
HPM 39 ACI	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. Anchor bolts also have center marks on the top of each bolt for alternative positioning methods. 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.

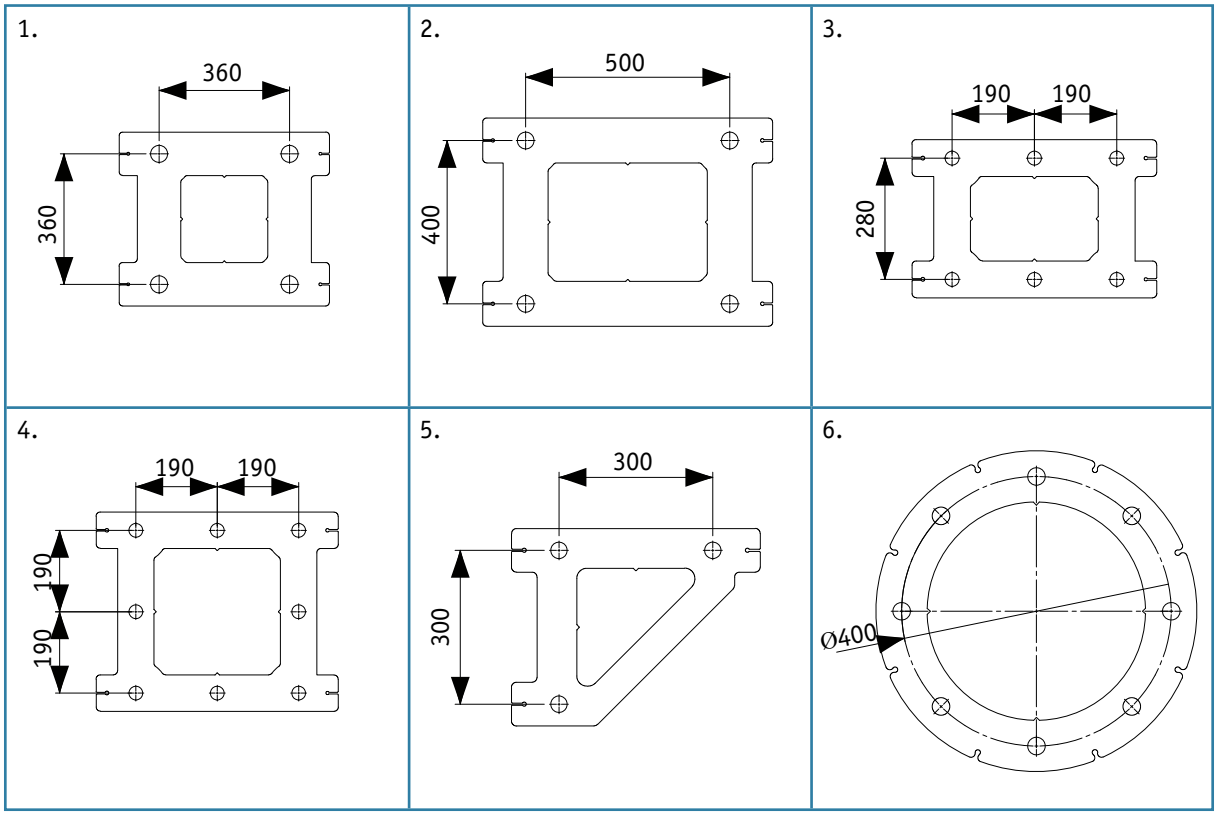


Ordering PPL Installation Templates

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

Examples of installation plates:

1. **PPL39-4** 360x360: 4 pieces M39 bolts in square form.
2. **PPL39-4** 500x400: 4 pieces M39 bolts in rectangular form.
3. **PPL30-6** 280x(190 + 190): 6 pieces M30 bolts rectangular form.
4. **PPL30-8** (190+190) x (190+190): 8 pieces M30 bolts in the form of a square.
5. **PPL30-3** 300x300: 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.

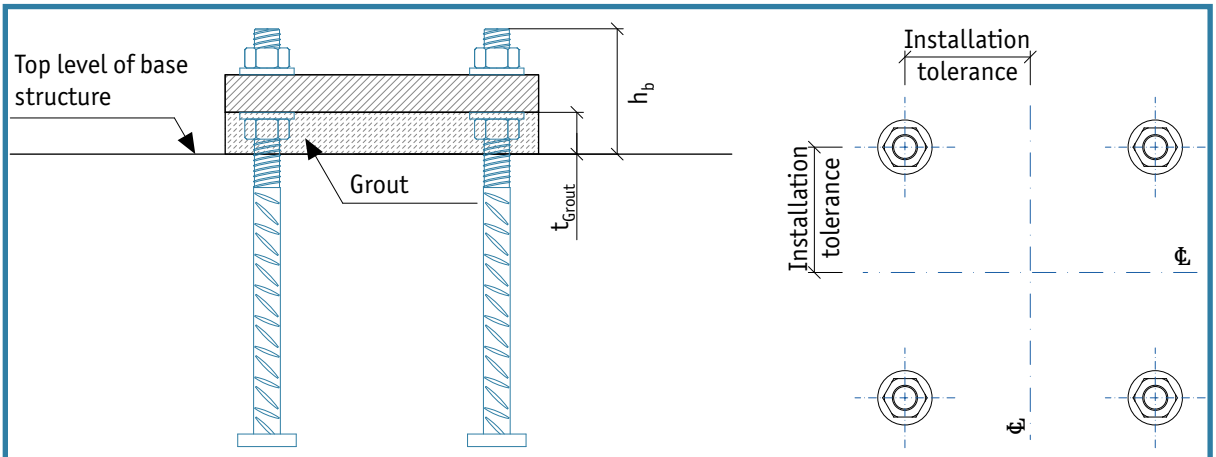


PPL Installation Templates can also be manufactured according to drawings that present the location of the bolts and thread diameters.

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 ACI	HPM 20 ACI	HPM 24 ACI	HPM 30 ACI	HPM 39 ACI
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

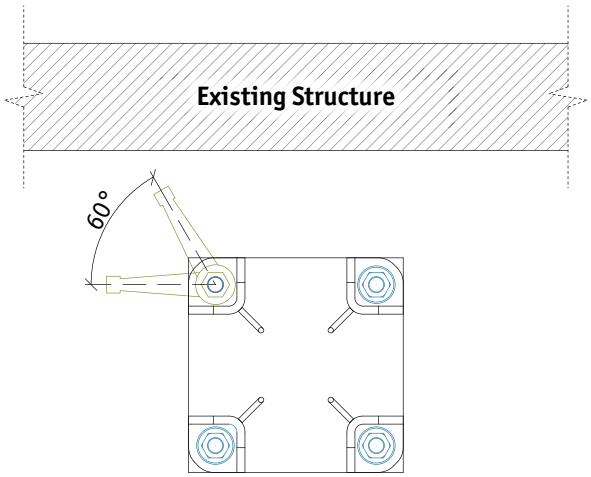
HPM Rebar Anchor Bolts are made of *yield strength 420 MPa or higher* ribbed reinforcement steel. Bending must be done in accordance with ACI 318M-11 section 7.2. See Annex E of this manual with application examples.

Welding the bolts

Welding of the bolts is not recommended.

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 Customer Engineering Service.



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. After initial tightening (between 20 to 30% of verification torque), the nuts should be turned to the required nut rotation specified in the Table below. Subsequently a torque wrench should be used to verify that a torque at least equal to the T_v is required to additionally tighten the nuts. Detailed information about nut tightening procedure and sequence of the steps can be found in Steel design guide 1, 2nd edition / Base plate and anchor rod design, Appendix A, section A2.1.

Nut rotation and verification torque T_v value per bolt size.

Anchor Bolt	Nut Rotation	T_v [Nm]
HPM 16 ACI	1/3 Turn	95
HPM 20 ACI	1/3 Turn	165
HPM 24 ACI	1/3 Turn	395
HPM 30 ACI	1/3 Turn	795
HPM 39 ACI	1/6 Turn	1365

Grouting the joint

Before loading the attachment with any other structures the joint must be grouted following the grout supplier's instructions. The grouting must be non-shrink 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 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 Customer Engineering Service can provide advice.

Check the following:

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

Technical Manual Revisions

Version: PEIKKO GROUP ACI-M 03/2016. 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.

peikko.com/design-tools

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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EPDS AND MANAGEMENT SYSTEM CERTIFICATES

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

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