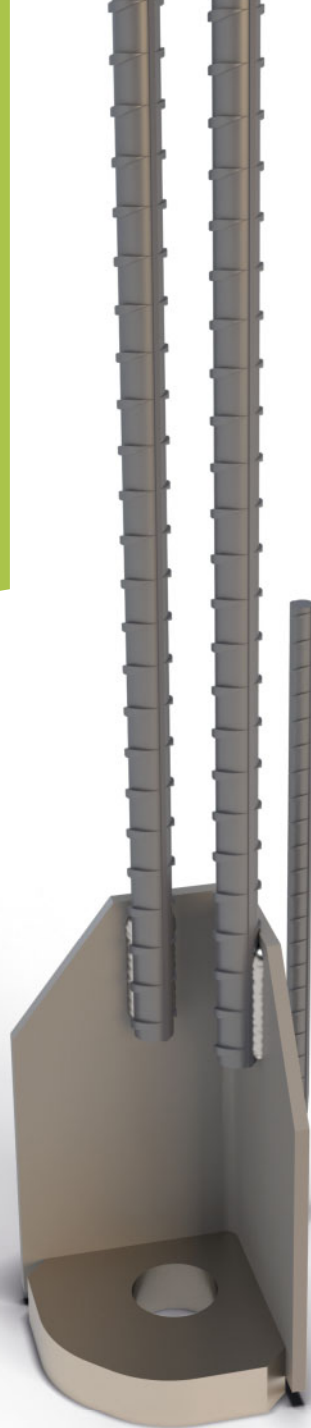


TECHNICAL MANUAL



HPKM[®] Column Shoe

Reliable Bolted Column Connections

Version: PEIKKO GROUP 05/2014

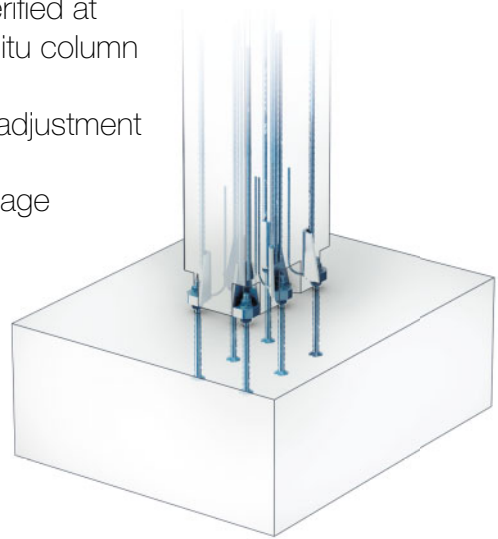


HPKM Column Shoe

For bolted column connections

System benefits

- The stiffness of Peikko's column connection is verified at least as rigid as continuously reinforced cast-in-situ column connection by experimental concrete units tests
- Fast and easy erection of the column with good adjustment possibilities
- No need for temporary bracing during erection stage
- No need for welding on site
- Easy to design with free Peikko Designer[®] software
- First approved and completely analyzed precast column connection on the market (stiffness, bending, shear and fire resistances)
- Approved by EOTA, granted European Technical Approval ETA-13/0603



HPKM Column Shoes are building products used to create cost-effective moment resisting stiff connections between precast concrete columns and foundations, or between precast concrete columns.

The system consists of column shoes and anchor bolts. Column shoes are cast into precast concrete column whereas anchor bolts are cast into foundation or another column. On construction site the columns are erected on the anchor bolts, adjusted on the correct level and vertical position and fixed to the bolts. Finally the joint between column and base structure is grouted.

The column does not require any temporary bracing during erection stage. In final stage the grouted joint and anchor bolts will act as a traditional reinforced concrete cross section. Typically four column shoes are enough to create a moment resisting connection. The product range includes also accessories for easy installation of the column shoes.



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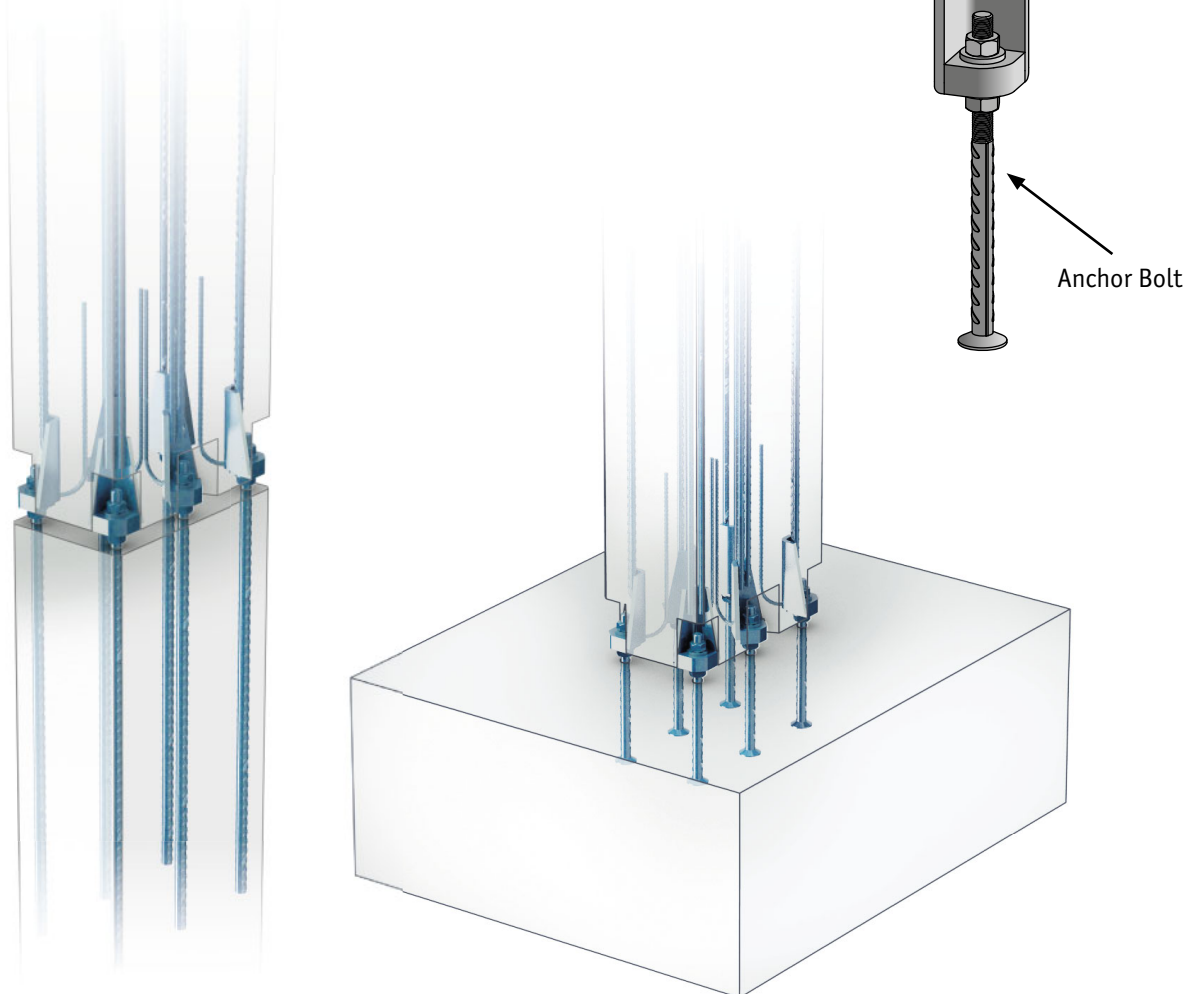
1. Product properties

HPKM Column Shoes are available in several standard models to solve the most of precast concrete column connections. The original Peikko column connection system consists of:

- Column shoes
- Anchor bolts
- Accessories: recess formers and installation templates

HPKM Column Shoes are used with HPM Anchor Bolts to achieve moment resisting precast concrete column connection. The connection can be designed to be at least as stiff as continuously reinforced cast-in-situ connection by using ETA-approved HPKM Column Shoes. Column Shoes are cast into the bottom part of the column together with main and supplementary reinforcement, detailed in Annex A of this manual. HPM Anchor Bolts are either cast into foundation (column to foundation connection) or in the top part of lower column (column to column connection). Column shoe has a round hole that fits with the corresponding anchor bolt. The column connection is achieved by fastening the anchor bolts to column shoes by using nuts and washers. The bolted connection offers sufficient assembly tolerances to adjust the column at the correct level and vertical position. To finalize the connection, the joint underneath the column and recesses are grouted with non-shrink grout material.

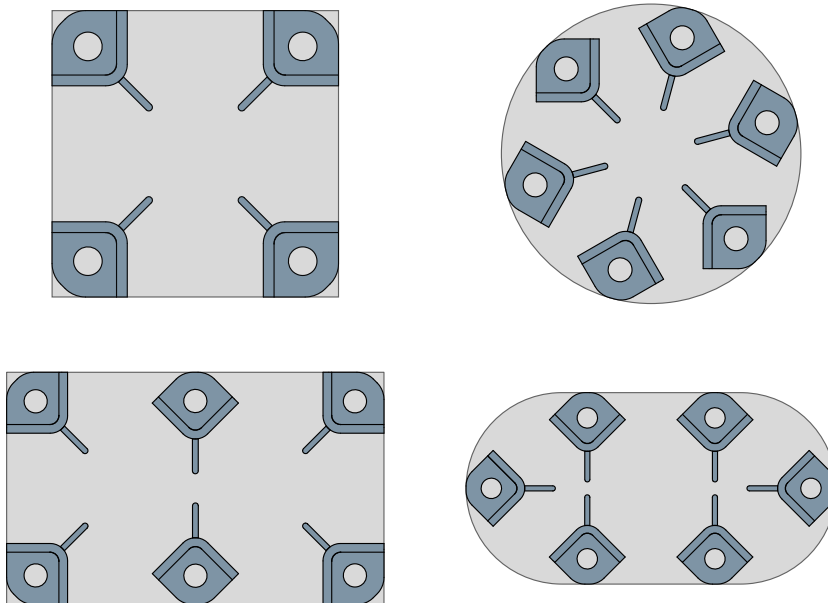
Figure 1. HPKM Column Shoes and HPM anchor bolts in column connection.



Resistances of single HPKM Column Shoes are equal to the resistances of corresponding HPM Anchor bolts. For more information about anchor bolts, see the Technical Manual of HPM Anchor Bolts.

Peikko column connection can be designed to resist axial forces, bending moments, shear forces and their combinations and fire exposure. The appropriate type of column shoe and anchor bolt to be used in connection may be selected and the resistance of the connection verified by using Peikko Designer® software (download from www.peikko.com). It is possible to use four or more column shoes in one column cross-section depending on the dimensions of the columns and the magnitude of forces to be transmitted.

Figure 2. Arrangement of HPKM Column Shoes in different column cross sections.



1.1 Structural behavior

HPKM Column Shoes are pre-designed so that they have sufficient resistance against maximal design values of tensile and compressive forces from the corresponding HPM Anchor Bolts.

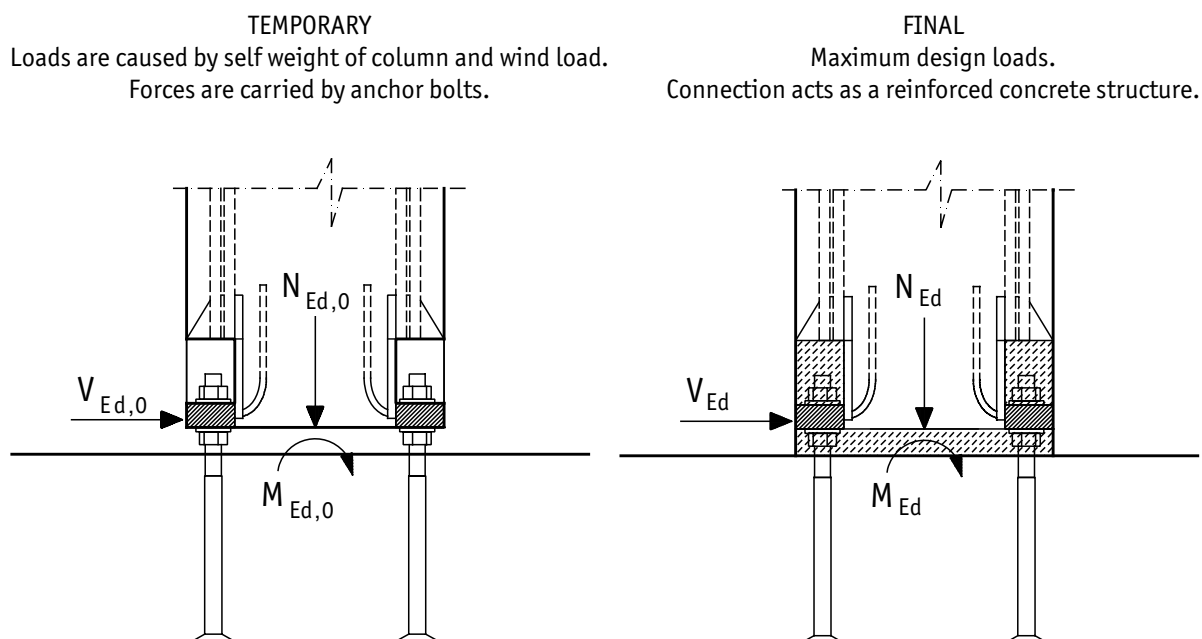
1.1.1 Temporary conditions

At erection stage the forces loading column shoes are caused principally by self weight of the column and bending moment and shear force due to wind load. Since the joint between the column and the base structure is not grouted, all the forces from the column shoes are carried solely by anchor bolts. The bolts must be designed for buckling and bending. If the size of the bolt is not sufficient for the load, size or number of bolts and column shoes should be increased. The open joint underneath the column and recesses has to be grouted by non-shrink grout and grout has to be hardened before the column is loaded by other structures.

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. Column shoes in interaction with anchor bolts and grout are able to resist actions designed for final conditions. The behavior of the connection has been verified to fulfill requirements of cast-in-situ reinforced columns when designing according to ETA approvals of these products.

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



1.2 Application conditions

The standard models of HPKM Column Shoes are pre-designed to be used under conditions mentioned hereafter in this chapter. In the case when these conditions may not be satisfied, please contact Peikko Technical Support for individual design of HPKM Column Shoes.

1.2.1 Loading and environmental conditions

HPKM Column Shoes are designed to bear static loads. In the case of dynamic, fatigue or seismic loads, individual design has to be made.

Column Shoes are designed to be used in indoors and dry conditions. When using HPKM Column Shoes in other conditions, the surface treatment, concrete cover or raw materials must be adequate according to environmental exposure class and intended operating life.

Table 1. Concrete cover of column shoes in different exposure classes, design working life of 50 years.

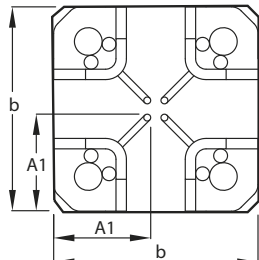
Exposure class	Concrete cover requirement according to ETA-13/0603	Concrete cover of plates of shoes according to EN 1992-1-1 c_{nom} [mm]
X0	Not required	-
XC1	Either concrete cover or coating	25
XC2	Either concrete cover or coating	35
XC3	Either concrete cover or coating	35
XC4	Required	40
XD1 / XS1	Required	45
XD2 / XS2	Required	50
XD3 / XS3	Required	55

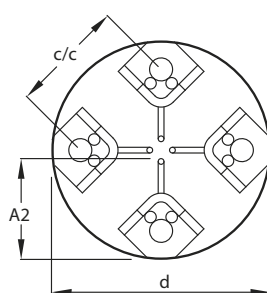
The lowest temperature in use is -20°C.

1.2.2 Interaction with column

HPKM Columns Shoes are pre-designed to be used in reinforced concrete columns with minimum dimensions summarized in Table 2. If column shoes must be placed in the column with smaller dimensions, please contact Peikko Technical Support.

Table 2. The minimum sizes [mm] of column cross sections for standard HPKM Column Shoes.

	HPKM 16	HPKM 20	HPKM 24	HPKM 30	HPKM 39
A1	115	120	125	140	180
b_{min}	230	240	250	280	360

	HPKM 16	HPKM 20	HPKM 24	HPKM 30	HPKM 39
A2	135	145	150	175	225
d_{min}	270	290	300	350	450

$$c/c = \frac{d - 2E}{\sqrt{2}}, \text{ where } E \text{ is taken from dimensions table – Table 4.}$$

The standard properties of HPKM Column Shoes are guaranteed in reinforced concrete columns made of concrete grade C30/37 to C70/85. The strength of grout in the joint must be at least equivalent or higher than the designed concrete grade of the column. For minimum concrete grade for anchor bolts, see Technical Manual of HPM Anchor Bolts.

The structural properties of HPKM Column Shoes are guaranteed only if supplementary reinforcement is provided in the column in accordance with rules of Annex A of this Technical Manual. It is notable that the supplementary reinforcement is used in addition to the main reinforcement designed to resist internal forces in the column.

1.2.3 Positioning of the column shoe

The concrete cover of main anchor bars of column shoe is 40 - 46 mm when HPKM Column Shoe is located at the corner of column. If the HPKM Column Shoe is in the middle position, the concrete cover thickness is more than in corner position (see Figure 4 and Table 3).

Figure 4. Concrete cover of main anchor bars – corner and middle position of column shoe.

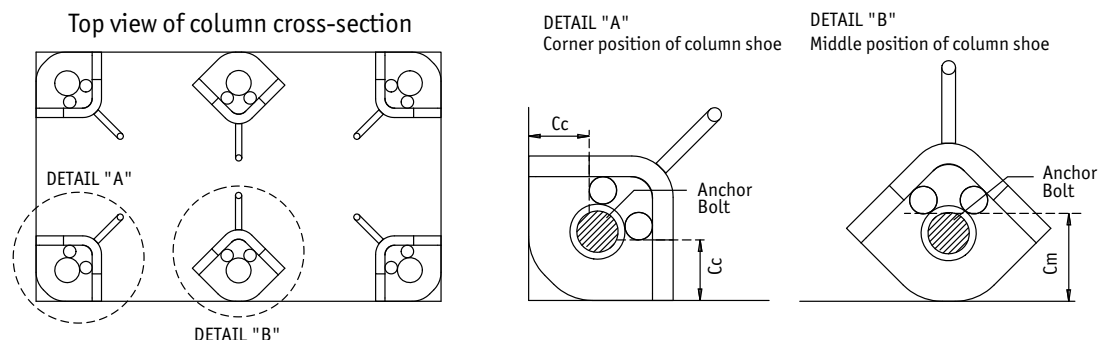


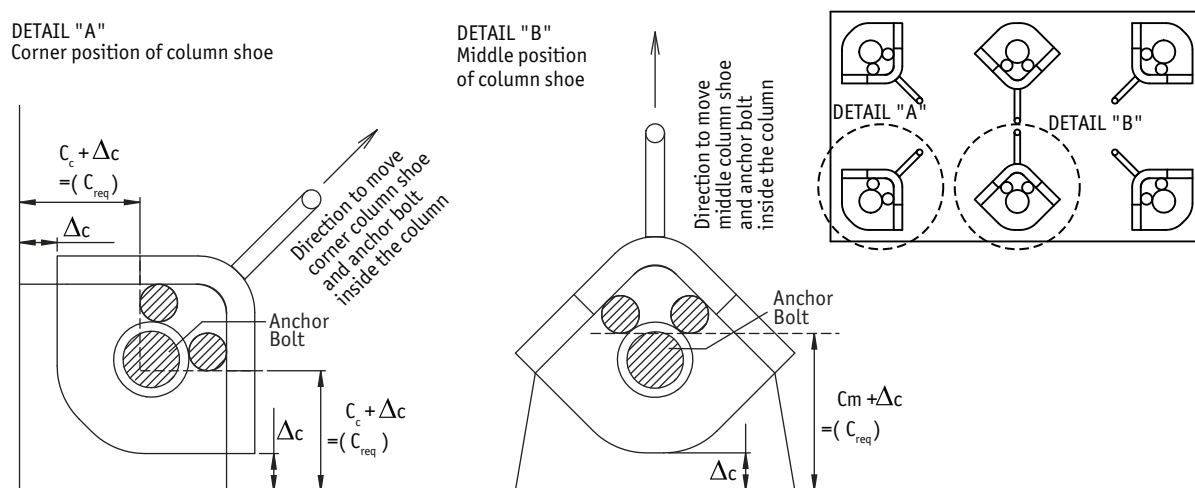
Table 3. Concrete cover of main anchor bars in corner or middle position of column shoe

	HPKM 16	HPKM 20	HPKM 24	HPKM 30	HPKM 39
Corner concrete cover C_c [mm]	40	42	42	44	46
Middle concrete cover C_m [mm]	55	58	60	63	72

If higher values of concrete cover are required ($c_{req} > c_c$ or $c_{req} > c_m$), HPKM Column Shoes need to be placed toward the column centre (see Figure 5). To prevent concrete to fill up the pocket during casting, the recess boxes may be used. When column shoes are located away from column surface, there are special request to prevent the concrete to fill up the the gap of Δ_c size. For detailed information see the installation chapter of HPKM Column Shoes.

NOTE! When column shoes are moved towards centre of the column, the anchor bolts should be moved accordingly in the bolt assembly drawings.

Figure 5. Concrete cover of main anchor bars – determination of required concrete cover thickness c_{req} .



1.3 Other properties

HPKM Column Shoes are fabricated of steel plates and reinforcement steel with the following material properties:

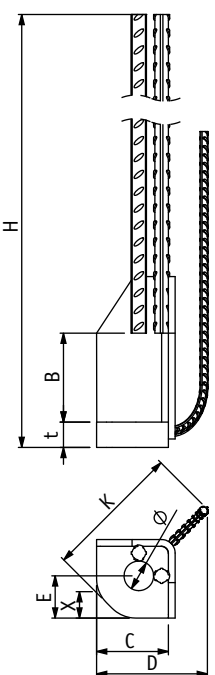





Steel plates	S355J2+N	EN 10025-2
Ribbed bars	B500B	EN 10080
	B500B	DIN 488-1

Peikko Group's production units are externally controlled and periodically audited on the basis of production certifications and product approvals by various organizations, including Inspecta Certification, VTT Expert Services,

Nordcert, SLV, TSUS and SPSC among others.

Products are marked with the mark of VTT Expert Services, the emblem of Peikko Group, the type of product and year and week of manufacturing.

Table 4. Dimensions [mm], weights [kg] and color codes of HPKM Column Shoes.

		HPKM 16	HPKM 20	HPKM 24	HPKM 30	HPKM 39	manuf. tolerances
	B	85	95	105	120	150	+3, -0
	C	75	80	85	90	110	+2, -0
	D	115	120	125	140	180	
	E	50	50	50	50	60	± 1
	H	725	875	1105	1430	1885	± 10
	K	135	145	150	175	225	
	t	15	20	30	45	50	
	X	30	30	30	30	37	
	Ø	28	31	35	40	55	+2, -0
	weight	2,1	3,7	6,5	13,4	26,4	
	color code	 yellow  blue  gray  green  orange					

Lap lengths of anchor bars are defined according to concrete grade C30/37 in poor bond conditions.

2. Resistances

Peikko Group is pioneer to establish ETA-design concept for precast concrete column connections according to Eurocode 2 = EN 1992-1-1, which will take into account that resistances and behavior of whole connection and its components have been verified by experimental tests.

When calculating the action effects of a column, the rigidity of the end connections has to be estimated. It is verified in the demanding initial type testing with concrete column connections, that the rectangular cross-sections with at least four column shoes behave rigidly in bending or they are at least as stiff as continuously reinforced cast-in-situ columns.

The resistances of HPKM Column Shoes are determined by a design concept that makes reference to the following standards and specifications:

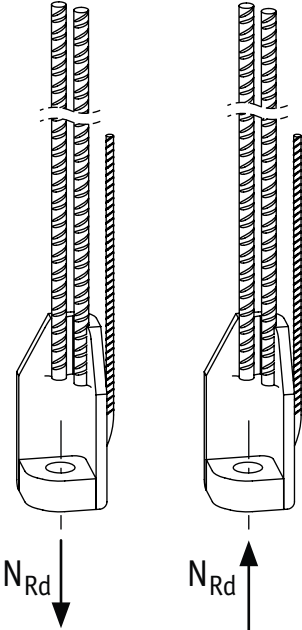
- EN 1992-1-1:2004/AC:2010
- EN 1993-1-1:2005/AC:2009
- EN 1993-1-8:2005/AC:2005
- ETAG 001, Annex C:2010
- ETA-02/0006: ETA-approval of short HPM L anchor bolts
- ETA-13/0603: ETA-approval of Column shoe for connecting columns to concrete structures

2.1 Axial resistances

HPKM Column Shoes are designed to withstand tensile and compressive forces corresponding to the design values of resistances of HPM Anchor Bolts.

It is recommended to calculate the resistances of column connection by using Peikko Designer® software. Peikko Designer® software will make column connection design procedure fast and easy. In the software there is implemented a design code selection, which is required for each design case and which offers many options to the user. By selecting the valid design code it's possible to check the resistances of each column connection easily. Checking erection stage resistances of column connection when the joint is not grouted is also an implemented feature.

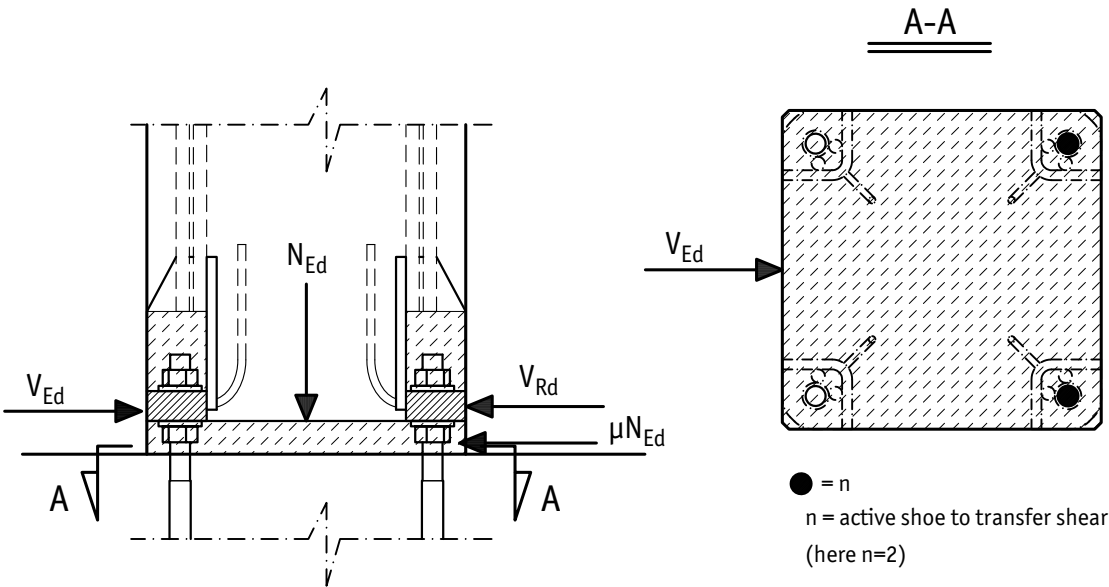
Table 5. Design values of tensile or compressive resistances N_{Rd} of individual HPKM Column Shoes for concrete grade C30/37.

Column Shoe	Anchor Bolt	N_{Rd} [kN]	
HPKM 16	HPM 16	62	
HPKM 20	HPM 20	96	
HPKM 24	HPM 24	139	
HPKM 30	HPM 30	220	
HPKM 39	HPM 39	383	

2.2 Shear resistances

The action effects at the connection are first divided to the individual column shoes.

Figure 6. Column shoes on the right hand side are considered active against shear.



The design value of the shear force for a single column shoe on the active side, see Figure 6, is calculated from

$$V_{Ed}^I = \frac{V_{Ed} - \mu \cdot N_{Ed}}{n}$$

where:

V_{Ed} = total shear force of column connection

N_{Ed} = axial force of column connection

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

μ = friction coefficient between base plate and grout = 0,20 (according to EN 1993-1-8, Chapter 6.2.2)

n = the number of the individual active column shoes resisting shear force, see figure 6

Shear resistances of Peikko column connections were verified by experimental tests. The shear resistance of a column shoe is calculated according to EN 1993-1-8, Chapter 6.2.2, Equation (6.2).

Table 6. Design values of shear resistance V_{Rd} of individual HPKM Column Shoe.

	HPKM 16	HPKM 20	HPKM 24	HPKM 30	HPKM 39
V_{Rd} [kN]	20	31	45	72	125

The shear resistance of a column shoe subjected to shear and compression shall meet the requirement:

$$V_{Ed}^I \leq V_{Rd}$$

It is recommended to calculate the shear resistances of column connections with Peikko Designer® software. Peikko Designer® software makes column connection shear design both final and erection stage fast and easy.

2.3 Fire resistances

Temperature development and critical minimum sections of the unprotected Peikko column connections were determined by using both experimental fire tests and numerical analysis. In tests the Peikko column connections were exposed to standard fire according to standard EN 1363-1.

Peikko Designer® software offers fire resistance design procedure of the Peikko column connections according to EN 1992-1-2.

Selecting HPKM Column Shoe

The following aspects have to be considered when selecting the appropriate type of HPKM Column Shoe to be used in a column connection:

- Resistances
- Properties of the column
- Properties of the grout
- Position and arrangement of the column shoes in the column
- Design value of actions

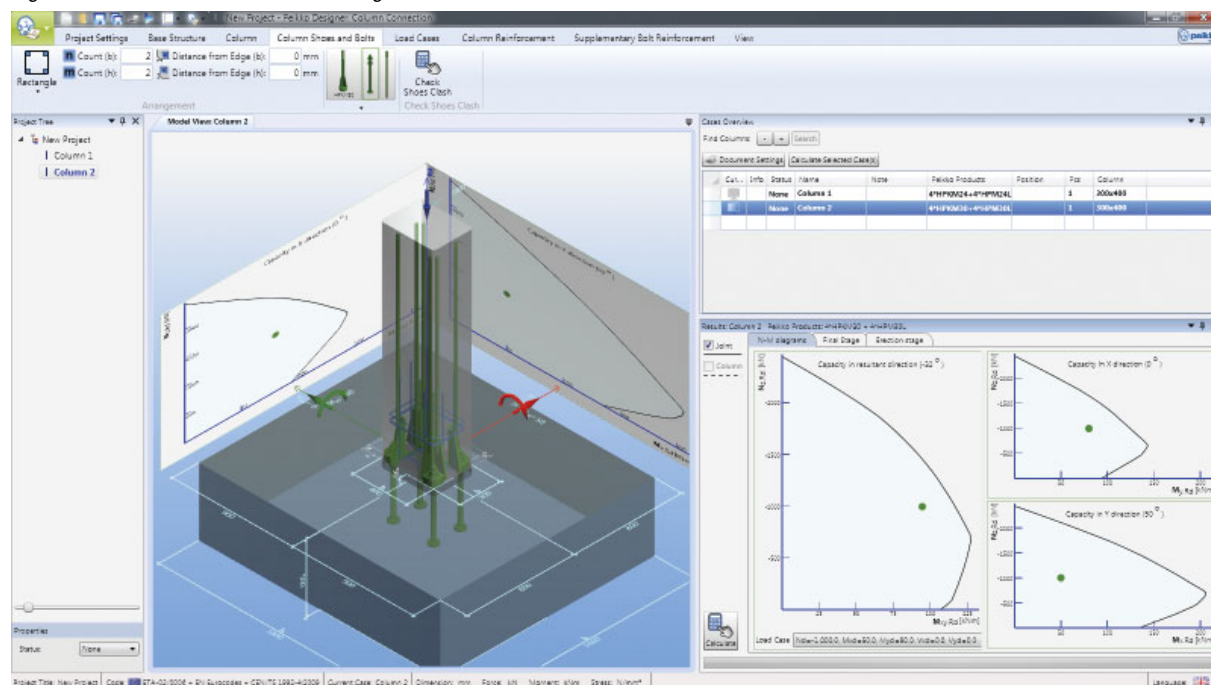
The resistance of column connection should be verified for the following design situations:

- Erection stage
- Final stage
- Fire situation
- Environmental exposure conditions

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. With Column Connection module the user can design connection to resist actual loadings and optimize the connections to meet the requirements of the whole project. The output reports of the software can be used further 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.



The typical selection procedure is done in the following steps:

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 stage
- 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 – Transverse reinforcement in the lap zone and supplementary reinforcement

Details of transverse reinforcement in the lap zone and supplementary reinforcement for HPKM Column Shoes are shown in following figures. Required quantities and lengths of stirrups are given in the Table 7.

Table 7. Transverse reinforcement in the lap zone and supplementary reinforcement (B500B).

		HPKM 16	HPKM 20	HPKM 24	HPKM 30	HPKM 39
U-stirrup	①	4 Ø 6	4 Ø 6	4 Ø 6	4 Ø 6	4 Ø 6
U-stirrup	②	2 Ø 6	2 Ø 6	2 Ø 6	2 Ø 6	2 Ø 6
Stirrup	③	2 Ø 8	2 Ø 8	3 Ø 8	3 Ø 8	3 Ø 10
Stirrup	④	2 Ø 8	2 Ø 8	3 Ø 8	3 Ø 8	3 Ø 10
Stirrup	⑤	Ø 8	Ø 8	Ø 8	Ø 8	Ø 10
a		140	165	200	250	300
l_b		300	300	300	300	300

Recommended spacing ≤ 100 mm of transverse reinforcement ⑤ in the lap zone l_0

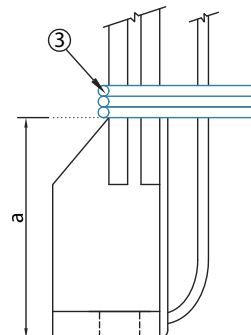
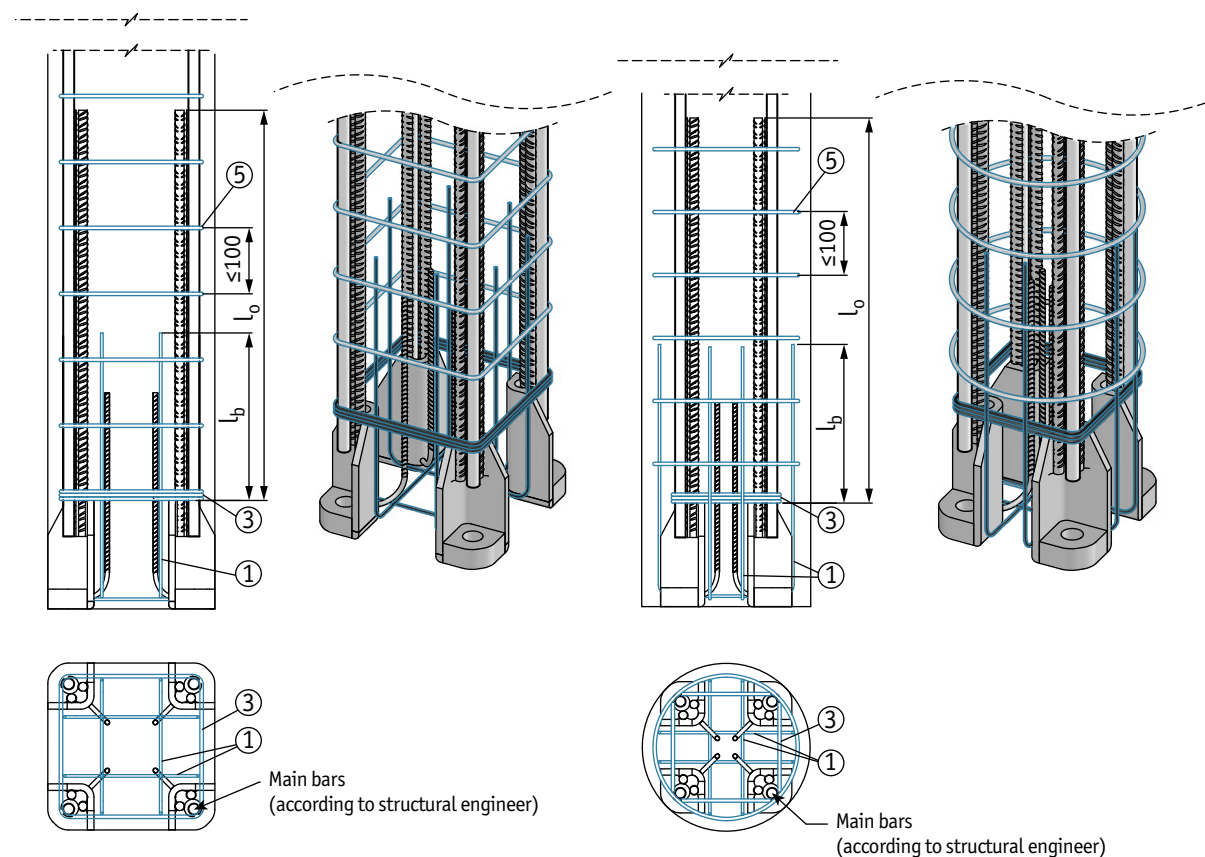
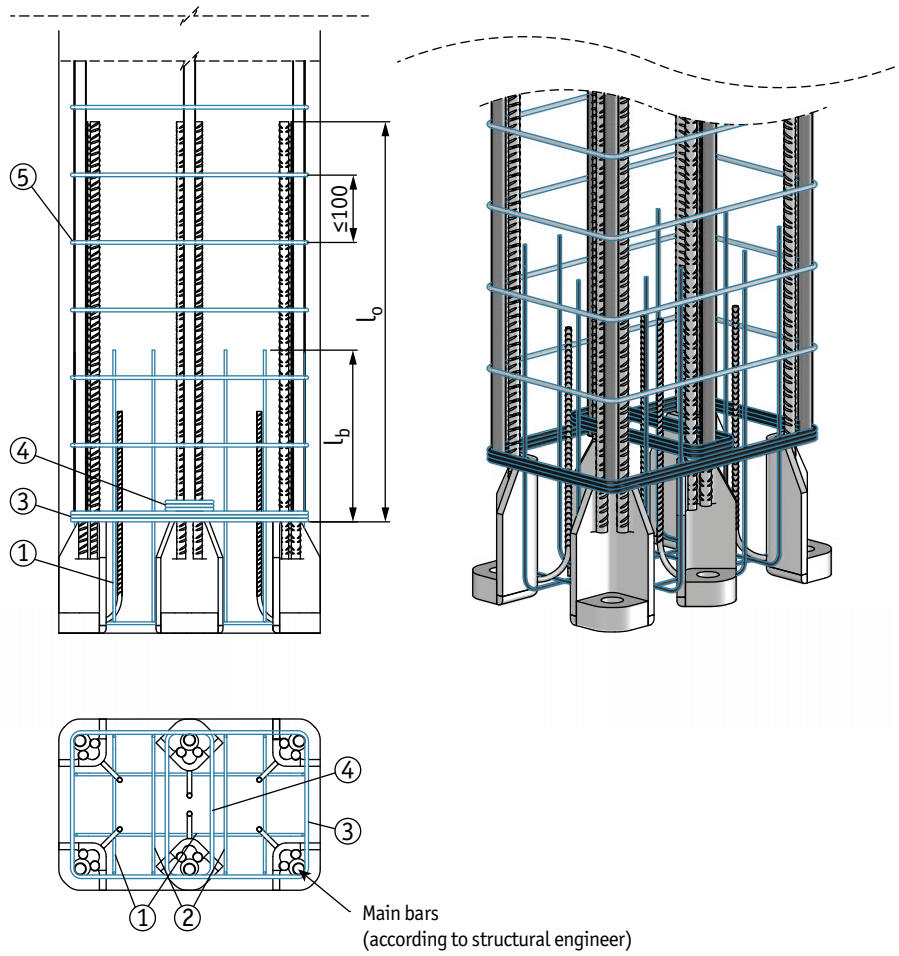


Figure 8. Transverse and supplementary reinforcement needed for HPKM Column Shoes (HPKM 30 shown in the pictures).



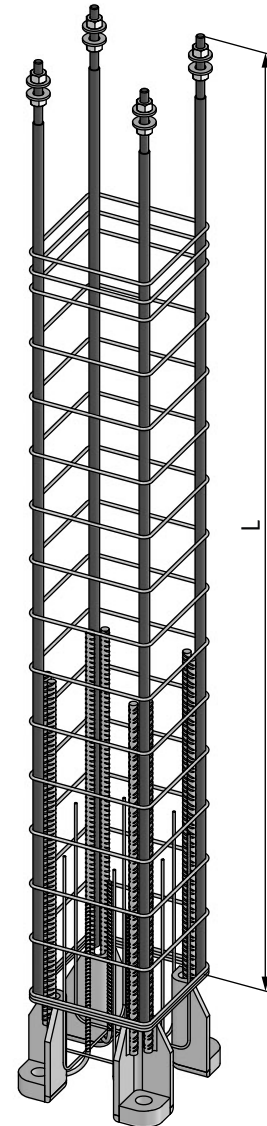


Annex B – Alternative use of HPKM Column Shoe

Column shoes in short columns

Short columns are typically one storey high columns. HPKM Column Shoes are designed to be used with reinforcing bars of the column, where splices of bars are needed to ensure the transfer of forces from column to the column shoe. By using HPKM Column Shoes with column height HPM Bolts, the number of splices can be reduced as well as reinforcement material. The bolts act as the main reinforcement of the column which can be fully replaced by HPM Bolts. The anchor bolts are manufactured to the required length L (max. 6 m).

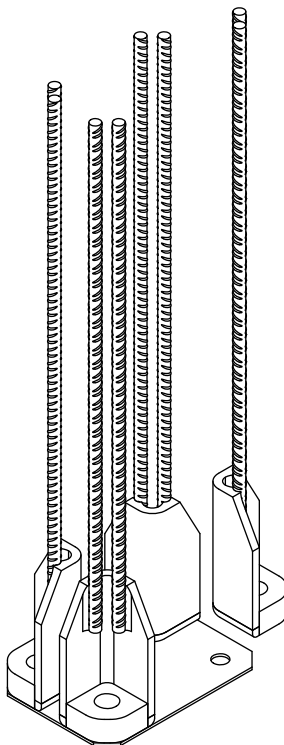
Figure 9. Column height anchor bolts.



Column shoes on an integrated steel plate

In the case when column shoes are colliding in the column (column cross section is too small for the column shoes designed for the column) an integrated steel plate may be used to connect shoes together. By welding column shoes on the plate, the rear anchor bars may be removed to reduce required space. The steel plate may be used as an end plate of the mould as well. The minimum clear distance between anchor bars and side plates of column shoes should be not less than distance requirements according to EN 1992-1-1, chapter 8.2. Shoes on integrated steel plates are manufactured according to customer's specifications. Please ask more instructions from Peikko Technical Support.

Figure 10. Column shoes on an integrated steel plate.



Self-made recess formers

Recess formers can be alternatively made by customers themselves, according to required dimensions shown in Table 8 and Table 9. They can be made of wood, polystyrene or similar material. Column shoes should be fixed into the formwork properly either by bolting them to end plate of the mould or welding all shoes together.

Table 8. Dimensions of corner recess boxes to use with HPKM Column Shoe.

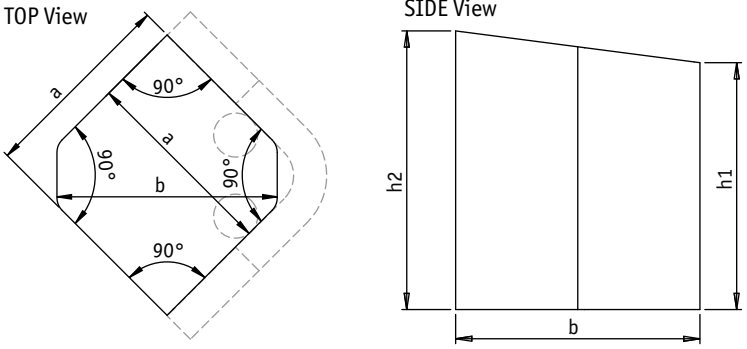
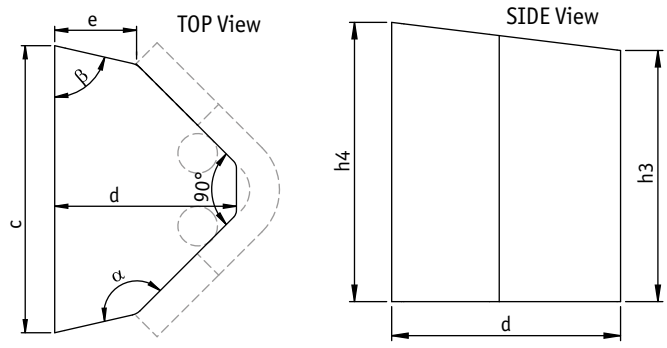
Corner recess box – dimension [mm]		a	b	h1	h2
	HPKM 16	75	83	77	87
	HPKM 20	80	88	87	97
	HPKM 24	85	94	97	107
	HPKM 30	90	99	109	122
	HPKM 39	110	127	124	136

Table 9. Dimensions of middle recess boxes to use with HPKM Column Shoe.






Middle recess box – dimension [mm, °]		c	d	e	h3	h4	α	β
	HPKM 16	110	73	33	77	87	140	85
	HPKM 20	117	79	34	87	96	139	85
	HPKM 24	128	87	38	97	107	141	83
	HPKM 30	145	92	41	109	120	148	77
	HPKM 39	175	115	51	136	150	147	78

INSTALL THE PRODUCT – PRECAST FACTORY

Identification of the product

HPKM Column Shoes are available in standard models (16, 20, 24, 30 and 39) analogous to M-thread sizes of the HPM Anchor Bolts. The model of column shoe can be identified by the name in the label on the product and also according to the color of the product. Color codes are shown in the table hereafter. Color codes of recess boxes are corresponding to the color codes of HPKM Column Shoes.

HPKM Column Shoe with corresponding recess box.

Column Shoe	Anchor Bolt	Corner recess	Middle recess	Color code
HPKM 16	HPM 16	HPKM 16 CBOX	HPKM 16 MBOX	 yellow
HPKM 20	HPM 20	HPKM 20 CBOX	HPKM 20 MBOX	 blue
HPKM 24	HPM 24	HPKM 24 CBOX	HPKM 24 MBOX	 gray
HPKM 30	HPM 30	HPKM 30 CBOX	HPKM 30 MBOX	 green
HPKM 39	HPM 39	HPKM 39 CBOX	HPKM 39 MBOX	 orange

Installation of the column shoes

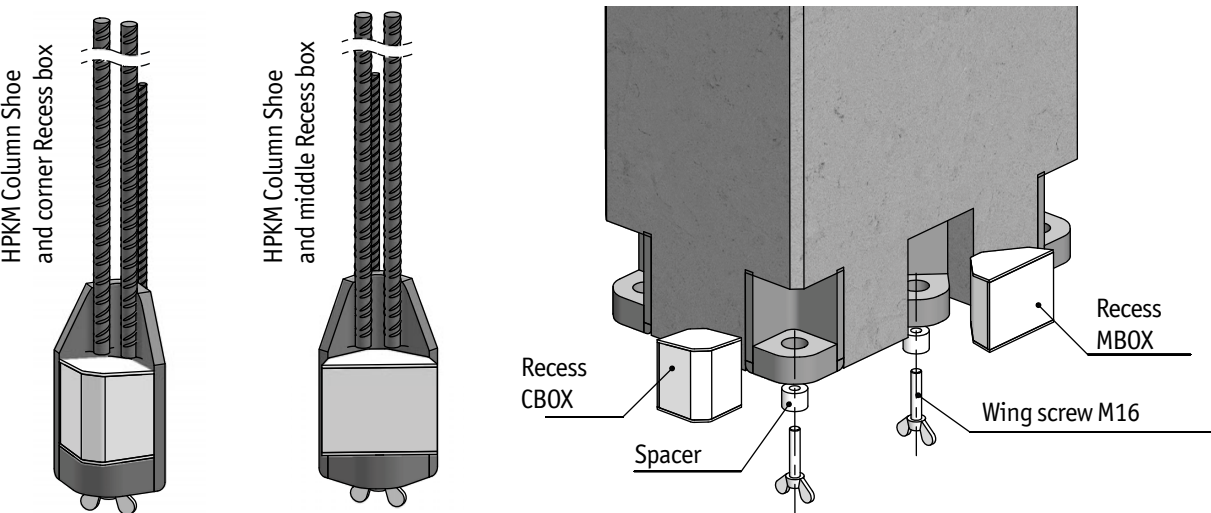
The HPKM Column Shoes are placed into the reinforcement of the column and fixed through their base plates to the end plate of the mould with recess boxes. Installation tolerance of column shoe in crosswise direction of the column is ± 2 mm. Supplementary reinforcement must be placed at the area of column base, according to drawings (Technical Manual Annex A). After casting the column, boxes are removed from shoes and voids are checked that they are clean from concrete.

Recess boxes are fixing accessories used to form pockets in concrete column for anchor bolts. There are separate recess boxes available for all types of column shoes and depending on the column shoe position in column’s cross section:

- CBOX is used with column shoes fixed in corner of the column
- MBOX is used with column shoes fixed in middle of the column

Recess boxes enable the shoes to be fastened and positioned to the end plate of the mould. The wing screw M16, which comes with a spacer equal to the size of the column shoe’s bolt hole, is used for fixing. With the help of the spacer, the shoe can be fixed to the correct place in the end plate. Environmental friendly formers are very durable and re-usable. It is recommended to maintain them to achieve long operating life.

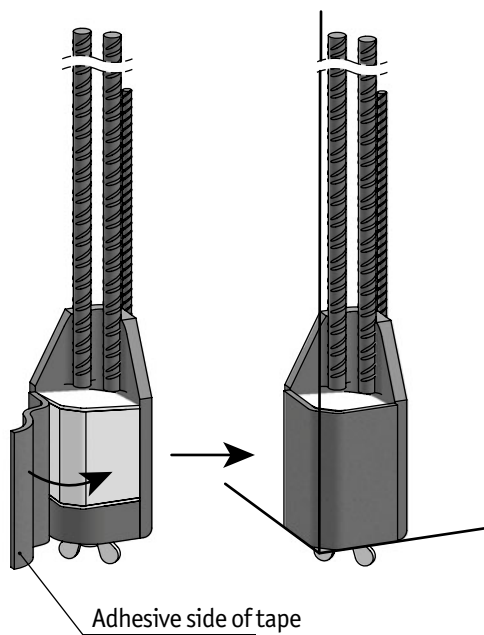
Recess boxes for corner and middle position of HPKM Column Shoe.



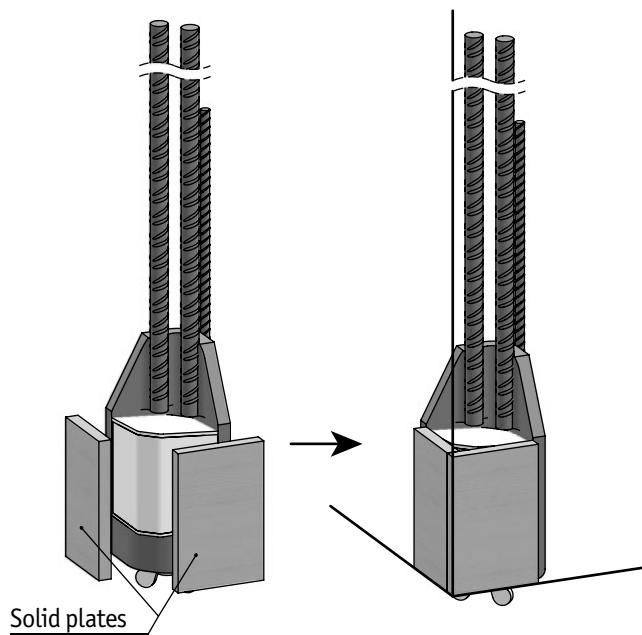
To ensure higher values of concrete cover thicknesses of main anchor bars, in accordance with chapter 1.2.3 of the technical manual, follow these instructions for increased values Δ_c of concrete cover:

- $\Delta_c < 5 \text{ mm}$, there is no special request for recess boxes; instructions are same as for standard concrete cover of column shoes. The gap is too small to be filled up with concrete. However if the gap is filled or partially filled, the concrete shell can be easily crushed after removing mould.
- $5 \text{ mm} \leq \Delta_c \leq 10 \text{ mm}$, self-adhesive foam tape or equivalent can be used to prevent the fill up of the gap. Foam tape of corresponding thickness Δ_c is fixed on two sides of the recess box.
- $\Delta_c > 10 \text{ mm}$, to prevent the concrete to fill up the gap, it is recommended to use some kind of solid plate – e.g. plywood or hardened polystyrene of corresponding thickness Δ_c . These plates can be fixed to the surface of the mould.

*Use of **self-adhesive foam tape** to prevent the fill up the gap with concrete.*



*Use of **solid plates** to prevent the fill up the gap with concrete.*



Ensure of thicker concrete cover by self-adhesive foam tape or solid plates

HPKM Column Shoes before and after casting








INSTALL THE PRODUCT – CONSTRUCTION SITE

Identification of the product

HPKM Column Shoes are available in standard models (16, 20, 24, 30 and 39) analogous to HPM Anchor Bolts M-thread sizes. The model of column shoe can be identified by the name in the label on the product and also according to the color of the product. Color codes are shown in the table hereafter.

HPKM Column Shoe color identification

Column Shoe	Color code	Anchor Bolt	Installation template
HPKM 16	 yellow	HPM 16	PPL 16
HPKM 20	 blue	HPM 20	PPL 20
HPKM 24	 gray	HPM 24	PPL 24
HPKM 30	 green	HPM 30	PPL 30
HPKM 39	 orange	HPM 39	PPL 39

Erection of precast column

1. To level precast concrete column

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

In alternative method shims are placed between anchor bolts and adjusted at the proper level. Lower leveling nuts must be leveled at least 5 mm under the top level of shims to secure that column will rest first on the shims. This method is recommended for heavier columns for easier and faster alignment of the column.

2. To align precast concrete column

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

Recommended minimum T_{min} and maximum T_{max} torque values of nuts.

	HPKM 16	HPKM 20	HPKM 24	HPKM 30	HPKM 39
T_{min} [Nm]	120	150	200	250	350
T_{max} [Nm]	170	330	570	1150	2640



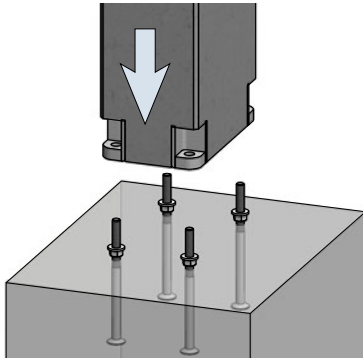
3. To grout joint and recesses

Before loading the column by any other structures e.g. beams or columns, the joint underneath the column and bolt recesses must be grouted by following instructions of the grout supplier. The grout must be non-shrink grade and strength according to plans. To avoid air being trapped in the joint, it is recommended to pour grout from one side of the column only. Grouting formwork is made so that adequate concrete cover for column shoes and anchor bolts is achieved.

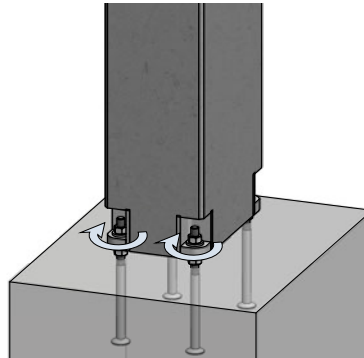
After grout has reached sufficient strength, the connection is finalized and joining structures may be erected on the column.

Erection of precast concrete column step by step.

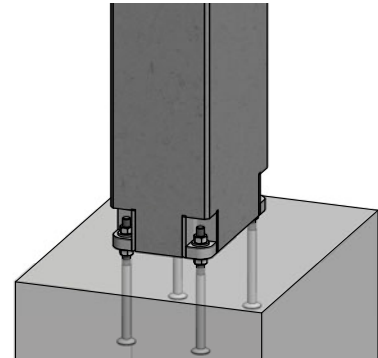
Column is installed directly on the pre-leveled washers and nuts



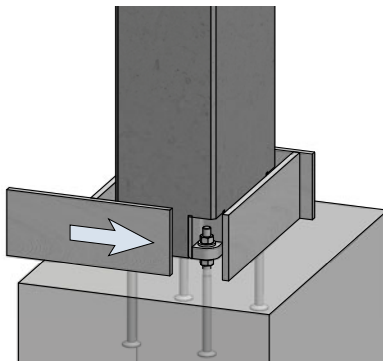
Upper nuts and washers are screwed on the bolts



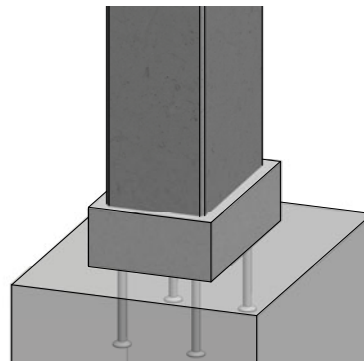
After the nuts are tightened, the crane can be released



Formwork for grouting joint and recesses

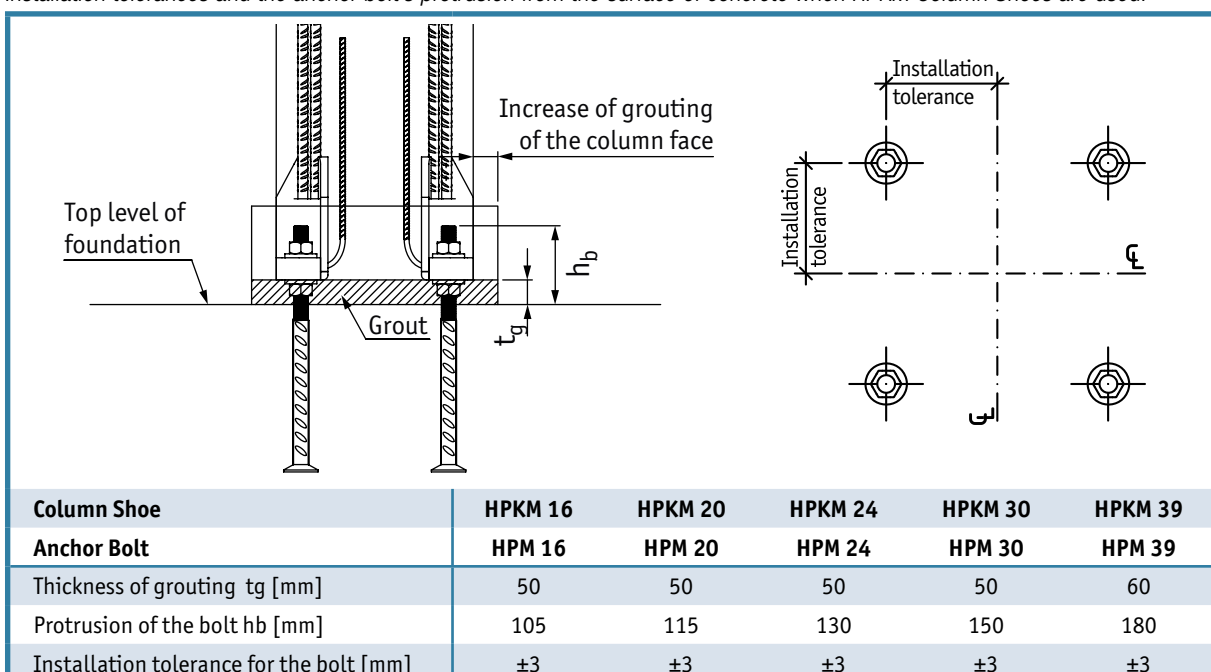


Finalized connection after grouting has hardened



In column to foundation connections wider grouting can be provided to ensure higher concrete cover if it is required. It is recommended to increase the cover in aggressive environment.

Installation tolerances and the anchor bolt's protrusion from the surface of concrete when HPKM Column Shoes are used.



Technical Manual Revisions

Version: PEIKKO GROUP 05/2014. Revision:002*

- 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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