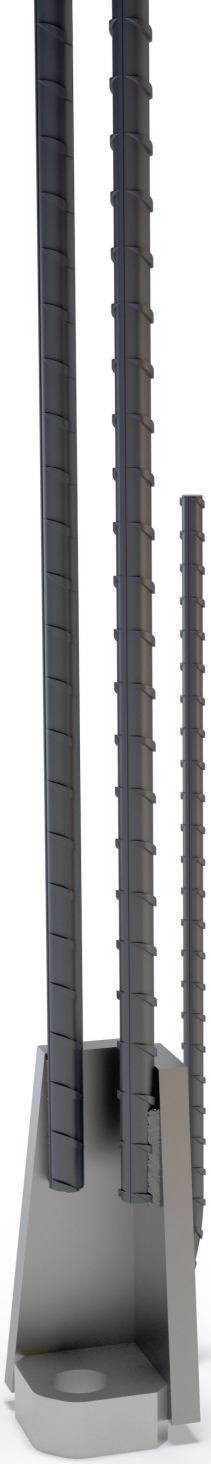
TECHNICAL MANUAL



PEC® Column Shoe

Heavy-duty Bolted Column Connections

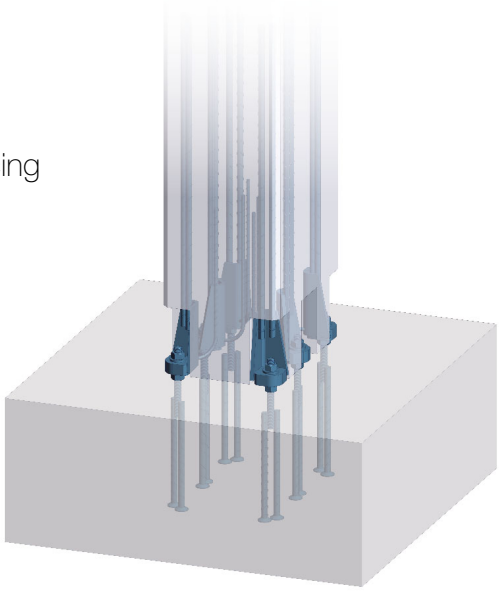
Version: PEIKKO GROUP 09/2018

peikko®

PEC® Column Shoe

For bolted column connections

- Advanced casting process with the help of standard accessories
- Safe, simple and quick assembly with no bracing and welding
- Cost-efficient column erection with reduced man- and crane-hours
- Increased design efficiency using Peikko Designer® software



PEC® Column Shoes are connecting items to form fast and safe connections between precast concrete columns and foundations, or between precast concrete columns. PEC® Column Shoes are used with PPM® High-Strength Anchor Bolts to create moment-resisting column connections under heavy loading conditions.

The typical bolted column connection is made by the column shoes and anchor bolts. The column shoes are cast into precast concrete column while anchor bolts are cast into foundation or another column. On construction site the columns are erected on the anchor bolts, adjusted to the correct level and vertical position. Fixing is achieved by tightening the nuts on the anchor bolts. The joint between column and structure below should be grouted before loading the column. After the grout has reached the designed strength the connection acts as reinforced concrete structure.

The main advantage in using bolted connections is that an immediate connection is made. Column is installed without temporary bracing only by leveling and tightening the nuts.

With a help of standard accessories casting process is quick and easy both at precast factory and construction site. Solution is cost-efficient by final savings coming from reduced excavation depth of the foundation, simplified supplementary reinforcement frame and less man- and crane-hours.

Contents

Revision: **001***

1. Product properties

PEC® 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

PEC® Column Shoes are used with PPM® High-Strength Anchor Bolts to achieve moment resisting precast concrete column connections. Column Shoes are cast into the bottom part of the column together with main and supplementary reinforcement, detailed in Annex A of this manual. PPM® High-Strength 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.

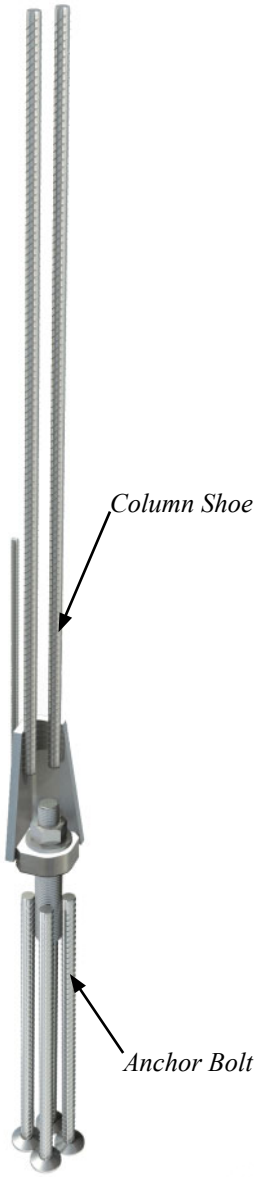
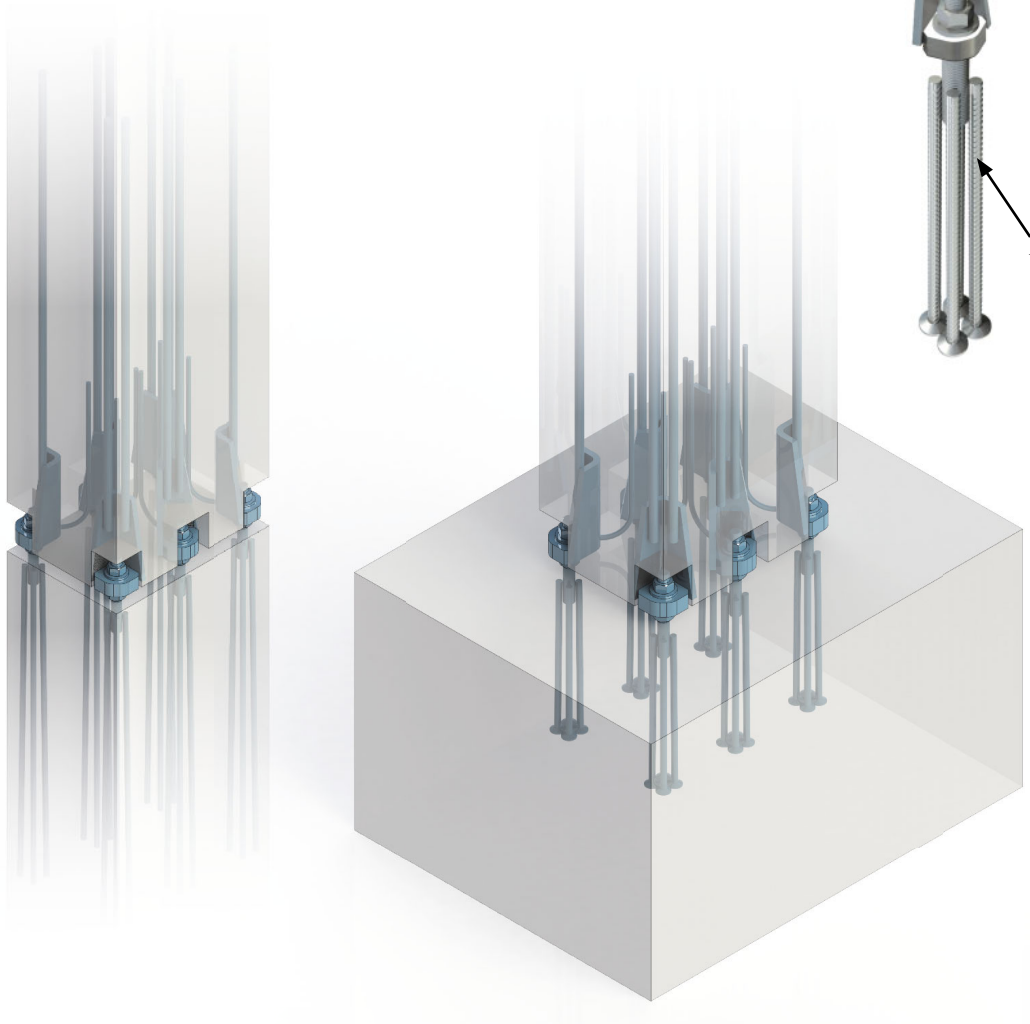


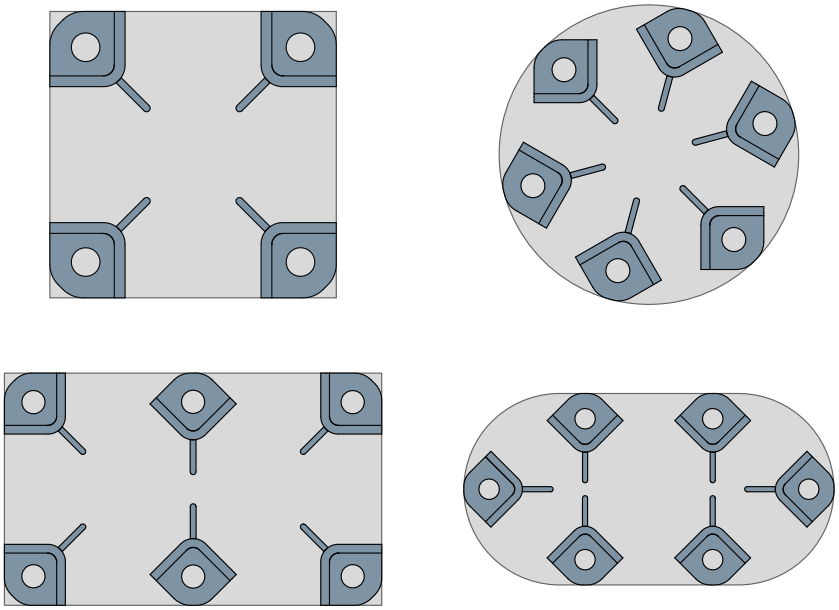
Figure 1. PEC® Column Shoes and PPM® High-Strength Anchor Bolts in column connection.



Resistances of single PEC® Column Shoes are equal to the resistances of corresponding PPM® High-Strength Anchor Bolts. For more information about anchor bolts, see the Technical Manual of PPM® High-Strength 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 column and the magnitude of forces to be transmitted.

Figure 2. Arrangement of PEC® Colum Shoes in different column cross sections.



1.1 Structural behavior

PEC® Column Shoes are pre-designed so that they have sufficient resistance against maximal design values of tensile, compressive and shear forces from the corresponding PPM® High-Strength Anchor Bolts.

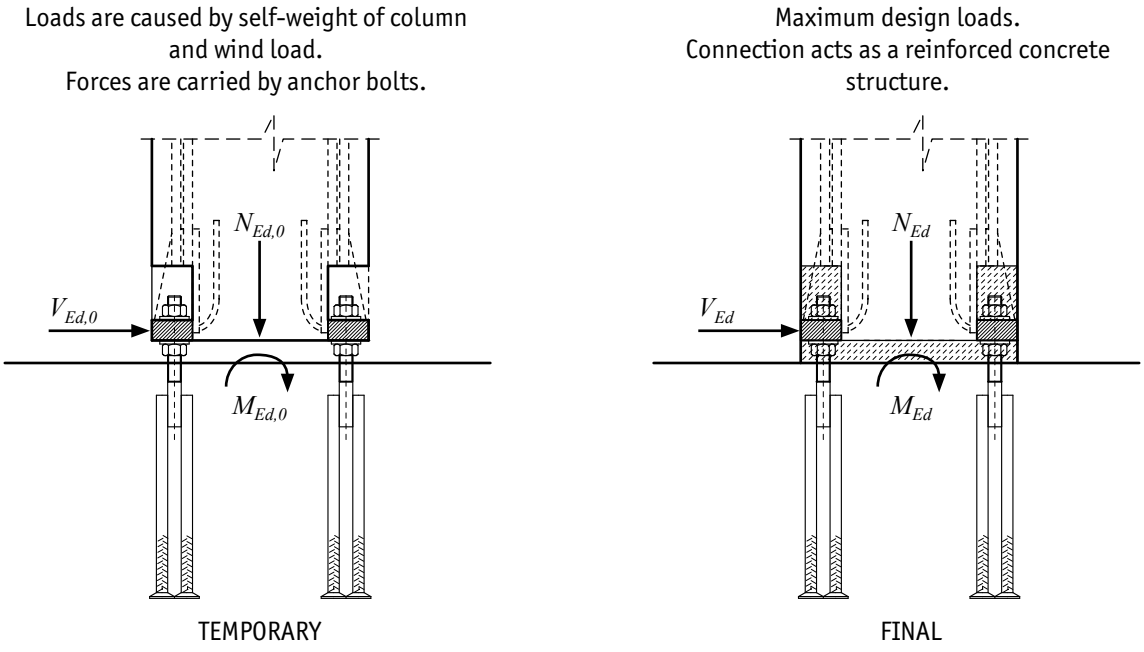
1.1.1 Temporary conditions

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.

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



1.2 Application conditions

The standard models of PEC® 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 Customer Engineering Service for individual design of PEC® Column Shoes.

1.2.1 Loading and environmental conditions

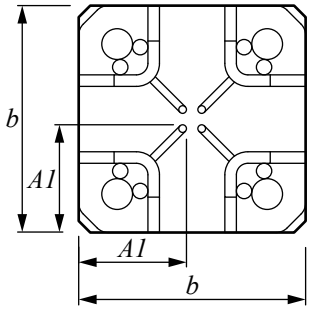
PEC® Column Shoes are designed to bear static loads. In the case of dynamic, fatigue or seismic loads, individual design has to be made.

Column Shoes are designed to be used in indoors and dry conditions. When using PEC® 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.

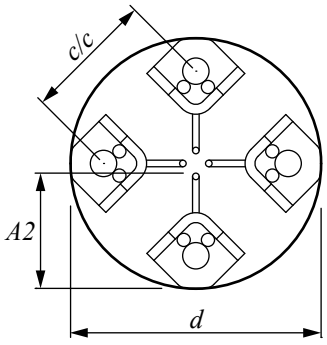
1.2.2 Interaction with column

PEC® Column Shoes are pre-designed to be used in reinforced concrete columns with minimum dimensions summarized in *Table 1*. If column shoes must be placed in the column with smaller dimensions, please contact Peikko Customer Engineering Service.

Table 1. The minimum sizes [mm] of column cross sections for standard PEC® Column Shoes.



	PEC 30	PEC 36	PEC 39	PEC 45	PEC 52
$A1$	175	195	210	250	280
b_{min}	350	390	420	500	560



	PEC 30	PEC 36	PEC 39	PEC 45	PEC 52
$A2$	225	250	275	325	375
d_{min}	450	500	550	650	750

$c/c = \frac{d - 2E}{\sqrt{2}}$, where E is taken from dimensions table – *Table 3*

The standard properties of PEC® Column Shoes are guaranteed in reinforced concrete columns made of concrete grade C30/37 or higher. 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 PPM® High-Strength Anchor Bolts.

The structural properties of PEC® 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 47 mm when PEC® Column Shoe is located at the corner of column. If the PEC® Column Shoe is in the middle position, the concrete cover thickness is more than in corner position (see *Figure 4* and *Table 2*).

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

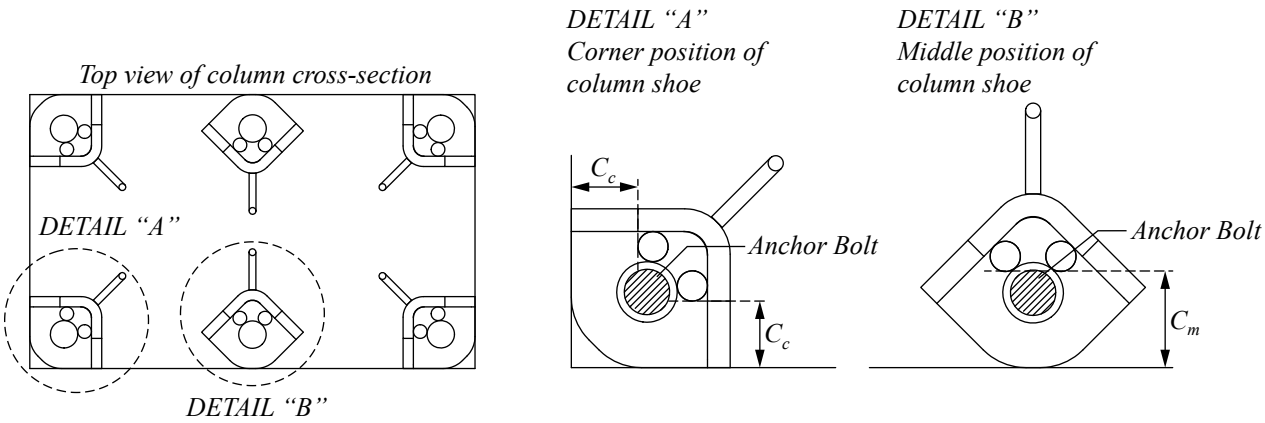


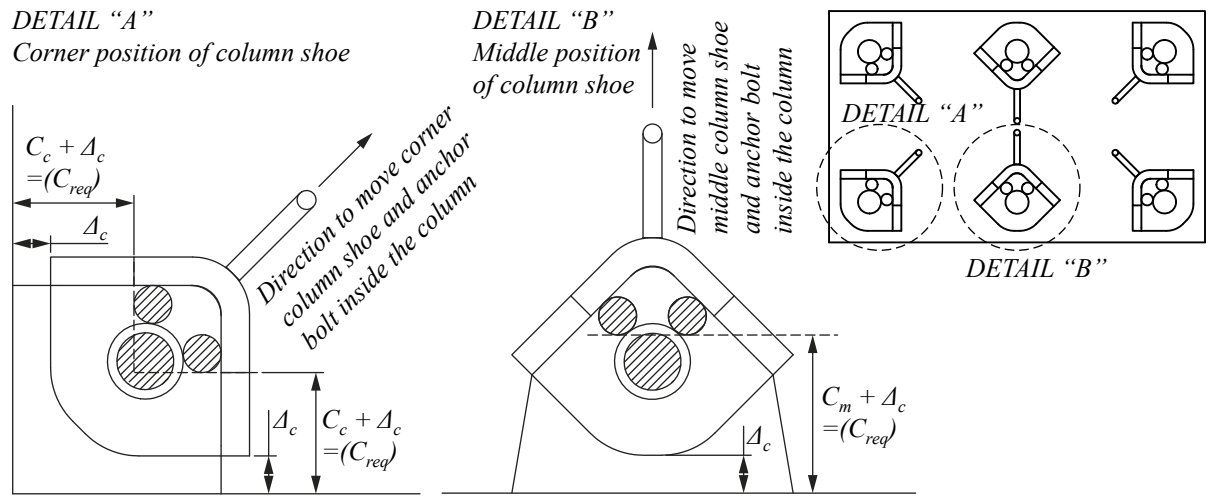
Table 2. Concrete cover of main anchor bars in corner or middle position of column shoe.

	PEC 30	PEC 36	PEC 39	PEC 45	PEC 52
Corner concrete cover c_c [mm]	47	47	47	47	47
Middle concrete cover c_m [mm]	73	74	85	93	96

If higher values of concrete cover are required ($c_{req}>c_c$ *or* $c_{req}>c_m$), PEC® Column Shoes need to be placed towards center of the column (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 PEC® Column Shoes.

NOTE! When column shoes are moved towards center 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

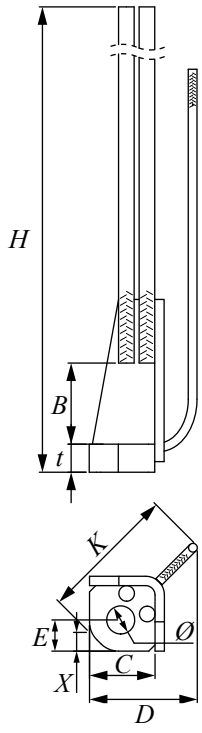
PEC® Column Shoes are fabricated of steel plates and reinforcement steel with the following material properties:

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 emblem of Peikko Group, the type of product and date of manufacturing.

Table 3. Dimensions [mm], weights [kg] and color codes of PEC® Column Shoes.



	PEC 30	PEC 36	PEC 39	PEC 45	PEC 52	manuf. tolerances
B	130	155	190	210	215	+3, -0
C	105	115	130	145	155	+2, -0
D	175	195	210	250	280	
E	50	60	60	60	60	± 1
H	1480	1890	2040	2420	2940	± 10
K	225	250	275	325	375	
t	45	50	60	60	70	
X	30	37	37	37	37	
Ø	45	55	55	65	70	+2, -0
Weight	19.3	30.4	37.0	62.2	101.6	
Color code	Black	Red	Brown	Violet	White	

Color code is marked on base surface of PEC® bottom plate.
Lap lengths of anchor bars are defined according to concrete grade C30/37 in poor bond conditions.

2. Resistances

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

- EN 1992-1-1:2004
- EN 1993-1-1:2005
- EN 1993-1-8:2005
- ETAG 001, Annex C:2010

2.1 Axial resistance

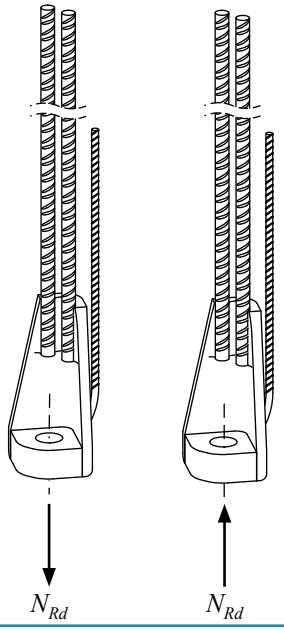
PEC® Column Shoes are designed to withstand tensile and compressive forces corresponding to the design values of resistances of PPM® High-Strength Anchor Bolts. The maximum design values of resistances of individual PEC® Column Shoes are given in *Table 4*.

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 4. Design values of tensile or compressive resistances of individual PEC® Column Shoes for concrete grade C30/37.

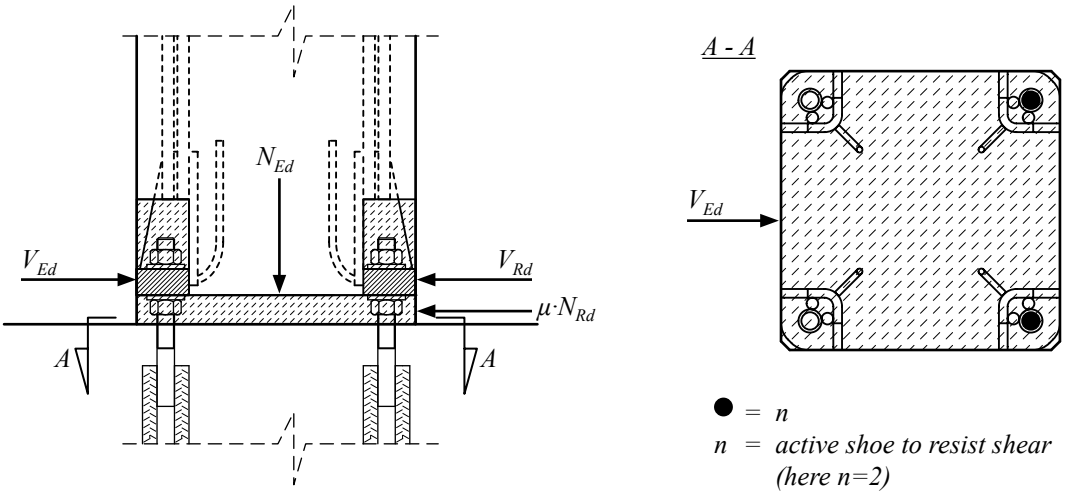
Column Shoe	Anchor Bolt	N_{Rd} [kN]
PEC 30	PPM 30	299
PEC 36	PPM 36	436
PEC 39	PPM 39	521
PEC 45	PPM 45	697
PEC 52	PPM 52	938



2.2 Shear resistance

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

$$V_{Ed}^{1} = \frac{V_{Ed} - \mu \cdot N_{Ed}}{n}$$

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*.

The shear resistance of a column shoe is equal to the shear resistance of corresponding anchor bolt.

Table 5. Design values of shear resistance V_{Rd} of individual PEC® Column Shoe.

		PEC 30	PEC 36	PEC 39	PEC 45	PEC 52
V_{Rd}	[kN]	89	130	155	207	219

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

$$V_{Ed}^{1} \leq V_{Rd}$$

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 resistance

The concrete cover of the anchor bolt and the anchor bars of the column shoes should be at least equivalent to the concrete cover of the reinforcement of the precast element. If the fire resistance of the column shoe connection is judged to be insufficient, the concrete cover of the column shoe could be increased by moving column shoes towards center of the column and increasing the size of cross section when necessary.

Selecting PEC® Column Shoe

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

- Resistance
- Properties of the column
- Properties of the grout
- Position and arrangement of the column shoes in the column
- Design values of actions

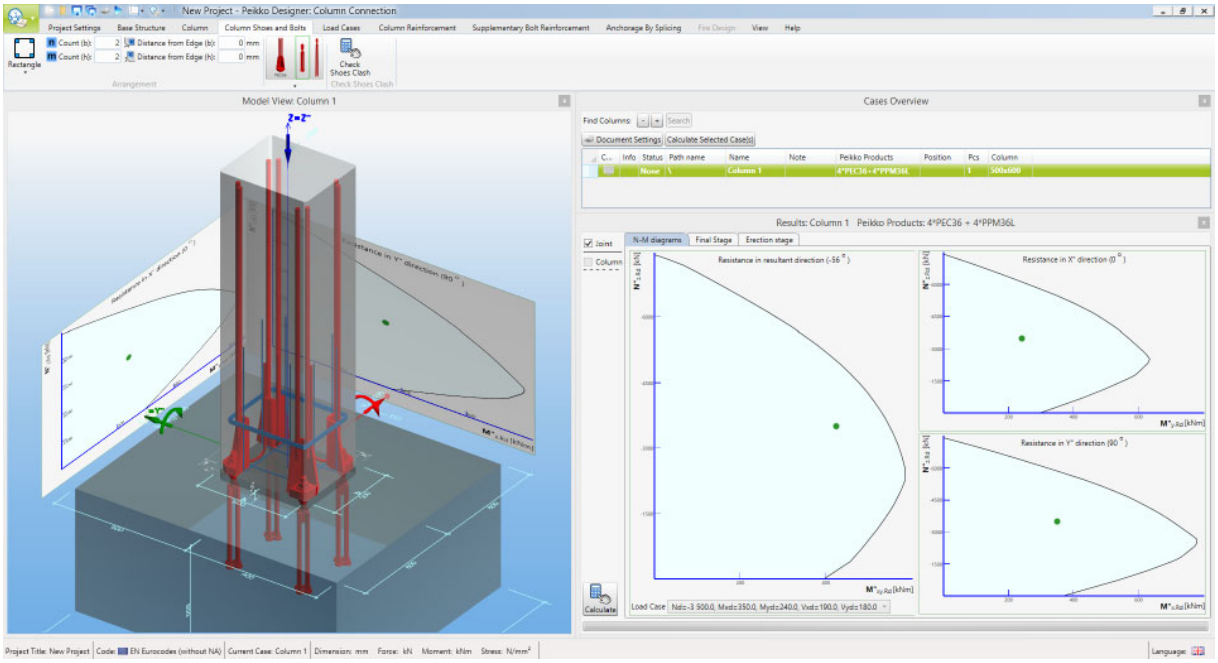
The resistance of column connection should be verified for the following design situations:

- 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 and final stage
- Type of column shoes and anchor bolts
- Column shoe arrangement
- Column reinforcement (optional)

PEIKKO DESIGNER OUTPUT

- N-M diagram (axial force-bending moment diagram) of joint in final stage
- N-M 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 PEC® Column Shoes are shown in following figures. Required quantities and lengths of stirrups are given in the *Table 6*.

Table 6. Transverse reinforcement in the lap zone and supplementary reinforcement (B500B).

		PEC 30	PEC 36	PEC 39	PEC 45	PEC 52
U-stirrup	①	4 Ø 6	4 Ø 8	4 Ø 10	4 Ø 12	4 Ø 10
U-stirrup	②	2 Ø 6	2 Ø 8	2 Ø 10	2 Ø 12	2 Ø 10
Stirrup	③	2+2 Ø 8	3 Ø 10	2+2 Ø 10	2+2 Ø 12	2+2 Ø 12
Stirrup	④	2+2 Ø 8	3 Ø 10	2+2 Ø 10	2+2 Ø 12	2+2 Ø 12
Stirrup	⑤	Ø 10	Ø 10	Ø 12	Ø 12	Ø 12
a		285	335	375	415	460
b		40	-	50	55	55
l_b		310	410	520	620	520

- Good bond conditions: recommended spacing ≤ 150 mm of transverse reinforcement ⑤ in the lap zone l_0.
- Poor bond conditions: recommended spacing ≤ 100 mm of transverse reinforcement ⑤ in the lap zone l_0.

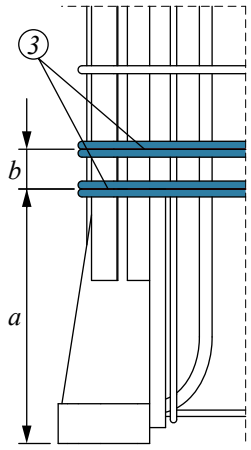
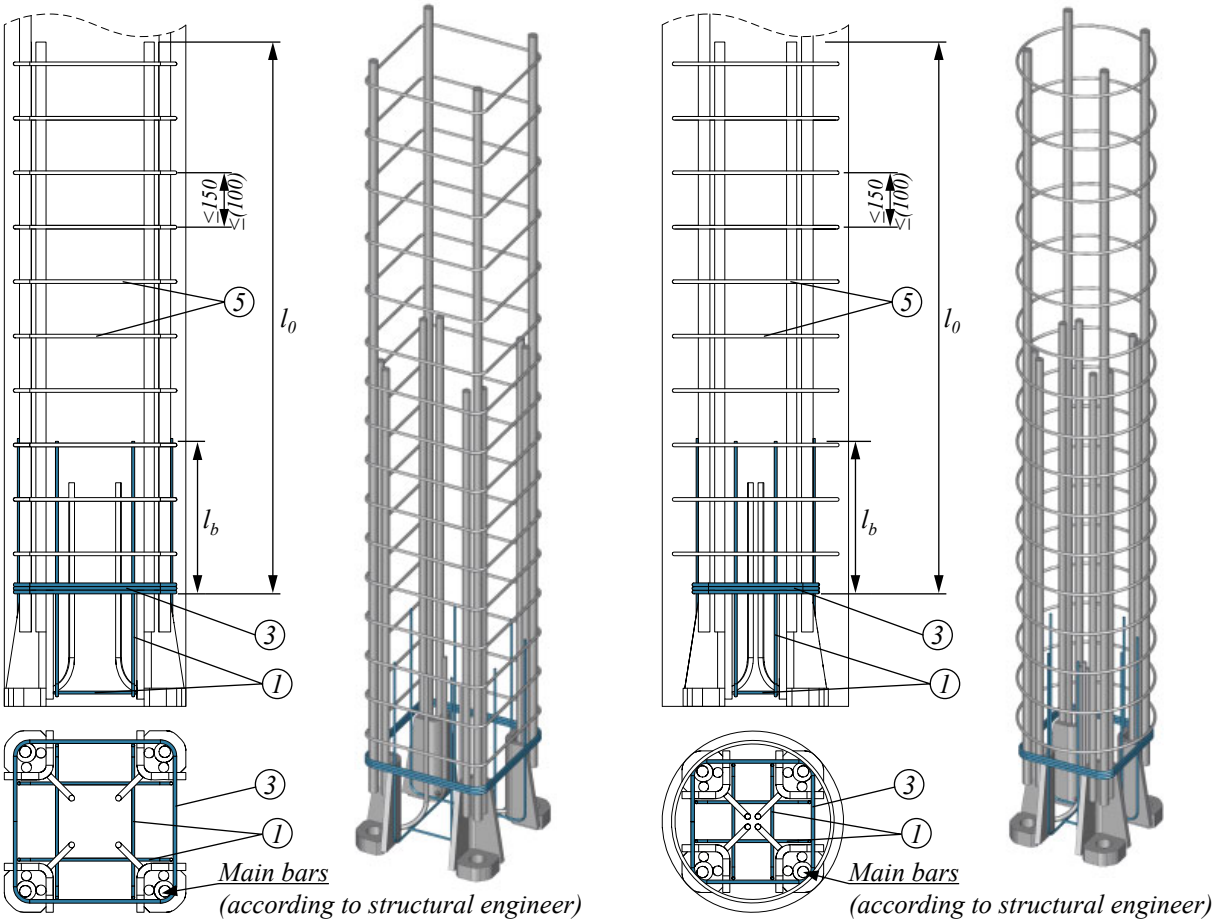
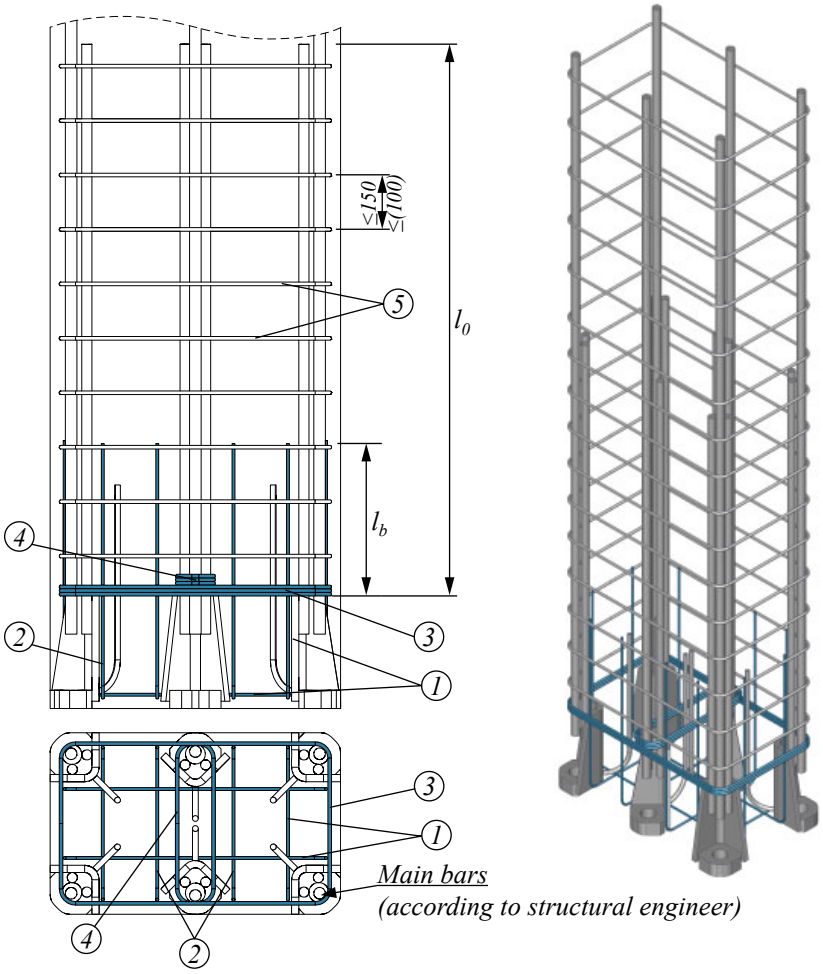


Figure 8. Transverse and supplementary reinforcement needed for PEC® Column Shoes (PEC 36 shown in the pictures).




≤150
(100)
≤150
5
l_0
l_b
4
3
2
1
3
1
4
2
Main bars
(according to structural engineer)

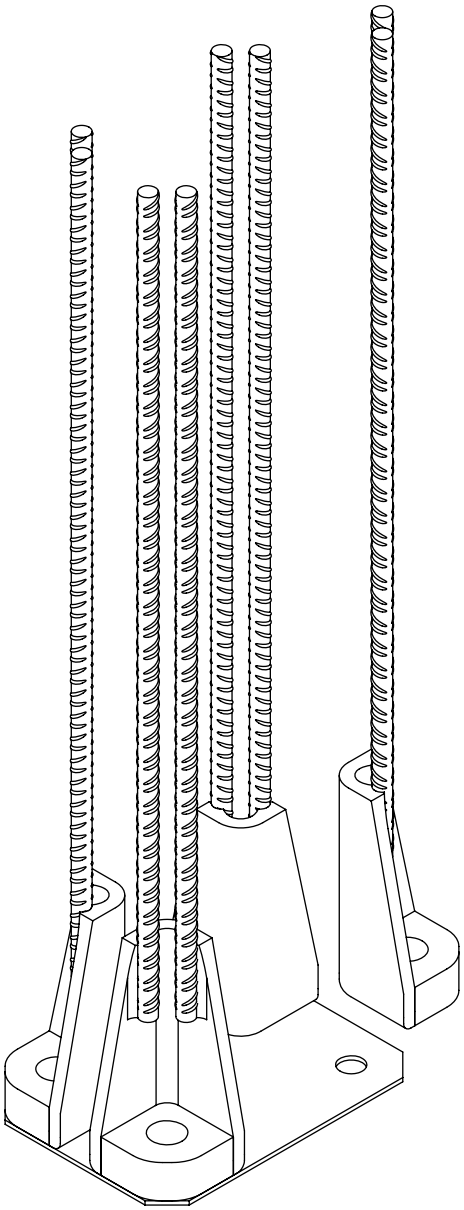
Annex B – Alternative use of PEC® Column Shoe

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. Supplementary reinforcement for anchor bolt's group must be checked.

Shoes on integrated steel plates are manufactured according to customer's specifications. Please ask more instructions from Peikko Customer Engineering Service.

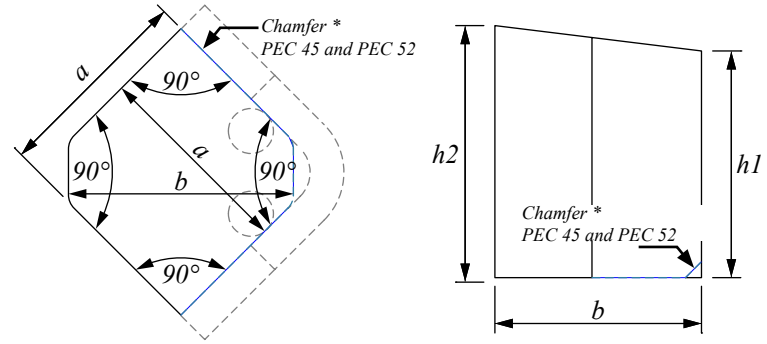
Figure 9. Column shoes on an integrated steel plate.



Self-made recess formers

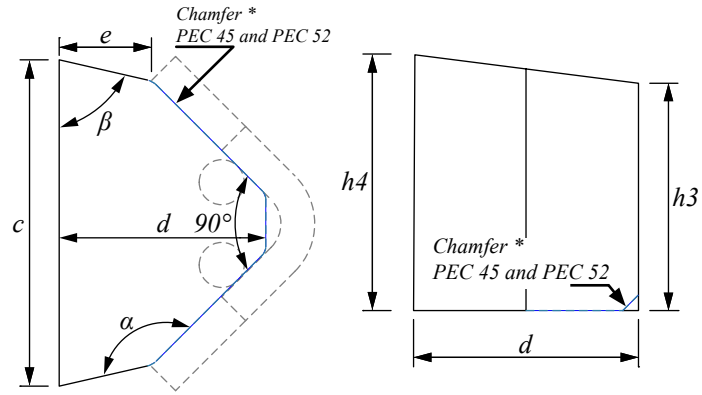
Recess formers can be alternatively made by customers themselves, according to required dimensions shown in *Table 7* and *Table 8*. They can be made of wood, polystyrene or similar material. Column shoes should be fixed into the formwork properly either by bolting them to end plate of the mould or welding all shoes together.

Table 7. Dimensions of corner recess boxes to use with PEC® Column Shoe.

Corner recess box – dimension [mm]		*a*	*b*	*h1*	*h2*
TOP View *SIDE View* 	**PEC 30**	105	115	103	117
	PEC 36	115	128	127	144
	PEC 39	129	148	139	158
	PEC 45	143	168	146	168
	PEC 52	153	182	154	178

* Chamfer 20x20 mm required on bottom part of recess for PEC 45
* Chamfer 25x25 mm required on bottom part of recess for PEC 52

Table 8. Dimensions of middle recess boxes to use with PEC® Column Shoe.

Middle recess box – dimension [mm,°]		*c*	*d*	*e*	h_3	h_4	*α*	*β*
TOP View *SIDE View* 	**PEC 30**	170	114	55	109	124	150	75
	PEC 36	185	120	59	129	144	150	75
	PEC 39	213	141	69	126	144	150	75
	PEC 45	234	162	83	147	168	150	75
	PEC 52	265	175	81	154	178	150	75

* Chamfer 20x20 mm required on bottom part of recess for PEC 45
* Chamfer 25x25 mm required on bottom part of recess for PEC 52

Precast factory - Casting of PEC® Column Shoe

Identification of the product

PEC® Column Shoes are available in standard models (30, 36, 39, 45 and 52) analogous to M-thread sizes of the PPM® High-Strength 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 PEC® Column Shoes.

PEC® Column Shoe with corresponding recess box.

Column Shoe	Anchor Bolt	Corner recess	Middle recess	Color Code
PEC 30	PPM 30	PEC 30 CBOX	PEC 30 MBOX	Black
PEC 36	PPM 36	PEC 36 CBOX	PEC 36 MBOX	Red
PEC 39	PPM 39	PEC 39 CBOX	PEC 39 MBOX	Brown
PEC 45	PPM 45	PEC 45 CBOX	PEC 45 MBOX	Violet
PEC 52	PPM 52	PEC 52 CBOX	PEC 52 MBOX	White

Installation of the column shoes

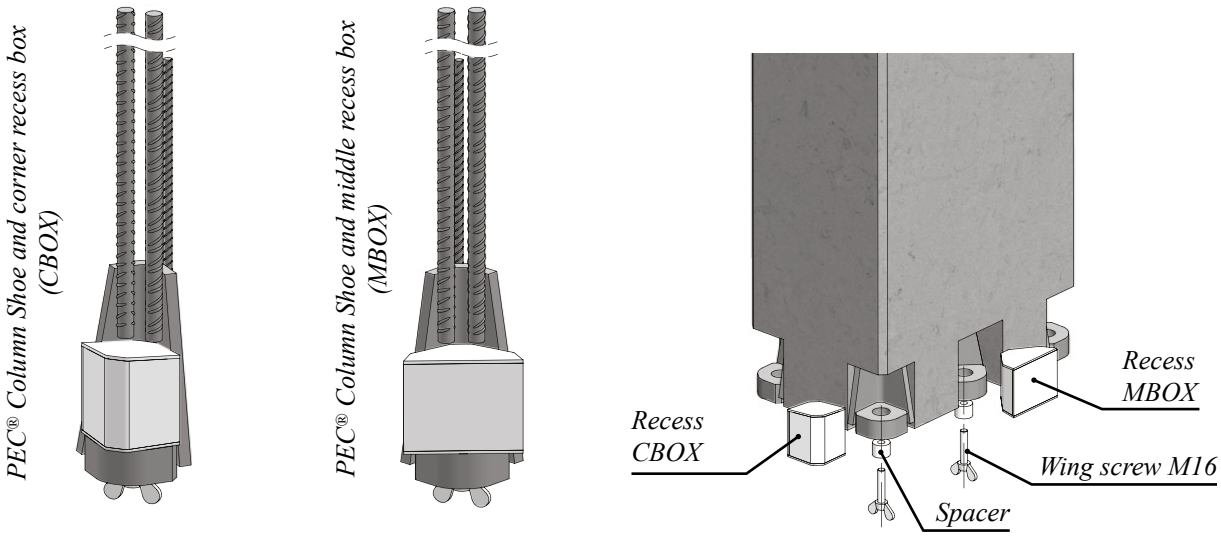
The PEC® Column Shoes are placed into the reinforcement of the column and fixed through their base plates to the end plate of the mould with recess boxes. Installation tolerance of column shoe in crosswise direction of the column is ± 2 mm. Supplementary reinforcement must be placed at the area of column 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 PEC® Column Shoe.

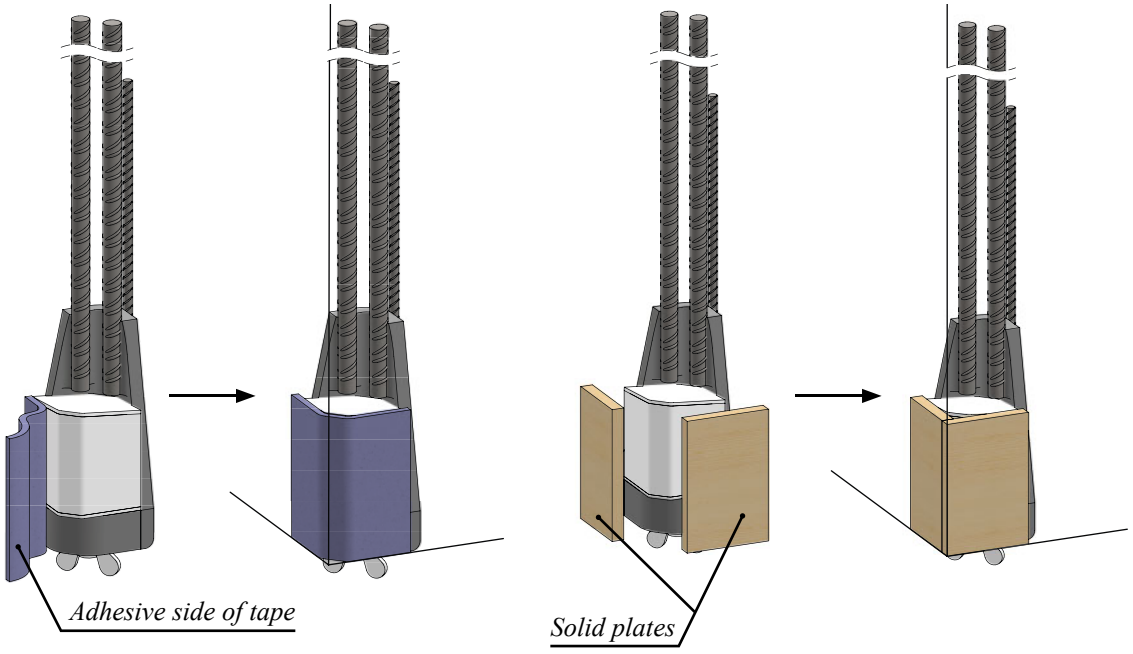


To ensure higher values of concrete cover thicknesses of main anchor bars, in accordance with chapter 1.2.3 of the technical manual, follow these instructions for increased values Δ_c of concrete cover:

- $\Delta_c < 5mm$, 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.
- $5\ mm \leq \Delta_c \leq 10mm$, 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.
- $\Delta_c > 10mm$, 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.

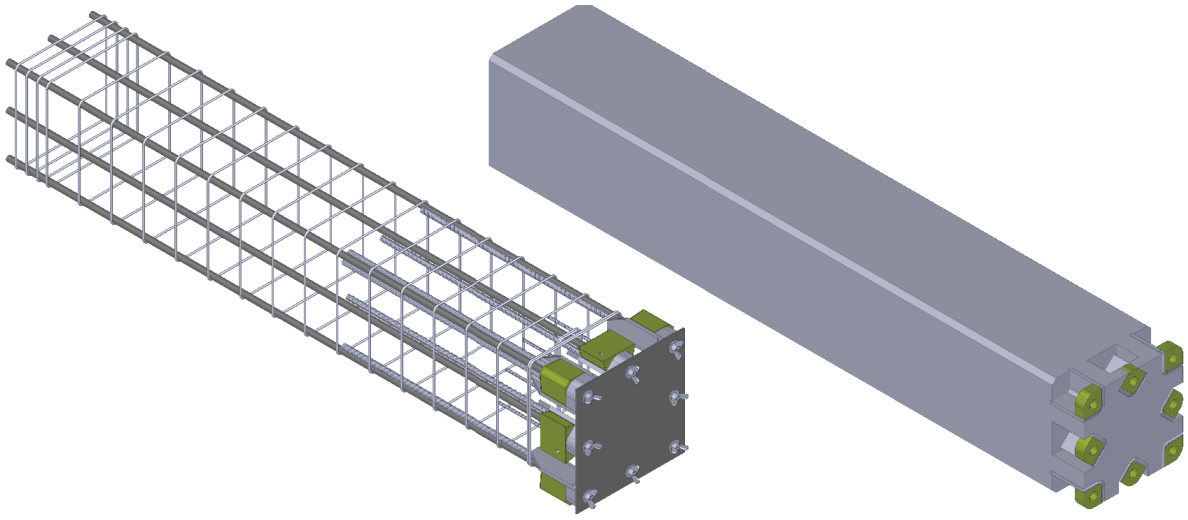
Use of **self-adhesive foam tape** to prevent the fill up the gap with concrete.

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.

PEC® Column Shoes before and after casting.



Construction site - Assembling the connection

Identification of the product

PEC® Column Shoes are available in standard models (30, 36, 39, 45 and 52) analogous to PPM® High-Strength 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.

PEC® Column Shoe color identification.

Column Shoe	Color Code	Anchor Bolt	Installation Template
PEC 30	Black	PPM 30	PPL 30
PEC 36	Red	PPM 36	PPL 36
PEC 39	Brown	PPM 39	PPL 39
PEC 45	Violet	PPM 45	PPL 45
PEC 52	White	PPM 52	PPL 52

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 long builder's spirit level, optical or laser level or two theodolites from different directions to ensure verticality. 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.

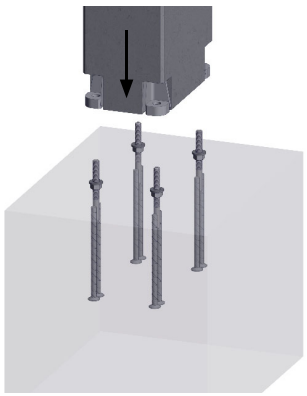
3. To grout joint and recesses

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.

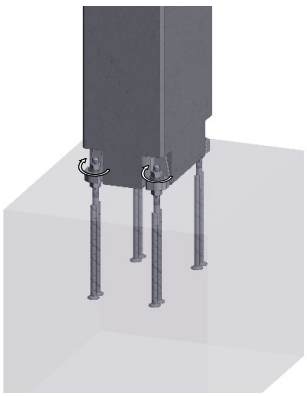
After grout has reached sufficient strength, the connection is finalized and joining structures may be erected on the column.

Erection of precast concrete column step by step.

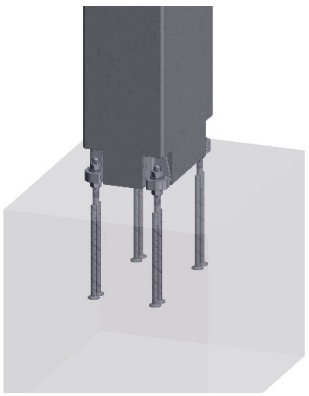
Column is installed directly on the pre-leveled washers and nuts.



Upper nuts and washers are screwed on the bolts.

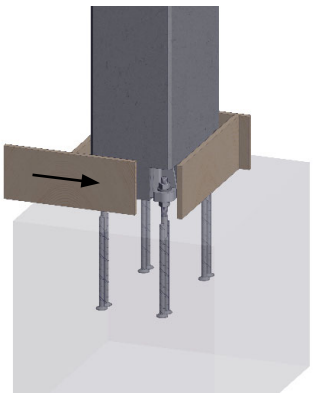


After the nuts are tightened, the crane hook and lifting slings can be released.

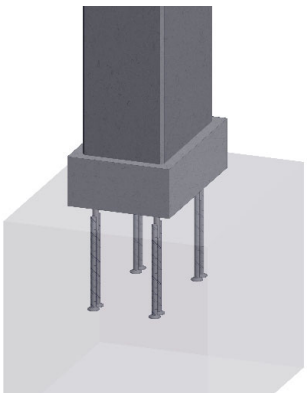


NOTE! Joint has to be grouted and grout has to reach the designed strength before the column is loaded by other structures.

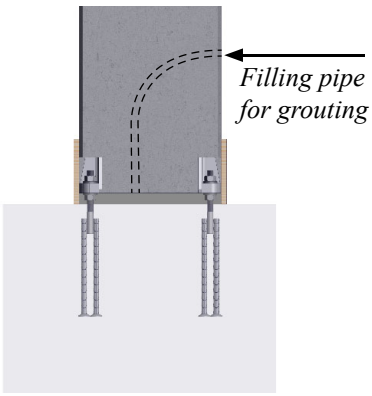
Formwork for grouting joint and recesses.



Finalized connection after grouting has hardened.

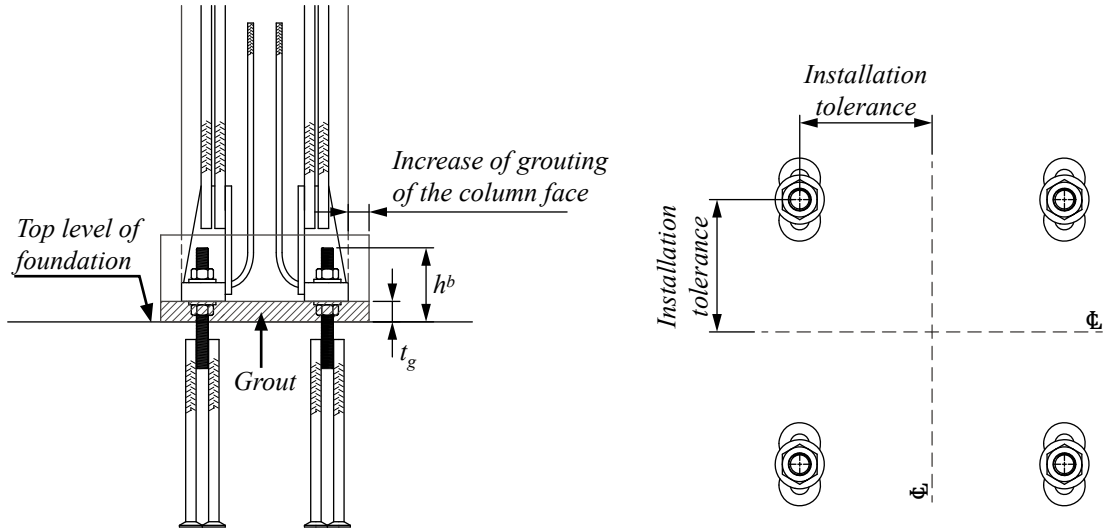


Alternative where grouting is aligned with column face.



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 PEC® Column Shoes are used.



Column Shoe	PEC 30	PEC 36	PEC 39	PEC 45	PEC 52
Anchor Bolt	**PPM 30**	**PPM 36**	**PPM 39**	**PPM 45**	**PPM 52**
Thickness of grouting t_g [mm]	50	55	60	65	70
Protrusion of the bolt h_b [mm]	155	170	190	200	235
Installation tolerance for the bolt [mm]	±3	±4	±4	±4	±5

Technical Manual Revisions

Version: PEIKKO GROUP 09/2018. 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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