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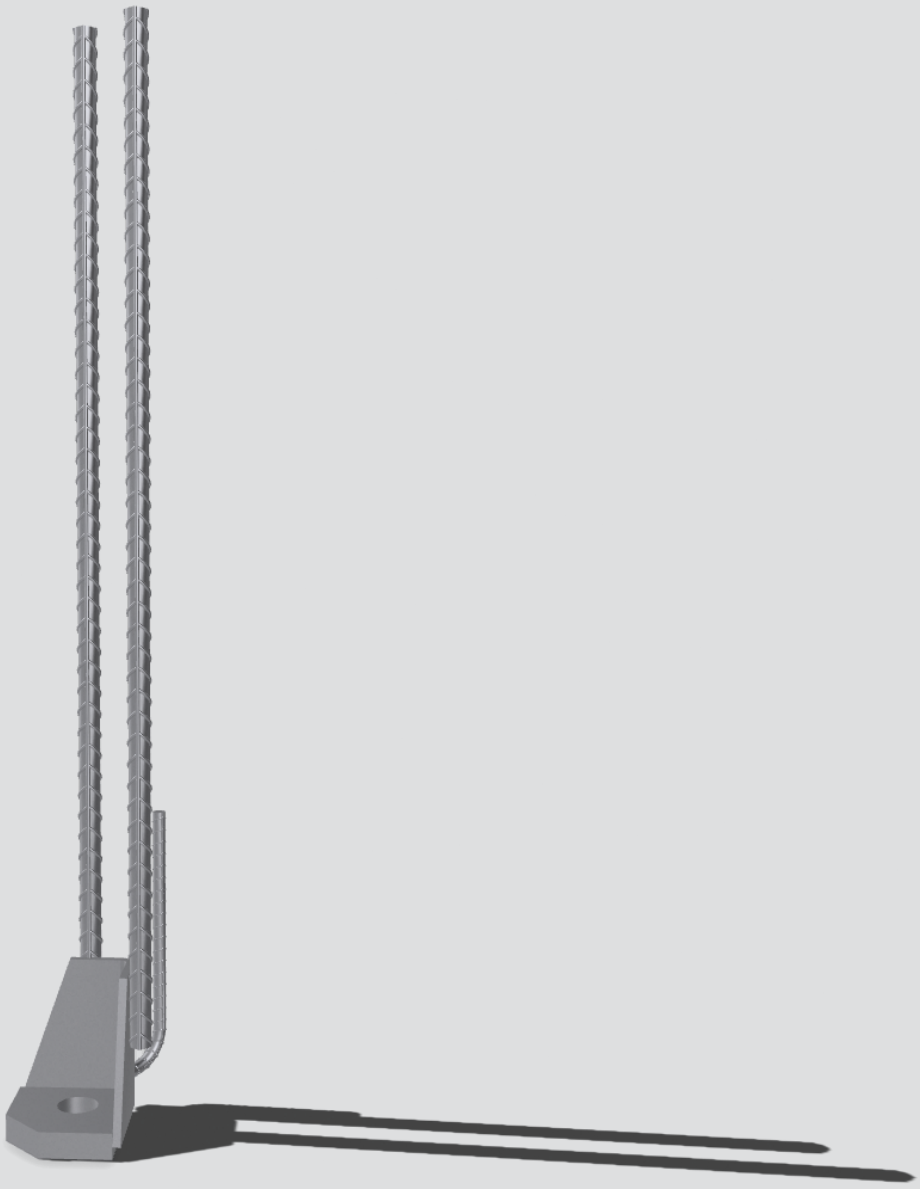

RPK-N3-column shoe

Design according to Eurocodes

TECHNICAL MANUAL

Technical changes and errors reserved

Version: **19.12.2022***

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1. INTRODUCTION

Column shoes are fastening components that are used to create moment resisting connections for precast columns. Stresses developed within the column are transferred to the column shoes, through the anchor bolts and across the grouted gap, to the adjoined structures e.g.to the foundations.

It is possible to adjust the vertical position and level of the column using the column shoes. The gap that remains between the base of the column and the top of the adjoined structure is grouted up as soon as possible after the connection is set. The base connection, once grouted, is designed to be stronger than the cross-section of the column.

Column shoes bring following benefits during the construction process:

- ✓ Simple connection by bolting members together
- ✓ Faster erection and easily adjustable connection
- ✓ Immediate transfer of erection forces once the column is erected and bolted
- ✓ No additional support or temporary bracing system required

2. MATERIALS AND DIMENSIONS

Table 1. Materials and standards of RPK-N3-column shoe

Part	Material	Standard
Plates	S355J2	EN 10025
	S355J2+N	EN 10025
Rebars	B500B	EN 10080 (SFS 1268)

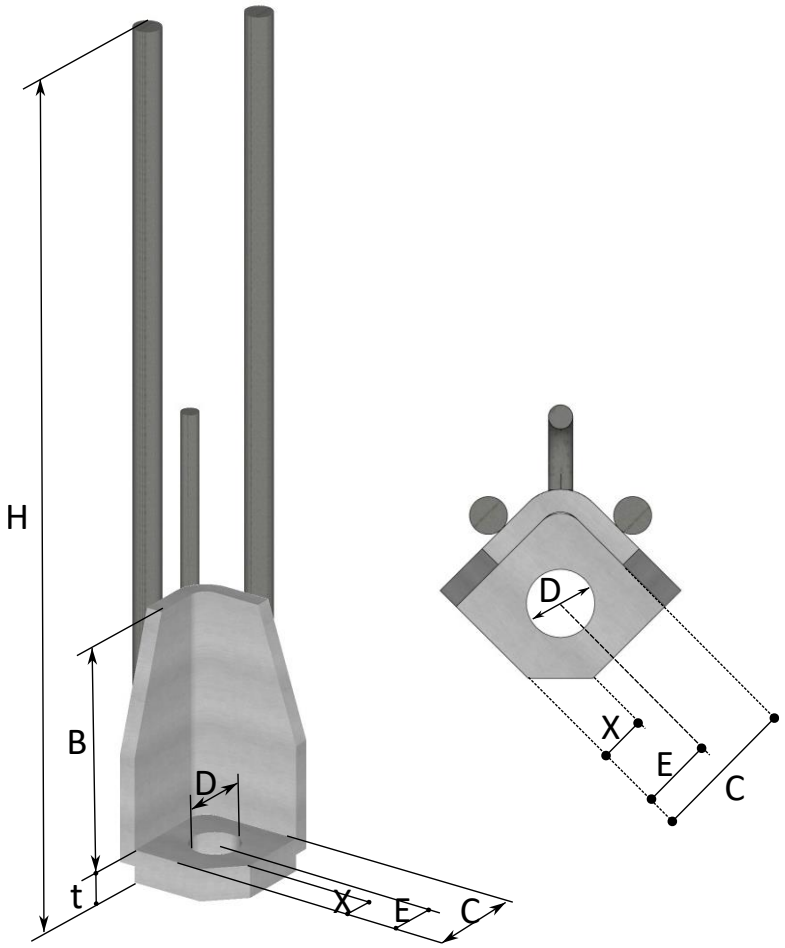


Table 2. Dimension of RPK-N3-column shoe

RPK-N3	B (mm +3/-0	C (mm) +2/-0	E (mm) ±1	H (mm)+ 0/-10	t (mm)	D (mm)+ 2/-0	X (mm)	Main rebars	Weight	Color
M16	102	80	50	597	15	28	30	2T12	2.4	
M20	100	83	50	820	20	31	30	2T16	4.3	
M24	120	90	50	1185	30	35	30	2T16	6.5	
M30	130	95	50	1390	45	40	30	2T20	11.5	
M39	210	120	60	1910	50	55	37	2T25	25.5	

3. MANUFACTURING

3.1. Manufacturing method

Execution standard:	EN 1090-2
Plates:	Flame cut, laser/plasma and mechanically cut
Rebars:	Mechanically cut
Welding:	MAG hand/robot
Welding class:	C (EN ISO 5817) in accordance with EXC 2
Surface treatment:	Untreated as standard

The product shall be produced clean and dry. Light surface rusting may be present at delivery of the product. The product is to be stored in dry conditions. The product may be installed with light surface rusting, and in accordance with general requirements for reinforcement bars.

3.2. Quality Control

Fabrication and quality control in accordance with SFS-EN 1090-2. R-Group Baltic OÜ internal quality control in accordance with ISO 9001 and ISO 14001. External quality control provided to R-Group Baltic OÜ by Inspecta Estonia OÜ

3.3. Markings

R-Group Baltic Oü identifier marking

Manufacturing date

Inspecta Estonia Oü check markings

4. RESISTANCES

The tension capacities of the column shoes, calculated in accordance with EC (EN 1992, 1993), are governed by the tension capacity of the connected RPP, RPP-E base bolt. More information is provided in the R-STEEL RPP-base bolt technical manual.

The minimum concrete grade of the column is C30/37. Normal material partial factors for resistance and normal production tolerances have been used for determining the length of main reinforcement bars for lapping.

The anchorage length (lap length) is determined based on the diameter of the anchor.

Anchorage coefficients, lap factor $\alpha_6 = 1.5$, $\alpha_2 = 0.7$, others $\alpha_1 \ldots \alpha_5 = 1.0$

Table 3. Nominal design tension resistances of RPK-N3-column shoe

RPK-N3	RPP	N_{Rd} (kN)
M16	M16	62.2
M20	M20	97.0
M24	M24	139.4
M30	M30	222.2
M39	M39	386.5

The shear capacity of the shoe is governed by the connected RPP-base bolt. The column shoe can also be used with base bolts from other suppliers, that are of equivalent strength and that are similarly approved.

R-Steel's R-Design Suite software for bolted connections on rsteel.fi. Registration is required.

Column connection rotational stiffness is covered by EOTA European Assessment Document DP 17-20-0102-03.02 (March 2018). When designing the column (EN 1992-1-1 figure 5.7), connection rotational stiffness parameter k_L is to be considered in accordance with section 3.4 of EOTA Technical Report 068 (September 2018 A:March 2020).

When RPK-N3 column shoes are used for forming the column connection, parameter k_L is equal to 1.0, and the column connection can be considered to be moment rigid. Column shoe installation and additional reinforcement must be in accordance with instructions in this user guide.

5. USER INSTRUCTIONS

5.1. Limits of use

The capacities of the column shoes have been calculated for static loads. Increased load factors are to be adopted for case specific dynamic and fatigue effects. For design in accordance with the Eurocodes, the lowest operating temperature is calculated from EN 1991-1-5.

5.2. Design guidance

The shear strength of the connection can be calculated in accordance with EN 1993-1-8 clause 6.2.2. The additional contribution of friction to shear strength can be taken into account; a friction coefficient of 0.2 can be adopted for a sand-cement grout, without additional tests.

5.2.1. Shear resistance

$$V_{Rd} = F_{f,Rd} + nF_{vb,rd}$$

where n is the number of bolts on the compression side of the column.

5.2.2. Resistance due to friction

$$F_{f,Rd} = C_{f,d}N_{c,Ed}$$

where $C_{f,d}$ is 0.2 and $N_{c,Ed}$ = the axial compression applied by the column.

5.2.3. Bolt shear resistance

$$F_{vb,Rd} = \min\{F_{1,vb,Rd}\ ;\ F_{2,vb,Rd}\}$$

$$F_{1,vb,Rd} = (k_1 a_b f_{base,u} d_b t_{base})/\gamma_{M2}$$

$$F_{2,vb,Rd} = (\alpha_b f_{bolt,u} A_{bolt})/\gamma_{M2}$$

$\alpha_b = 0.44 - 0.0003\ f_{bolt,y}$

k_1 and a_b EN 1993-1-8, Table 3.4

$f_{base,u}$, $f_{bolt,u}$ are the base plate and bolt ultimate tensile strengths respectively

A_{bolt} is the net tensile area of the bolt

γ_{M2} is the material partial factor for resistance, EN 1993-1-8, Table 2.1

5.2.4. Design criteria

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

$$N_{Ed} \leq N_{Rd}$$

$$N^{1}_{Ed} / 1.4N_{Rd} + V^{1}_{Ed} / V_{Rd} \leq 1$$

where N^{1}_{Ed} and V^{1}_{Ed} are applied coincident axial force and shear force.

Shear strength during erection, governed by the shear transfer capability of the base bolt, can be calculated using EOTA TR-068: 2020. Shear strength values calculated in accordance with EN 1992-4 are provided in the table below in brackets.

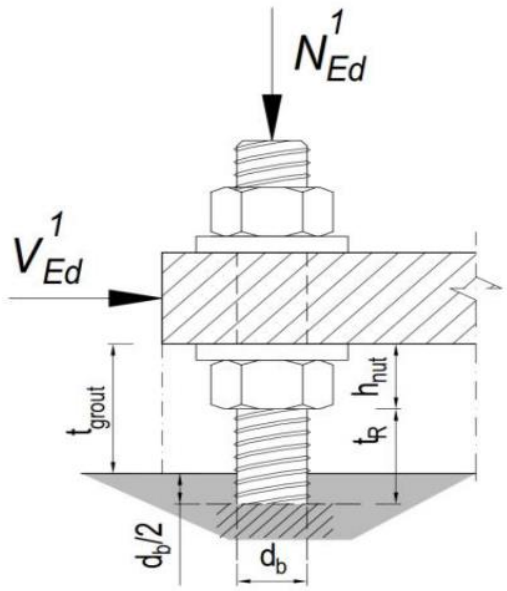
5.3. RPP-base bolt design resistances

Table 4. RPP-base bolt design resistances

RPP	Tension N_{Rd} (kN)	Shear V_{Rd} (kN)	Net tensile area A (mm2)	Lever arm t_R (mm)
M16	62.2	7.3 (4.5)[1]	157	38 (65) [1]
M20	97.0	14.7 (8.3)[1]	245	37 (69) [1]
M24	139.4	26.2 (13.0)[1]	352	36 (76) [1]
M30	222.2	59.8 (23.0)[1]	561	31 (86) [1]
M39	386.5	117.4 (44.3)[1]	976	37 (103) [1]

Shear resistance during installation and prior to grouting of the base

(…) [1]→V_{Rd} values in parentheses are calculated according to EN 1994-2:2018



EN 1993-1-8

$$NR,d = 0.9f_{uk} * A / \gamma_{Ms}$$

$$\gamma_{Ms} = 1.25 \text{ and } f_{uk} = 550 \text{ MPa}$$

EOTA TR 068:2020 (3.3.2)

$$16V_{ED}\, t_r/\pi d^3 + 4N_{ed}/\pi d^2 \leq f_{bolt,y}$$

(N_{ed}= 0; shear only)

$$V_{Ed} \leq f_{bolt,y}\, \pi d^3/\, 16t_r$$

$$V_{Rd} \leq f_{bolt,y}\, \pi d^3/\, 16t_r$$

$$f_{bolt,y} = 500 \text{ MPa}$$

Moment lever arm is calculated in accordance with base grout thickness presented in Section 6

The base is to be grouted as soon as possible following installation and setting of the column. Following hardening of the grout, structures can be added to the top or corbel of the column. The strength of the grout used (in the base joint as well as to fill the box of the shoe) is to be at least as strong as the design strength of the concrete of the connecting column. Cement grout must be non-shrink (zero shrinkage). Instructions provided by the grout manufacturer and by the designer must be followed.

In the erection case, base bolts are verified against applied wind loads and dead load, including stability loads. Additional wind load from column corbels must be taken into account.

Nominal concrete cover is to be in accordance with guidance presented in EN 1992-1-1.

When the RPK-N3 shoe is positioned in the column mould using the casting box, the concrete cover to the anchor bars is according to table 5.

Table 5. Minimum concrete cover

RPK-N3	Concrete cover (mm)
M16	45
M20	45
M24	45
M30	45
M39	45

If greater cover is required, then the shoe is to be positioned deeper into the column.

5.4. Fire design

Structural fire design of the column is to be undertaken in accordance with EN 1992-1-2. Fire resistance of R90-R120 can be achieved with the above concrete cover values, following the dimensioning criteria set-out in tabulated data of EN 1992-1-2.

The fire resistance of the base plate of the shoe, without any additional provided fire protection, is R60. For exposure class X0 (dry internal environment) the base plate can be left exposed if the surfaces can be accessed for maintenance of the surface treatment eg. corrosion protection system and fire protection system. For exposure classes XC, XD and XS, corrosion protection (surface treatment and/or protective concrete cover layer) is to be provided for at least the exposure class and design life of the connected structures. For exposure class XC hot dip galvanization is required. For exposure classes XD as well as XS, in addition to hot dip galvanization, an additional layer of reinforced concrete (that prevents water ingress up to the column shoe) is required.

Table 6. Minimum column size that can be made with the RPK-N3

RPK-N3	Rectangular (mm x mm)	Circular (mm)
M16	230 x 230	285
M20	240 x 240	300
M24	250 x 250	315
M30	280 x 280	360
M39	360 x 360	460

If the required column is smaller than the minimum column size given in the table above, then please contact RSTEEL technical support.

5.5. Column reinforcement instructions

The reinforcement to the column adjacent to the column shoes is to be in accordance with instructions provided in EC 2, as well as the following details.

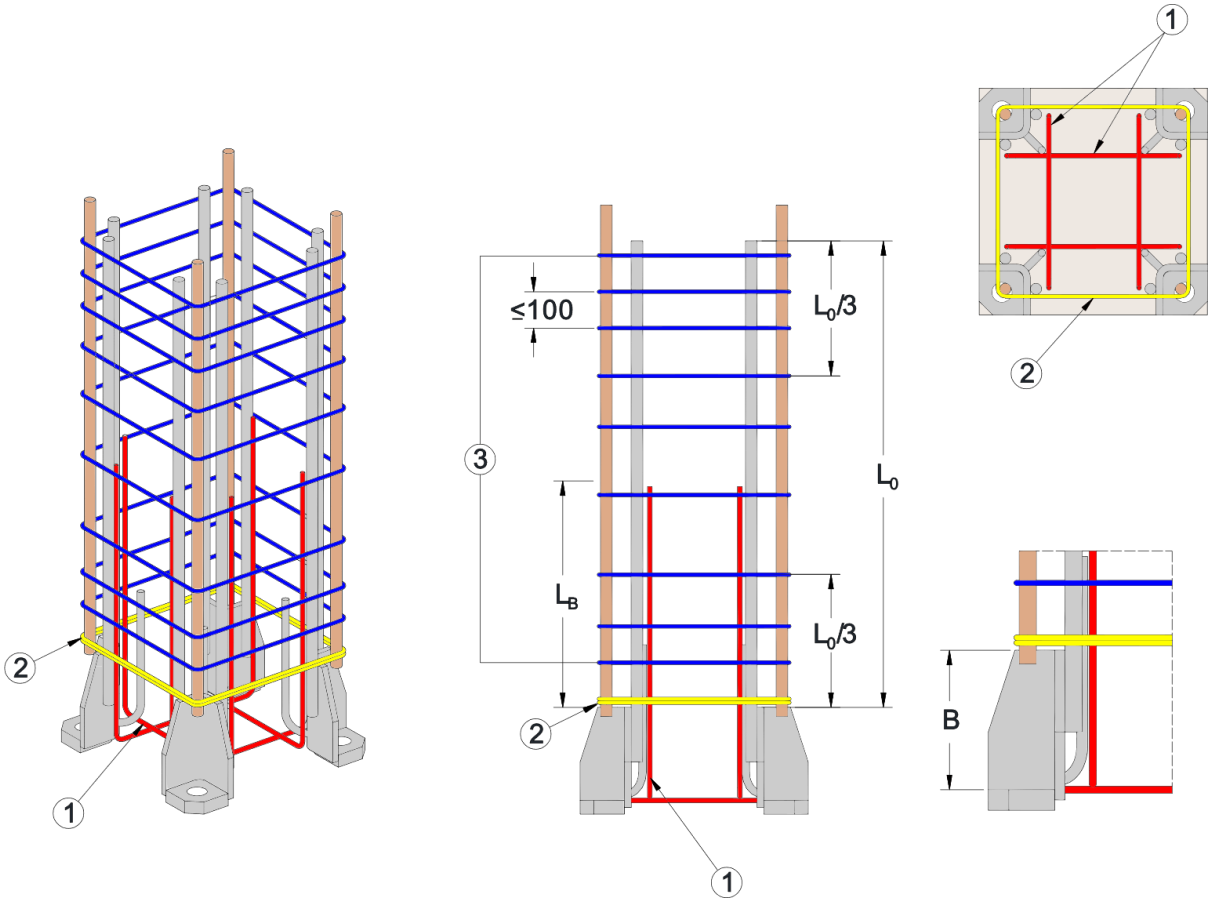


Figure 1. Supplementary reinforcements for square column

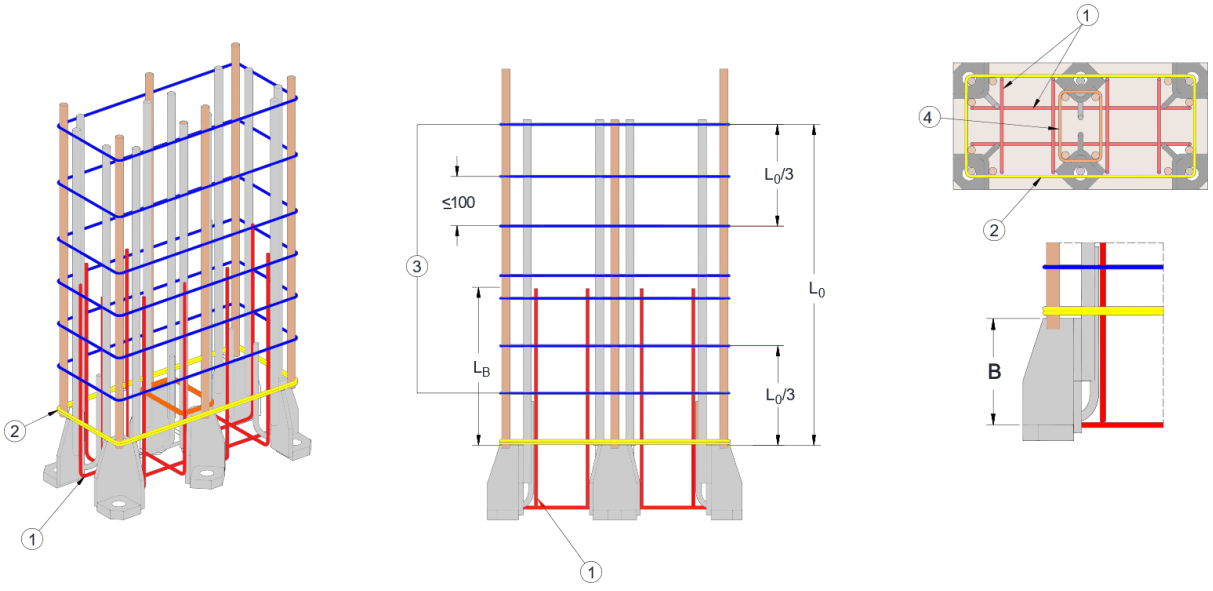


Figure 2. Supplementary reinforcements for rectangular column

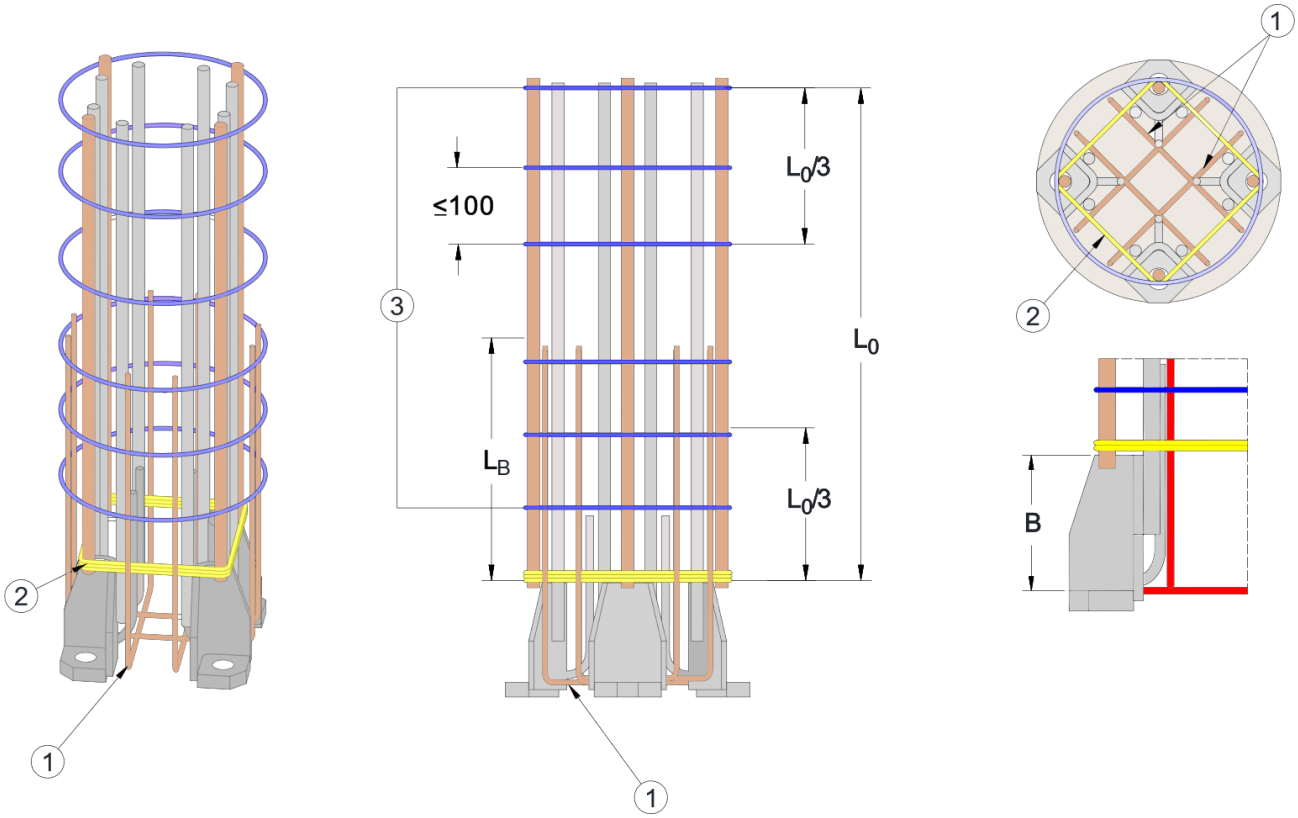


Figure 3. Supplementary reinforcements for round column

Table 7. Supplementary reinforcement for the RPK-N3-column shoe

RPK-N3	① U-Stirrups				② Stirrups	③ Stirrups	④ Stirrups	Lap Zone		Main rebar
	Quantity	Ø	L_b (mm)	B (mm)				L_0 (mm)	$L_0/3$ (mm)	D_{max} (mm)
M16	≥4	T6	500	102	2T8	T8	2T8	480	160	20
M20	≥4	T6	500	100	2T8	T8	2T8	750	250	20
M24	≥4	T6	500	120	3T8	T8	3T8	1100	350	25
M30	≥4	T6	500	130	3T8	T8	3T8	1300	430	32
M39	≥4	T6	500	210	3T10	T8	3T10	1800	600	32

Within the zone defined by L_0, the maximum recommended spacing of stirrups according to SFS-EN 1992-1-1 is 100mm.

Columns with centrally positioned shoes:

Stirrup (1): add 2 pieces of (1) stirrups per shoe pair (1 pc to each side of each pair).

Stirrup (4): add (4) stirrups around each shoe pair. Required number of stirrups according to the table.

6. INSTALLATION

The shoe is tied into the main reinforcement cage, and is connected to the end plate of the mould by bolting through the base plate.

Table 8. Installation tolerances

RPK-N3	Installation tolerance in cross-section (mm)
M16	±2
M20	±2
M24	±2
M30	±2
M39	±2

6.1. At the factory

Checklist before casting:

- The correct shoe type and size is installed
- The positioning of the shoe is correct and according to installation tolerances
- The shoe is properly secured in the reinforcement and mould
- The correct supplementary reinforcement is installed according to manufacturing drawings

Checklist after casting:

- Position of the shoe is correct and according to tolerances
- Shoes are cleaned and any casting boxes are removed
- Casting boxes are removed

6.2. Installation of the column

The column is installed at the correct level either by adjusting the nuts to the bolted connection or by using packer plates. Nuts are to be firmly tightened, for example using an impact wrench. Following tightening of the nuts, lifting connections can be disconnected and removed. Erection must follow the erection scheme that is approved by the responsible engineer.

Table 9. Minimum tightening torque for nuts

RPP	Tightening torque (Nm)
M16	120
M20	150
M24	200
M30	250
M39	300

Space required for tightening the nut with an impact wrench is verified in accordance with DIN 7444.

Once the column is set at the correct level and inclination, and the nuts are tightened, the base is to be grouted in accordance with the manufacturer's guidance. The grout must be of a non-shrinkage type and with strength greater than the weakest of the concrete structures that are connected with the bolt and shoe assembly. The sides of the grouted joint may be formed vertically for example with the help of a casting form.

Table 10. Installation tolerances and available length of the anchor bolts above concrete surface

RPK-N3	RPP	Base grout (mm)	Length of bolt above concrete surface (mm)	Bolt installation tolerance (mm)
M16	M16	50	105	±3
M20	M20	50	115	±3
M24	M24	50	130	±3
M30	M30	50	150	±3
M39	M39	60	180	±3

Tolerance on position of the base bolt group is ±10 mm. Tolerance for height is ±20 mm

NOTES

TECHNICAL MANUAL REVISIONS

23.08.2022 (FA, JK)

- Shoe types and generations separated into own technical manuals
- New graphical layout

19.12.2022 (FA)

- Column shoe dimension figure updated