

**NKK COLUMN SHOE
(BOLTED CONNECTIONS)**

RIGHTS TO CHANGES AND ERRORS RESERVED

**TECHNICAL
MANUAL**

EXM-BAS-DC-1002
R3 - 28.09.2022

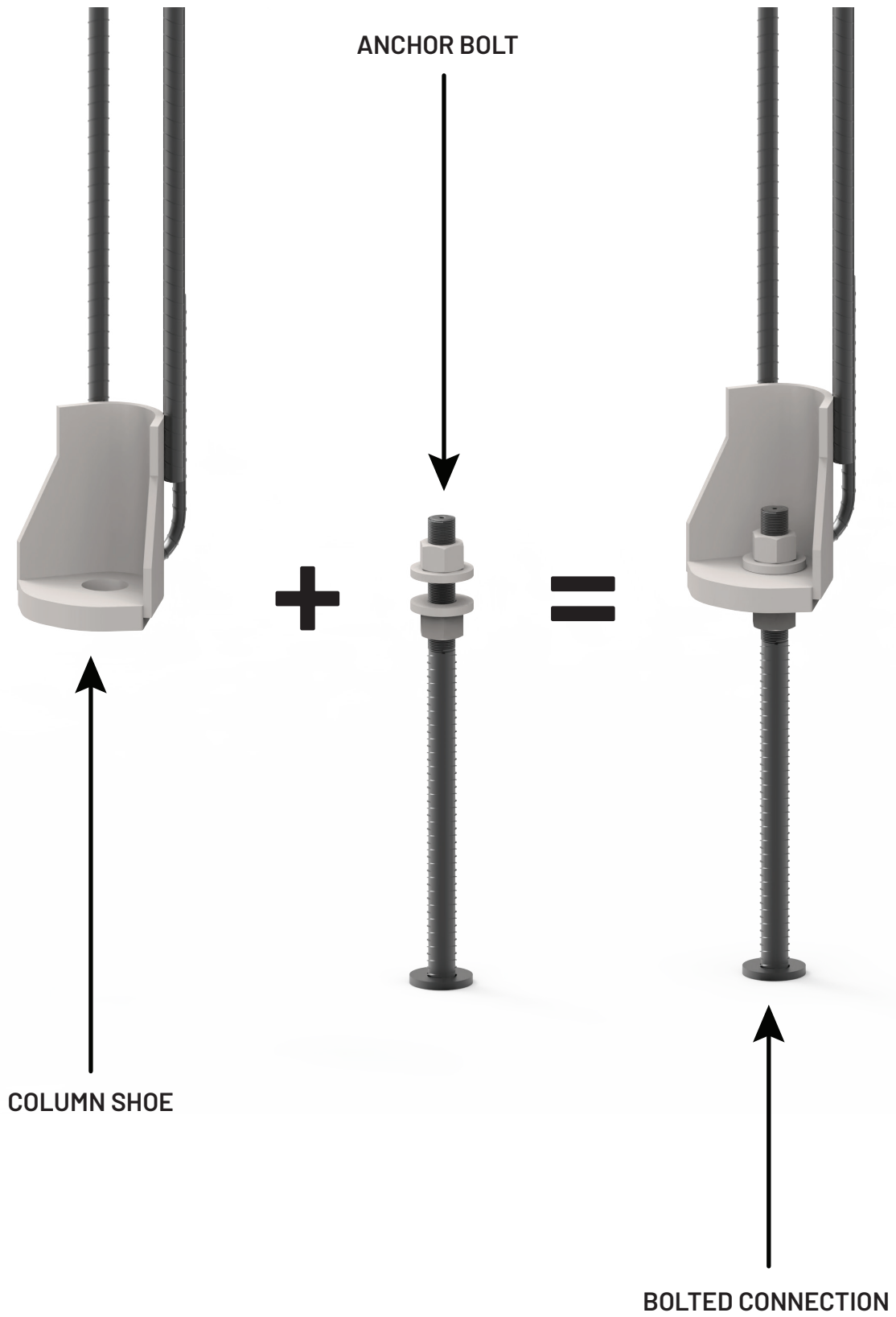


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NKK COLUMN SHOES

BENEFITS:

Exmet's NKK Column Shoes are fast becoming a preferred solution for column to foundation or column to column connection. Among various other benefits, the key benefits of using NKK columns shoe are:

- Simple connection by bolting members together
- Faster erection and easily adjustable connection
- Immediate transfer of erection forces once the column is erected and bolted
- Erection without temporary bracing or additional support
- Rigid connection

Exmet offers a wide range of Columns Shoes and Anchor Bolts to suit various connection requirements. NKK Column shoes have been tested at European Laboratory and have been found to provide as rigid connection as continuously reinforced CIP connection.

NKK Column shoe and Anchor bolt connections provide a stiff and moment resisting connection between column and foundation or two columns. Exmet also offers related products such as casting block and installation plate that are used for easy installation of column shoes in precast element at factory and erection of precast column at the right level at site respectively.

NKK column shoes can be used in situations where the connection is required to resist bending moment. Upon grouting, the column shoe and anchor bolt connection act as a stiff moment resisting joint between two columns or column and foundation.

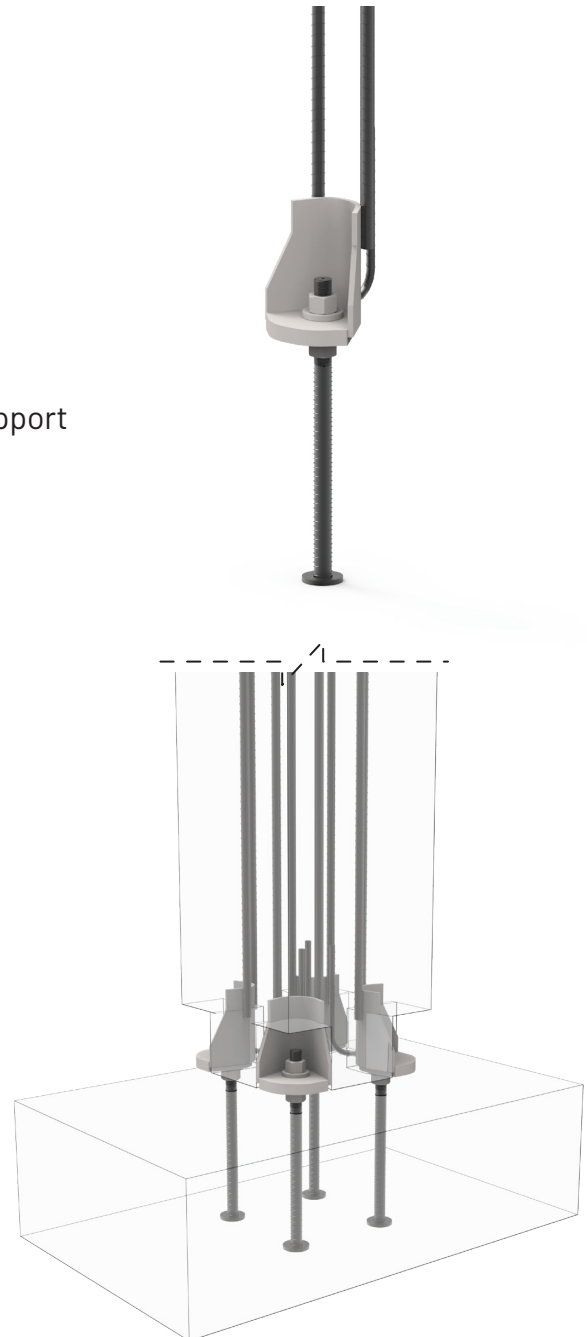


Figure 1: Column Shoe

1. PRODUCT DESCRIPTION & PROPERTIES

NKK column shoe is constructed by welding together base plate, side plate and secondary and primary rebars. Exmet's Column shoe connection system consists of Column Shoes, Anchor Bolts and Accessories such as casting block, installation plate. NKK Column shoes are available in 5 sizes to cater to a range of moment resisting connections.

NKK Column shoes are installed at the bottom of the column along with main and supplementary reinforcement and the anchor bolts are installed at the top of foundation or the column below. The anchor bolt passes through the hole in the column shoe above and is fastened with the help of nuts and washers. The gap between column and foundation or column and column is filled with non-shrink grout. Sufficient tolerances have been provided in the design to allow for variations at factory and on site.

The resistance provided by column shoes connection is dictated by resistance of anchor bolt used. Column shoe connection can resist axial loads, bending moments, shear force and combination of these.

NKK column shoes can be used in square, rectangular and circular columns in many different configurations to achieve required resistances.

1.1 STRUCTURAL BEHAVIOUR

1.1.1 Erection Stage

At this stage, the forces acting on the connection are due to the self-weight of the column and the wind load. In the absence of grout in the connection, these actions are resisted entirely by anchor bolts. Required resistance against these actions in Erection stage can be achieved by choosing a bigger size and/or a greater number of bolts and corresponding column shoes. The column must not be loaded before the gap has been grouted and allowed to reach its designed strength.

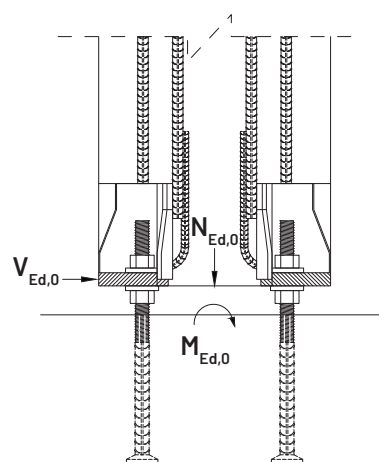


Figure 2: Erection Stage

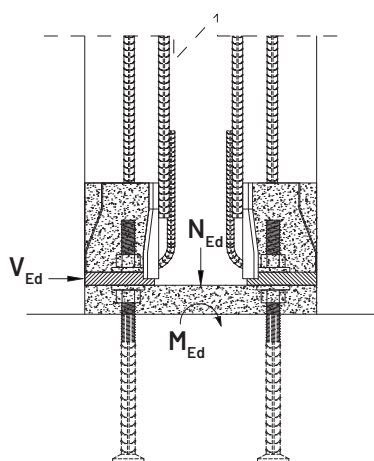


Figure 3: Final Stage

1.1.2 Final Stage

After the grout reaches its designed strength, the column shoe connection can take the designed loads by virtue of interaction among column shoes, anchor bolts and grout. The final grouted connection is as stiff as the continuously reinforced cast in situ column connection.

1.2 CONDITIONS FOR USE OF NKK-COLUMN SHOES

1.2.1 Exposure Conditions

NKK Column shoes have been designed to withstand static loads. For use of NKK Column shoes under dynamic or seismic loads, kindly contact Exmet's technical team (technical@exmet.ee).

NKK column shoes are uncoated by default. In case, NKK columns shoes are to be used in harsh conditions, appropriate surface coating or concrete cover must be provided. Exmet offers various surface coating options for NKK shoes such as HDG and Acid resistant.

Table 1: Concrete cover for column shoes for different exposure

Exposed Class	Concrete Cover according to EN-1992-1-1 (Δ)	Concrete Cover of plates of shoes according to EN-1992-1-1 (Δ)	Surface Treatment
X0	20	0	No Surface Treatment
XC1	25	25	No Surface treatment if placed inwards
			Hot-dip galvanised if placed at edge
XC2	35	35	No Surface treatment if placed inwards
			Hot-dip galvanised if placed at edge
XC3	35	35	No Surface treatment if placed inwards
			Hot-dip galvanised if placed at edge
XC4	40	40	Hot-dip galvanised
XD1 / XS1	45	45	Hot-dip galvanised
XD2 / XS2	50	50	Hot-dip galvanised
XD3 / XS3	55	55	Hot-dip galvanised

1.2.2 Minimum Column Size and Properties

Please refer the table below for minimum column size for NKK column shoes. In case, the column shoe is required to be used in a column smaller than the minimum size, please contact Exmet's technical team (technical@exmet.ee).

Table 2: Minimum Column Sizes

Column Shoe	Rectangular [mm]	
	L [mm]	La [mm]
NKK-M16	230x230	104
NKK-M20	240x240	108
NKK-M24	250x250	116
NKK-M30	280x280	137
NKK-M39	360x360	177

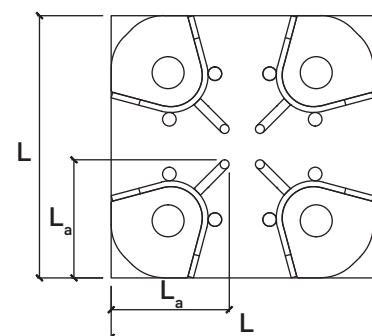


Figure 4: Minimum Column Sizes

Table 3: Minimum Column Sizes

Column Shoe	Circular [mm]	
	D [mm]	Ld [mm]
NKK-M16	124	135
NKK-M20	130	145
NKK-M24	140	150
NKK-M30	169	175
NKK-M39	221	225

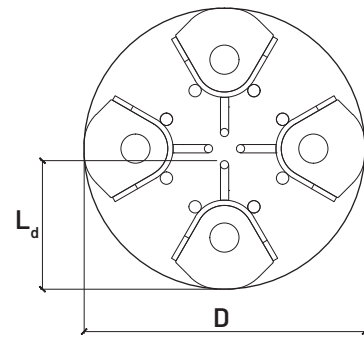


Figure 5: Minimum Column Sizes

NKK Column shoes can be used in concrete grade C30/37 to C70/85. The strength of the grout must be at least equal to or higher than the concrete grade used. Capacities mentioned in Table 8 and Table 9 can be achieved if supplementary reinforcement as per Table 12 is provided.

1.2.3 Concrete Cover

Please refer to Fig 6, 7 and Table 4 for information on concrete cover of primary bars for column shoes placed on the corner and in the middle.

Table 4: Concrete Cover for Main Bar of Column Shoe

Column Shoe	Middle Concrete Cover, C_x [mm]	Corner Concrete Cover, C_y [mm]
NKK-M16	73	45
NKK-M20	76	45
NKK-M24	82	45
NKK-M30	89	45
NKK-M39	109	45

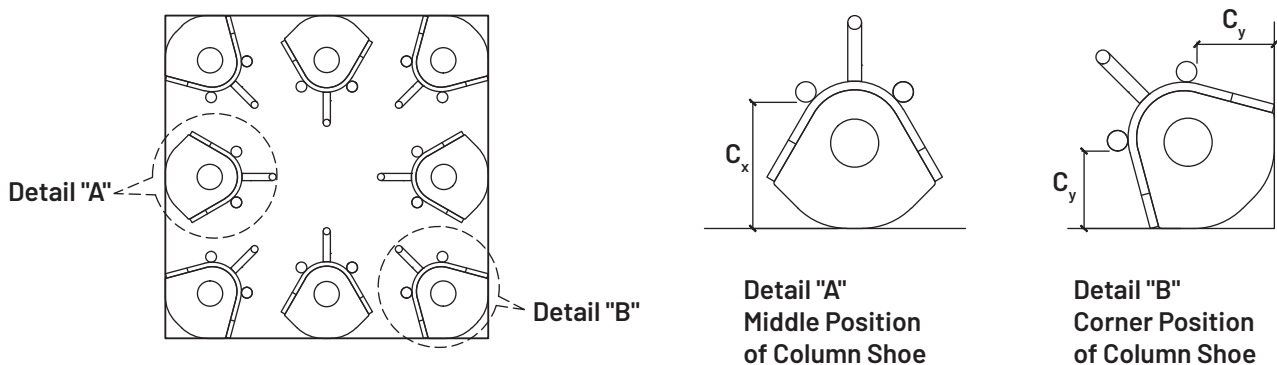


Figure 6: Concrete Cover for Main Bar of Column Shoe

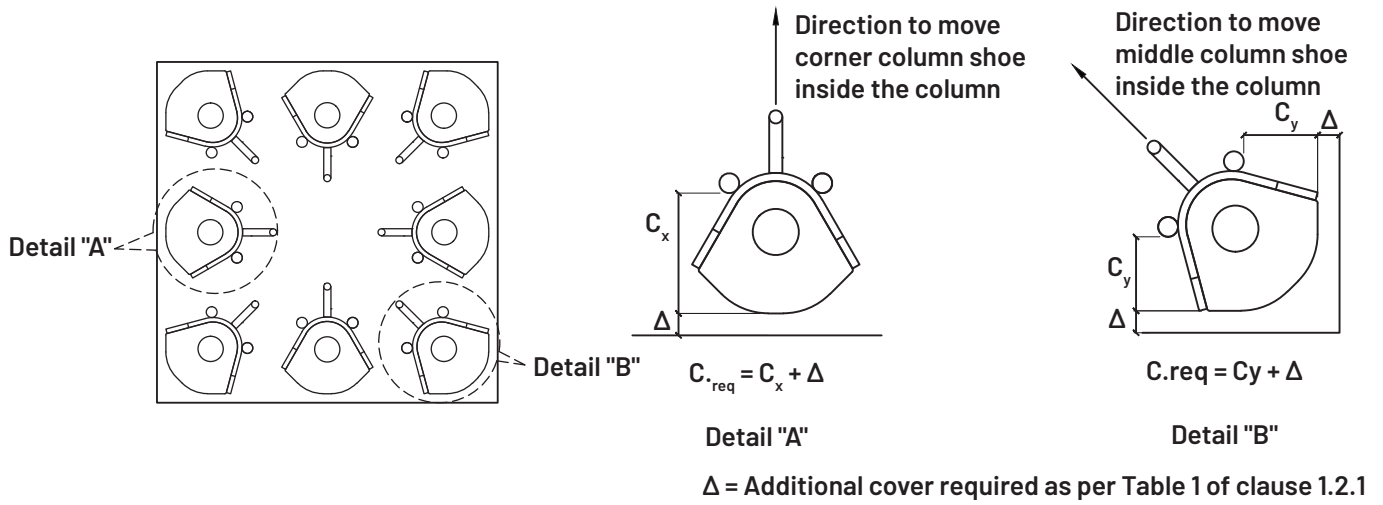


Figure 7: Required Concrete Cover for Main Bar of Column Shoe

In case a greater concrete cover is required, it can be achieved by moving the column shoes inside. It is to be noted that the position of Anchor Bolts must be changed to match the position of the column shoes.

Note: Exmet offers custom made casting blocks to suit your installation requirements.

1.3 PRODUCT DIMENSIONS

1.3.1 Structural Part Details

Table 5: Column Shoe Dimensions

Column Shoe	NKK-M16	NKK-M20	NKK-M24	NKK-M30	NKK-M39
H [mm]	597	820	1185	1390	1910
L1 [mm]	124	130	140	169	221
L2 [mm]	104	108	116	137	177
L3 [mm]	50	50	50	50	60
Ød1 [mm]	28	31	35	40	55
Ød2 [mm]	12	16	16	20	25
Ød3 [mm]	8	10	12	16	20
tp [mm]	15	20	30	45	50
Weight [kg]	2.3	4.2	6.7	12.2	26.7
Colour	Yellow	Blue	Grey	Green	Orange

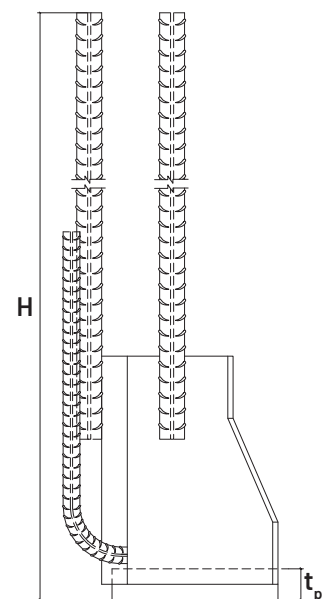
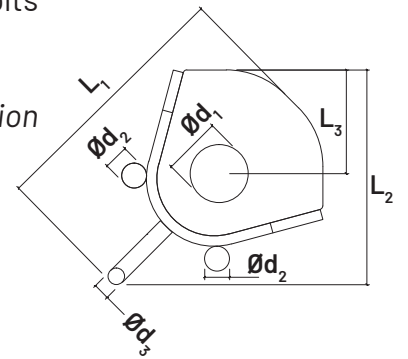


Figure 8: Dimensions

1.4 MATERIALS

Column Shoes are manufactured with the following materials which are shown below:

Table 6: Materials

Component	Material	Standard
Ribbed Bars	B500B	SFS 1300
Bottom, Side Plate	S355J2 + N	EN 10025-2

1.5. MARKINGS, MANUFACTURING & QUALITY CONTROL

1.5.1 Markings

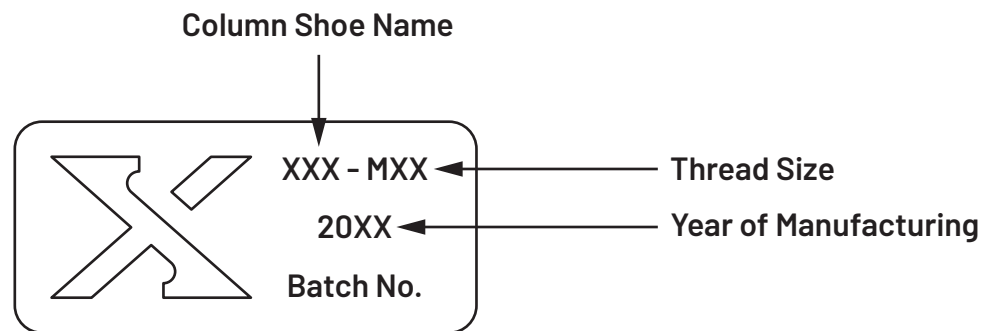


Figure 9: Marking

1.5.2 Manufacturing Method

Table 7: Materials

Rebars	Mechanically Cut
Plates	Flame Cut, Laser or Plasma Cut
Welding (Class C)	Robot Welding or Hand Welding (MAG)

1.5.3 Quality Control

Quality Control is in accordance with EN 1090-2.

2. RESISTANCES

Column shoes are designed as per the following standards.

- EN 1991-1-5
- EN 1992-1-1
- EN 1993-1-1

The tensile resistance of the Column shoes is governed by the tension capacity of NKP Anchor Bolts. The columns with column shoes should not be loaded with complete loading conditions unless the base has been grouted and the same hardens. The grade of grout to be used should be equal to higher than that of the column.

Table 8: Design values for Tensile Resistances

Column Shoe	N_{Rd} [kN]
NKK-M16	62.17
NKK-M20	97.02
NKK-M24	139.79
NKK-M30	222.16
NKK-M39	386.50

Following calculations are used to calculate Tensile resistance (N_{Rd}):

$$N_{Rd} = \frac{0.9f_{uk} * A}{\gamma_{Ms}} \quad \gamma_{Ms} = 1.25 \quad f_{uk} = 550 \text{ MPa}$$

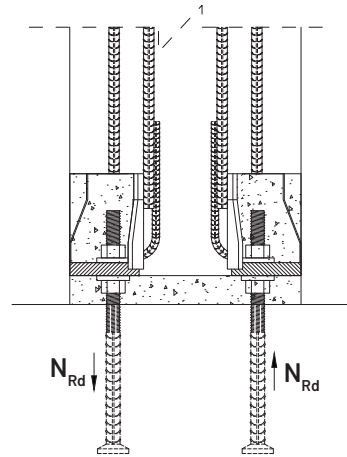
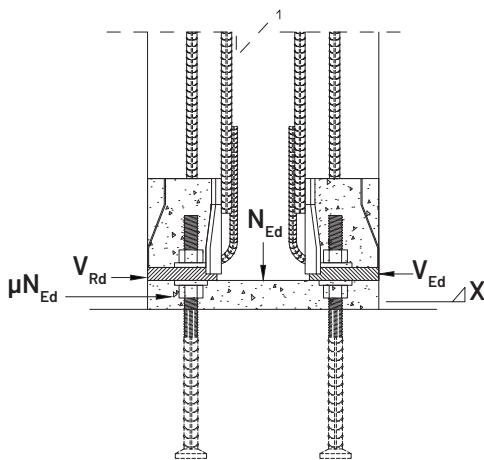


Figure 10: Tensile Resistances

Table 9: Design values for Shear Resistances at erection stage

Column Shoe	V_{Rd} [kN]
NKK-M16	4.47
NKK-M20	8.16
NKK-M24	12.83
NKK-M30	22.62
NKK-M39	43.46



Active shoe for shear transfer

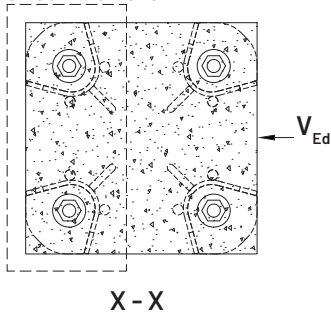


Figure 11: Shear Resistances

The design value of the shear force for a single column shoe on the active side, see Figure 11, is calculated from

$$V_{Rd} = V_{Rk} / \gamma_{Ms}$$

$$V_{Rk} = \alpha_M * M_{Rk} / l_a$$

$$M_{Rk} = M_{Rk}^0 (1 - N_{Ed} / N_{Rd}); [N_{Ed} = 0, \text{ shear only}]$$

$$M_{Rk}^0 = 1.2 W_{ef} * f_{uk}$$

$$W_{ef} = \pi * d^3 / 32$$

$$\alpha_M = 2.0$$

Table 10: Design values for Shear and Tensile Resistances at the final stage

Column Shoe	V_{Rd} [kN]	Thread Area [mm ²]
NKK-M16	20.10	157
NKK-M20	31.36	245
NKK-M24	45.18	352
NKK-M30	71.81	561
NKK-M39	124.93	976

Formulas for final stage Shear resistance:

$$F_{1.vb.Rd} = \alpha_v \cdot f_{bolt.u} \cdot A_{bolt} / \gamma_{M2}$$

$$F_{2.vb.Rd} = \alpha_b \cdot f_{ub} \cdot A_{bolt} / \gamma_{M2}$$

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

$$f_{bolt.u} = 550 \text{ N/mm}^2$$

$$f_{ub} = 640 \text{ N/mm}^2$$

$$\gamma_{M2} = 1.25$$

$$\alpha_v = 0.5$$

For design stage, following criteria is to be followed

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

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

$$\frac{V_{Ed}}{V_{Rd}} + \frac{N_{Ed}}{1.4 \cdot N_{Rd}} \leq 1$$

Where N_{Ed} and V_{Ed} are the applied loads acting together.

2.1 FIRE RESISTANCES

The fire resistances of columns are to be designed according to EN 1992-1-2. Based on the criterias of EN 1992-1-2 and for the concrete covers mentioned in the table 4 of clause 1.2.3., fire resistance of R90 to R120 can be achieved. If the fire resistance of the connection is still insufficient, the concrete cover must be increased by moving the column shoes deeper into the column.

Concrete cover is defined according to standard EN 1922-1-1

3. REINFORCEMENT

Table 12: Concrete Covers

Column Shoe	(A) U-Stirrup [mm]	(B) U-Stirrup [mm]	(C) Stirrup [mm]	(D) Stirrup [mm]	(E) Stirrup [mm]	L_b [mm]
NKK-M16	4-T6	2-T6	2-T8	2-T8	T8	500
NKK-M20	4-T6	2-T6	2-T8	2-T8	T8	500
NKK-M24	4-T6	2-T6	3-T8	3-T8	T8	500
NKK-M30	4-T6	2-T6	3-T8	3-T8	T8	500
NKK-M39	4-T6	2-T6	3-T10	3-T10	T10	500

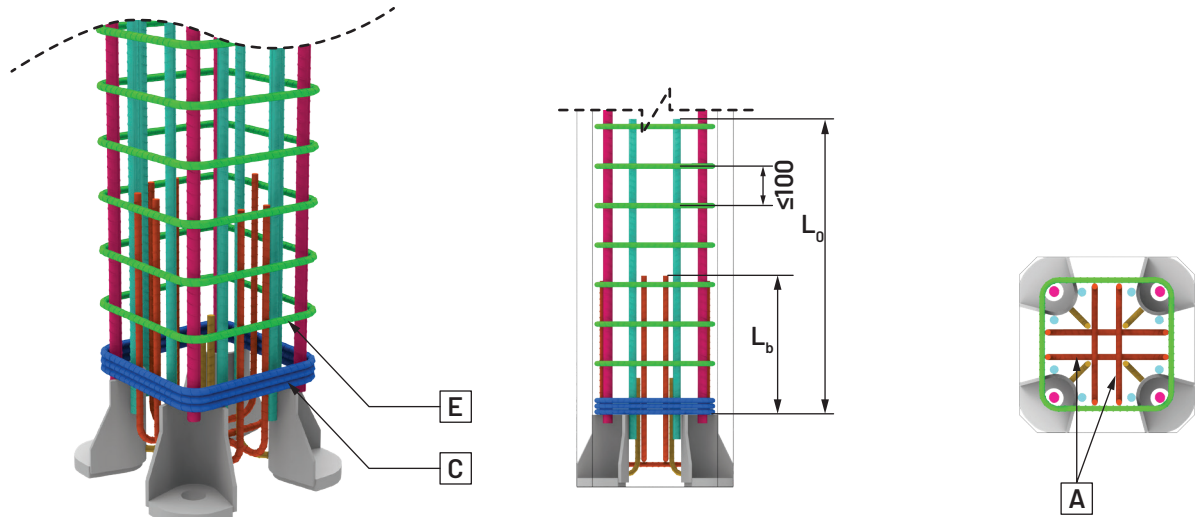


Figure 12

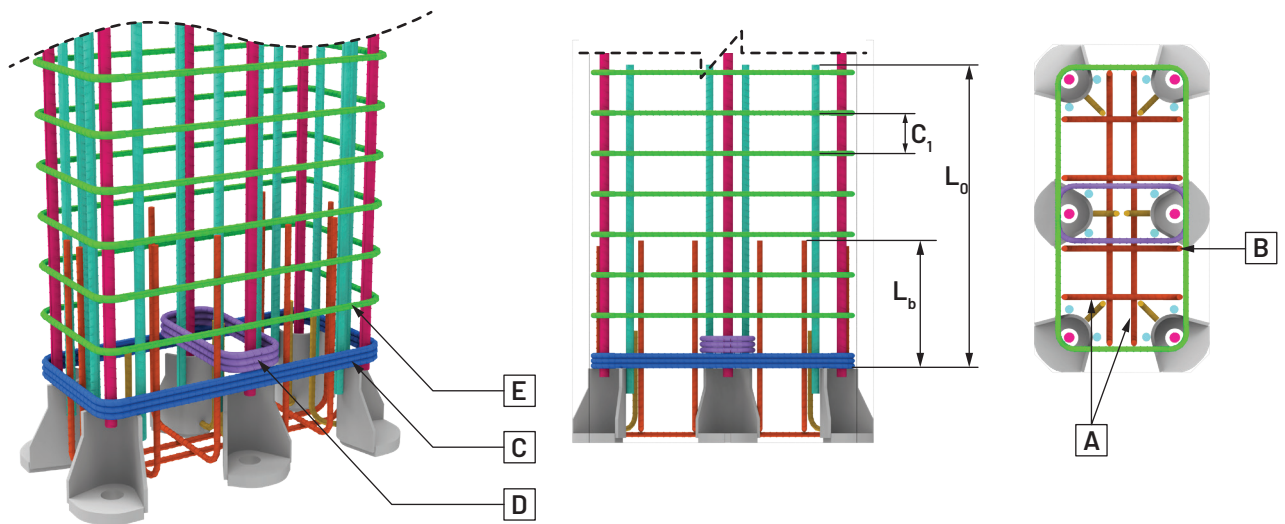


Figure 13

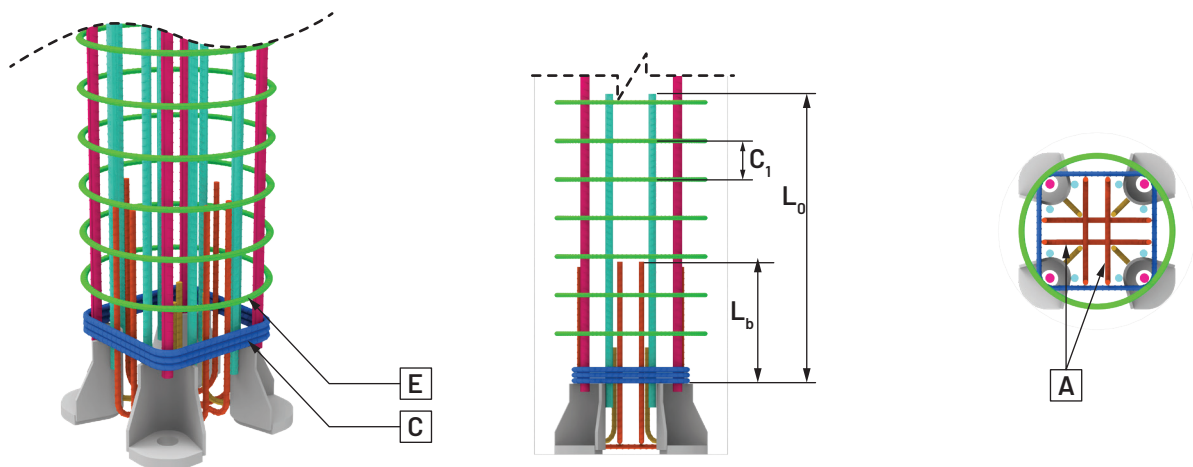


Figure 14

$c_1 \leq 100$ mm

The rebars should be evenly distributed for the complete lap length (L_0) as per EC2.

4. INSTALLATION OF COLUMN

Table 13: Minimum Tightened Torque Vale of the Nut

Column Shoe	$T_{min.}$ [mm]
NKK-M16	120
NKK-M20	150
NKK-M24	200
NKK-M30	250
NKK-M39	350

Table 14: Bolt Height and Grout Position

Column Shoe	Grout Thickness, h_g [mm]	H_0 [mm]	Tolerance for Bolt [mm]
NKK-M16	50	105	± 3
NKK-M20	50	115	± 3
NKK-M24	50	130	± 3
NKK-M30	50	150	± 3
NKK-M39	60	180	± 3

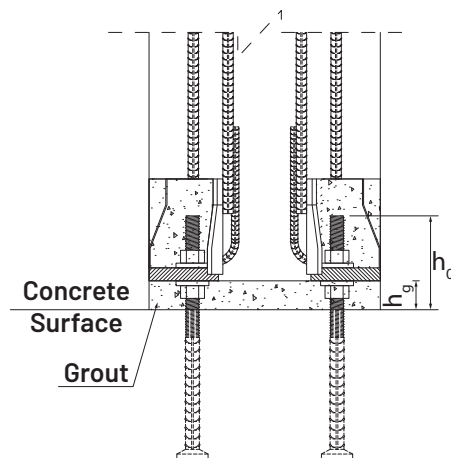


Figure 15



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