EXMET
PRECAST ACCESSORIES

REBAR ANCHOR BOLTS
(BOLTED CONNECTIONS)

TECHNICAL MANUAL

EXM-BAS-DC-1002
R7 - 02.11.2022

TABLE OF CONTENT

NKP AND SKP ANCHOR BOLTS

BENEFITS:

NKP and SKP Anchor Bolts are used for a wide range of applications where concrete or steel structures are needed to be anchored to concrete foundation or other structure. NKP and SKP anchor bolts are cast into the concrete along with the supplementary reinforcement as described in this user manual. Steel or Concrete structure is mounted on the bolts that protrude out of the base structure and fastened with the help of nuts and washers. The joint is then grouted in the final stage. NKP and SKP bolts can be headed or straight. While headed anchor bolts are used in low depth structures such as slabs and foundations, straight anchor bolts are used in long structures such as columns and walls etc. Anchor bolts are available with plain as well as Hot Dip Galvanised surface.

The key benefits and features of anchor bolts are as below:

- Simple connection by bolting members together
- Anchor system designed as per Euro Codes
- Wide range of applications in both CIS, Precast and steel construction
- Available in many different sizes to cater to a wide range of forces or loads
- Produced under strict Quality Control in compliance with EN 1090
- Readily available in Exmet Stock

1. PRODUCT DESCRIPTION & PROPERTIES

NKP and SKP anchor bolts are available in many different sizes to cater to a wide range of applications. These anchor bolts can be used in all types of building, bridges and infrastructure applications.

NKP and SKP anchor bolts have two different categories each.

1.1 NKP Anchor Bolt

NKP Anchor bolts are used in normal load conditions. NKP bolts are produced by threading one end of the rebar and keeping the other end either straight or forged to make a stud. NKP Anchor bolts come in five standard sizes i.e. M16, 20, 24, 20 and 39.

1.1.1 NKP – P Type

NKP – P type – These are anchor bolts with straight end. In these bolts, anchorage is achieved by bond between concrete and rebar. These anchors are used in long structures such as walls, columns poles etc where sufficient anchorage length is available.

1.1.2 NKP – L Type

NKP – L type – These are anchor bolts with stud end. In these bolts, anchorage is achieved by the stud head-. These anchor bolts are used in low depth structures such as foundations, slabs and beams etc.

1.2 SKP Anchor Bolt

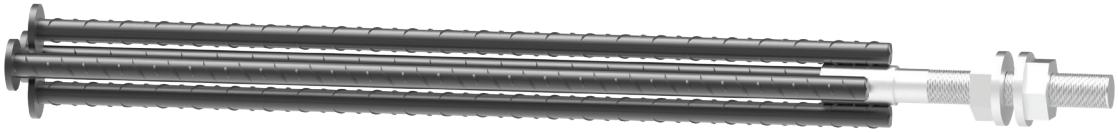
These are used in demanding situations where heavy loads have to be transferred. SKP Anchor bolts are produced by welding two to four rebars to a high strength threaded smooth bar. SKP Anchor bolts are available in six standard sizes i.e M 30, 36, 39, 45, 52 and 60.

1.2.1 SKP – P Type

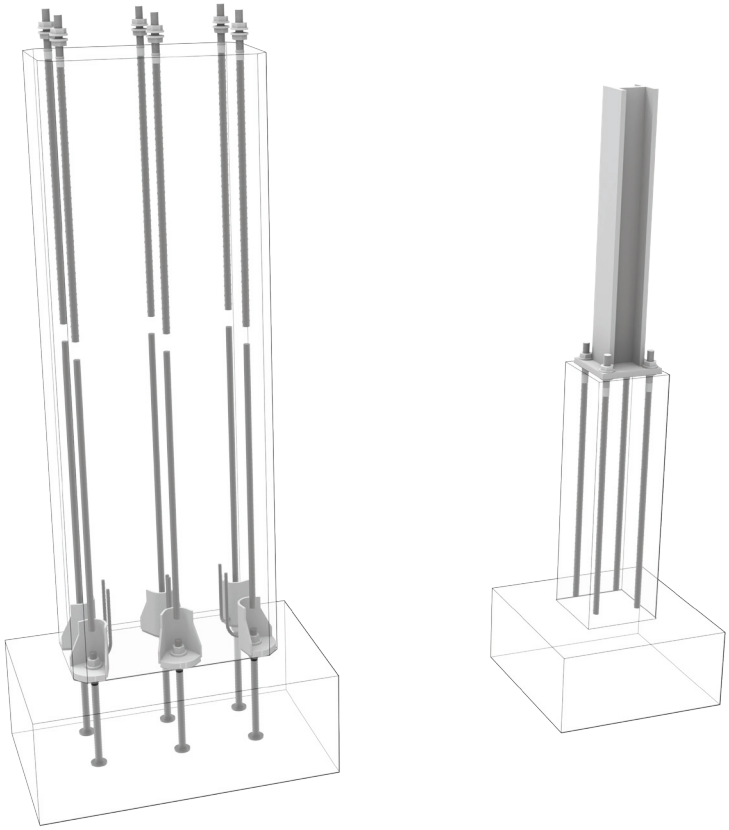
SKP – P type – These are anchor bolts with straight end. In these bolts, anchorage is achieved by bond between concrete and rebar. These anchors are used in long structures such as walls, columns poles etc where sufficient anchorage length is available.

1.2.2 SKP – L Type

SKP – L type – These are anchor bolts with stud end. In these bolts, anchorage is achieved by the stud head-. These anchor bolts are used in low depth structures such as foundations, slabs and beams etc.



Exmet's NKP and SKP Anchor bolts are designed to resist axial forces, bending moments, shear forces and combination of those. For special situations, Exmet also provides bespoke solutions. Please contact technical@exmet.ee for anchor bolts designed and produced to meet your special requirements.

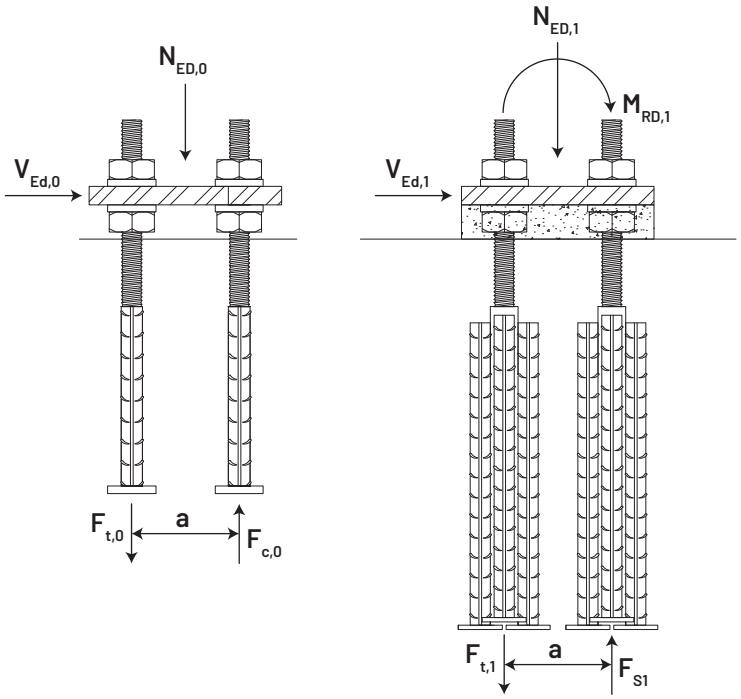


To increase the load-carrying capacity, anchors are assembled in a group. Moreover, this allows for a moment-resisting connection. For tension and shear load, the mechanical behavior is mainly influenced by

- The spacing between the anchors, and
- The possible difference in the applied forces.

2. STRUCTURAL BEHAVIOUR

Individual Anchor bolt is designed to carry Axial load and Shear force. When used in combination, Anchor Bolts can also carry bending moment. Size and number of anchor bolts are calculated based on the loads the connection is required to carry.

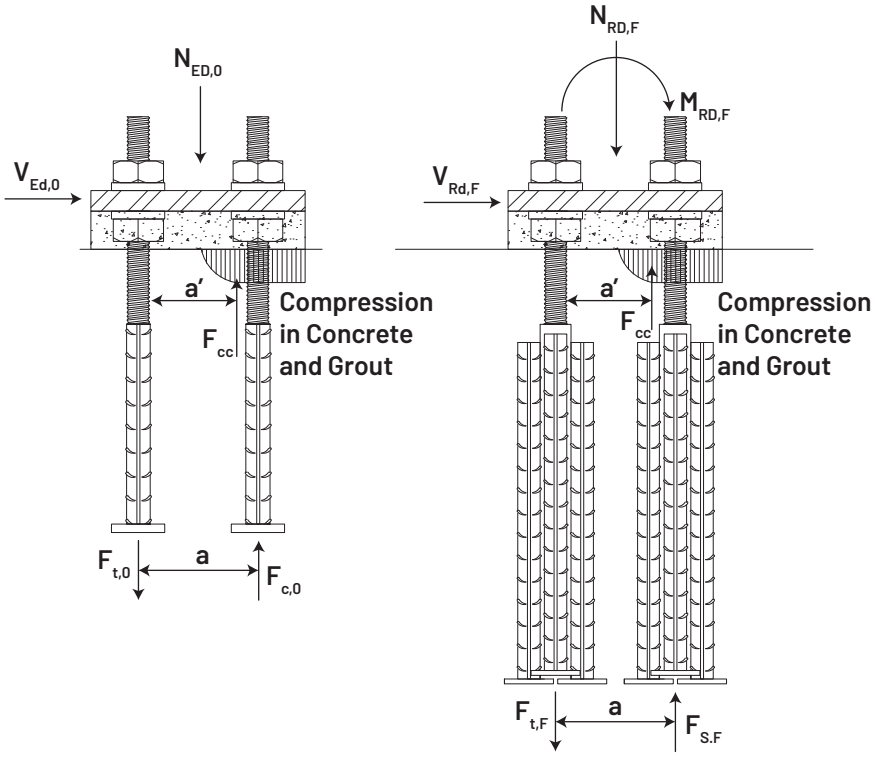


2.1 Erection Stage

At the time of erection, anchor bolts carry forces caused by self-weight of the structure and the wind loads acting on the structure. At this stage, all forces acting on the connection are carried entirely by the bolts. The joint is grouted with non shrink grout and allowed to reach its strength before the joint is loaded.

2.2 Final Stage

In the final stage, after the non shrink grout reaches the designed strength, the whole assembly behaves as a monolithic reinforced concrete structure. Shear Forces and compression are transferred to the base structure by grout. The grout should at-least have the compressive strength at-least equal to that of concrete members connected using the bolts.



2.3 Application Conditions

Anchor bolts are designed only for static loads. Anchor bolts are designed for all climate conditions whether it is hot, cold, or dry condition. For design by the Eurocode, the lowest operating temperature is calculated from SFS-EN 1991-1-5. For use in special cases, please contact Exmet's technical team at technical@exmet.ee.

2.4 Environmental Conditions

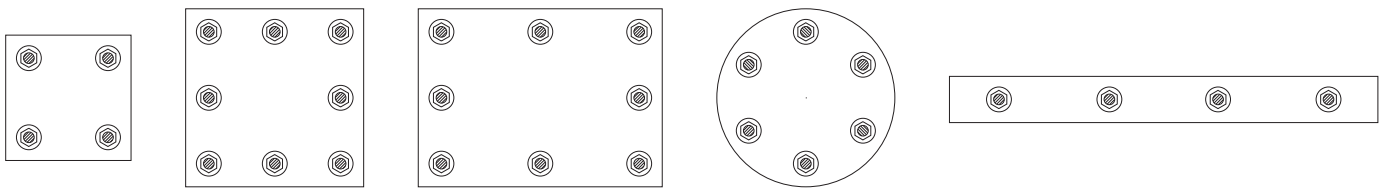
Sufficient cover to anchor bolts must be provided for resistance against corrosion. Alternatively, Exmet offers anchor bolts in two surface coating options: Hot-Dip Galvanization and anti-corrosion paints. Other methods such as onsite painting can also be used as an alternative. Please contact Exmet's technical team at technical@exmet.ee for more corrosion protection options.

Table 1. Concrete Cover for Anchor Bolt for Different Exposure

Exposed Class	Concrete Cover According to EN-1992-1-1 (Δ)	Concrete Cover of Anchor Bolts 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 galvanized if placed at edge
XC1	35	35	No Surface treatment if placed inwards Hot-dip galvanized if placed at edge
XC1	35	35	No Surface treatment if placed inwards Hot-dip galvanized if placed at edge
XC4	40	40	Hot-dip galvanized
XD1 / XS1	45	45	Hot-dip galvanized
XD2 / XS2	50	50	Hot-dip galvanized
XD3 / XS3	55	55	Hot-dip galvanized

2.5 Arrangement of Anchor Bolts

Anchor bolts are arranged in a symmetrical manner in the base structure. The arrangement must also align with the reinforcement as well as the attachments in the structure to be mounted such as column shoes and wall shoes. Some of the commonly used arrangements are shown below:



While arranging the anchor bolts, the minimum values as described in table below must be followed. Attention has to be paid to punching resistance under the stud while calculating the thickness of the base structure and reinforcement.

Table 2. Positioning of NKP - L Type Anchor Bolt

Normal Capacity Anchor Bolt	h_{min} [mm]	h_{ef} [mm]	c_{nom} [mm]	c [mm]	s [mm]	k [mm]
NKP – M16	270	169	85	50	80	10
NKP – M20	330	227	85	70	100	12
NKP – M24	395	290	85	70	100	13
NKP – M30	445	340	85	100	130	15
NKP – M39	610	508	85	130	150	18

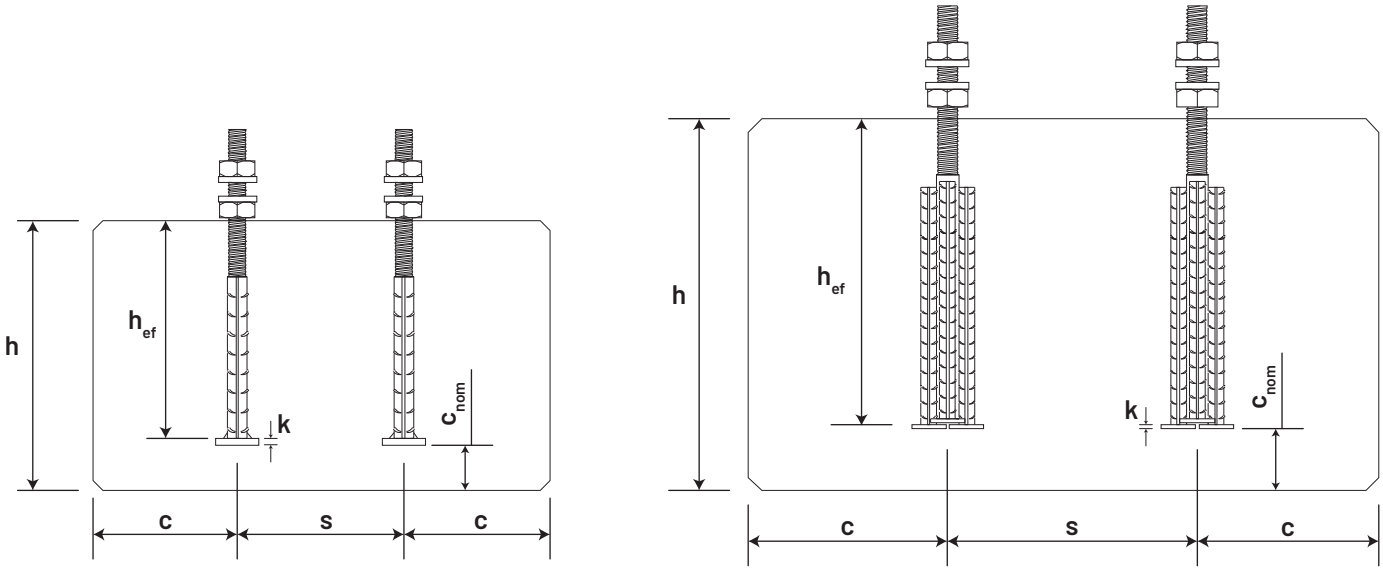


Table 3. Positioning of SKP -L Type High Capacity Anchor Bolt

High Capacity Anchor Bolt	h_{min} [mm]	h_{ef} [mm]	c_{nom} [mm]	c [mm]	s [mm]	k [mm]
SKP – M30	600	505	35	120	130	13
SKP – M36	655	562	35	140	160	12
SKP – M39	755	680	35	150	180	13
SKP – M45	865	764	35	160	200	13
SKP – M52	990	892	35	180	280	15
SKP – M60	1155	1057	35	180	280	15

3. PRODUCT DIMENSIONS

3.1 Structural Parts Details

Table 4. NKP - L Type Anchor Bolt

Normal Capacity Anchor Bolt	H [mm]	h [mm]	h1 [mm]	Øds [mm]	Ødh [mm]	Colour
NKP - L - M16	280	140	140	16	36	Yellow
NKP - L - M20	350	140	210	20	46	Blue
NKP - L - M24	430	170	260	25	55	Grey
NKP - L - M30	500	190	310	32	70	Green
NKP - L - M39	700	200	500	40	90	Orange

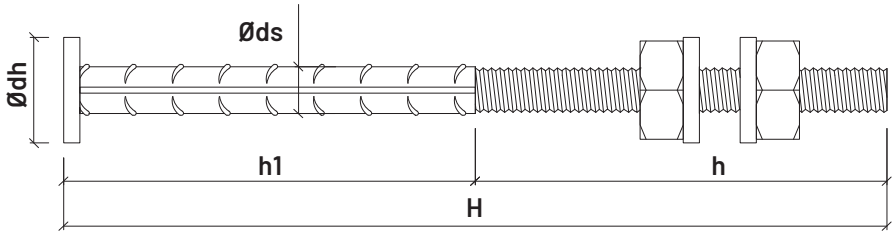


Table 5. NKP - P Type Anchor Bolt

Normal Capacity Anchor Bolt	H [mm]	h [mm]	Øds [mm]	Colour
NKP - P - M16	810	140	16	Yellow
NKP - P - M20	960	140	20	Blue
NKP - P - M24	1160	170	25	Grey
NKP - P - M30	1460	190	32	Green
NKP - P - M39	2000	200	40	Orange

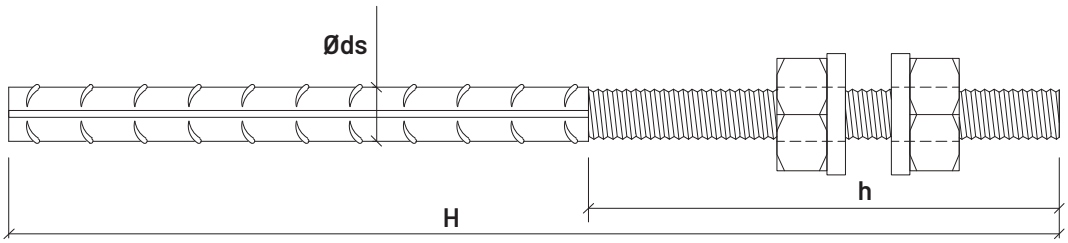


Table 6. SKP - L Type High Capacity Anchor Bolt

High Capacity Anchor Bolt	H [mm]	h [mm]	Øds [mm]	Ødh [mm]	t_h [mm]	Colour
SKP - L - M30	670	190	2 - 25	55	13	Black
SKP - L - M36	740	190	4 - 20	46	12	Red
SKP - L - M39	880	200	3 - 25	55	12	Brown
SKP - L - M45	990	220	4 - 25	55	12	Purple
SKP - L - M52	1140	250	4 - 32	70	5	White
SKP - L - M60	1330	310	4 - 32	70	15	Pink

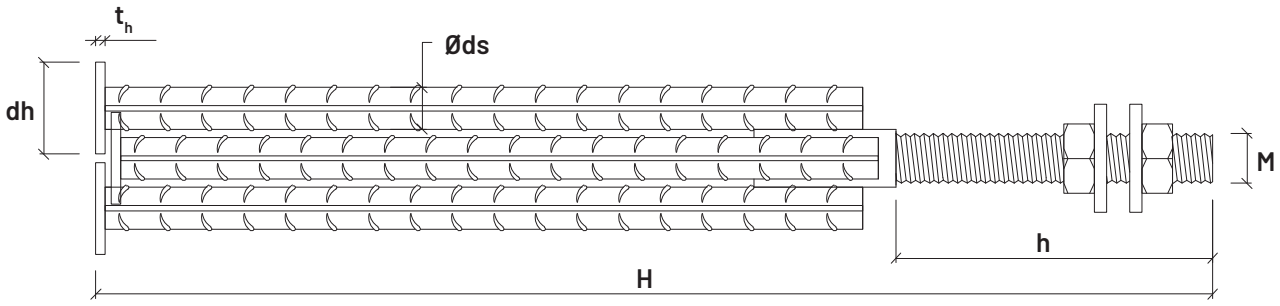
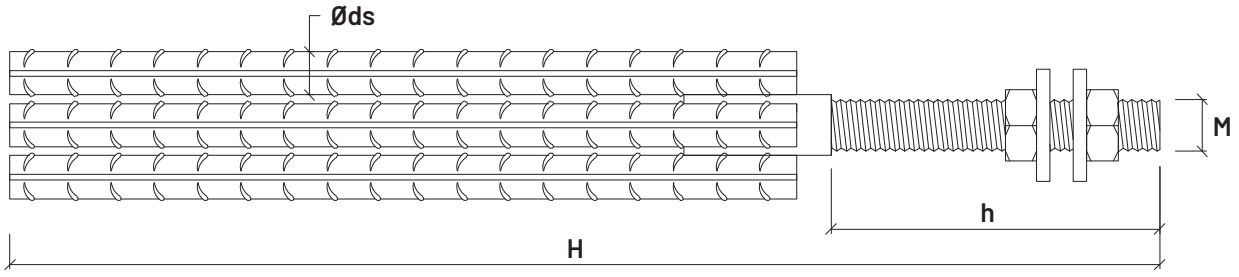


Table 7. SKP - P Type High Capacity Anchor Bolt

High Capacity Anchor Bolt	H [mm]	h [mm]	Øds [mm]	Colour
SKP - L - M30	1705	190	2 - 25	Black
SKP - L - M36	1370	190	4 - 20	Red
SKP - L - M39	1710	200	3 - 25	Brown
SKP - L - M45	1720	220	4 - 25	Purple
SKP - L - M52	1860	250	4 - 32	White
SKP - L - M60	2390	310	4 - 32	Pink



3.2 Materials

Anchor Bolts are manufactured with the following materials which are shown below:

Table 8. Materials

Component	Material	Material Type	Standard
Ribbed Bars	B500B	Electro-Zinced	EN 10080
Washers	S355J2 + N	Electro-Zinced	EN 10025-2
Nuts	Grade 8	Medium Carbon Steel	ISO 898-1
Nuts	Grade 10	Medium Carbon Steel	ISO 898-2
Bottom Stud (for welded type)	S355J2 + N	Electro-Zinced	EN 10025-2

Imacro M (EN 10027) fyk ≥ 700 MPa
fuk ≥ 800 MPa

Rebars (SFS 1300/EN 10080) fyk = 500 MPa
fuk = 550 MPa

3.3 MARKINGS, MANUFACTURING METHOD & TOLERANCES AND QUALITY CONTROL

3.3.1 Markings

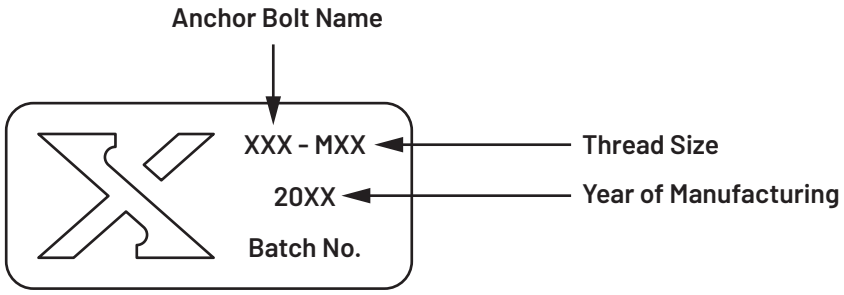


Table 9: Manufacturing Method

High Strength Bars (Imacro M)	Mechanically Cut
Rebars	Mechanically Cut
Welding (Class C)	Robot Welding or Hand Welding (MAG)

3.3.2 Manufacturing Tolerances

Table 10: Manufacturing tolerances are provided as given below:

Bolt Length	± 10
Thread Length	+ 5, -0

3.3.3 Quality Control

Quality Control is in accordance with EN 1090-2.

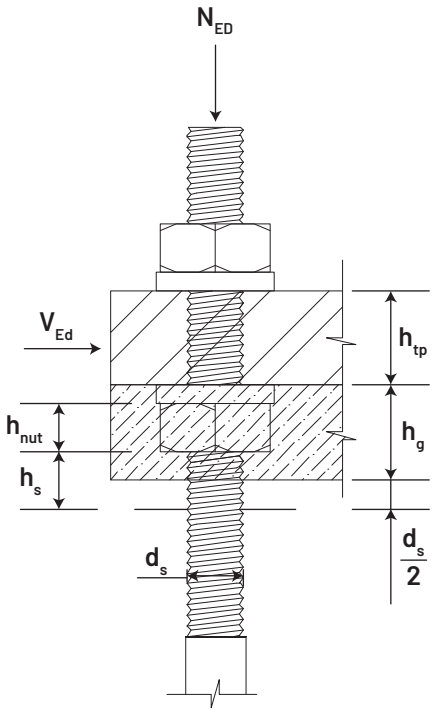
4. RESISTANCES

4.1 Tensile, Compressive and Shear Resistances

The resistances of NKP and SKP Anchor bolts are calculated according to the following standards:

- CEN/TS EN 1992-4:2018
- EN 1992-1-1:2004
- EN 1993-1-8:2005

d_s = diameter of stress area in thread
h_g = Grout thickness
h_{tp} = Plate thickness
h_{nut} = thickness of nut
h_s = Equal span of anchor bolt
= $h_g - h_{nut} + d_s / 2$



The resistance provided by the anchor bolts depends upon the anchor bolt steel, concrete strength and anchorage. If Anchor bolt's resistances cannot be transferred due to concrete failure, supplementary reinforcement to carry the forces must be provided.

Table 11. Design values for Shear and Tensile Resistances for NKP Type Anchor Bolt at Erection Stage:

Anchor Bolt	$N_{Rd,0}$ [kN]	$V_{Rd,0}$ [kN]
NKP L/P - M16	62.17	4.47
NKP L/P - M20	97.02	8.16
NKP L/P - M24	139.79	12.83
NKP L/P - M30	222.16	22.62
NKP L/P - M39	386.50	43.46

Table 12. Design values for Shear and Tensile Resistances for NKP Type Anchor Bolt at the Final Stage:

Anchor Bolt	N_{Rd} [kN]	V_{Rd} [kN]	Area [mm²]	Lever Arm l_s [mm]
NKP L/P - M16	62.17	20.10	157	64.57
NKP L/P - M20	97.02	31.36	245	68.83
NKP L/P - M24	139.79	45.18	352	75.60
NKP L/P - M30	222.16	71.81	561	85.86
NKP L/P - M39	386.50	124.93	976	102.63

Table 13. Design values for Shear and Tensile Resistances for SKP Type High Capacity Anchor Bolt at Erection Stage:

Anchor Bolt	$N_{Rd,0}$ [kN]	$V_{Rd,0}$ [kN]
SKP L/P - M30	299.20	34.48
SKP L/P - M36	435.73	52.43
SKP L/P - M39	520.53	61.45
SKP L/P - M45	696.53	88.53
SKP L/P - M52	937.60	124.03
SKP L/P - M60	1259.73	174.53

Table 14. Design values for Shear and Tensile Resistances for SKP Type High Capacity Anchor Bolt at the Final Stage:

Anchor Bolt	N_{Rd} [kN]	V_{Rd} [kN]	Area [mm^2]	Lever Arm l_s [mm]
SKP L/P - M30	299.20	71.23	561	83.50
SKP L/P - M36	435.73	103.74	817	96.50
SKP L/P - M39	520.53	123.93	976	107.50
SKP L/P - M45	696.53	165.83	1306	115.50
SKP L/P - M52	937.60	223.22	1758	128.75
SKP L/P - M60	1259.73	299.92	2362	142.50

The following checks are carried out for Base bolts if NKP Type Anchor Bolt is used:

Table 15. Design check for Tensile:

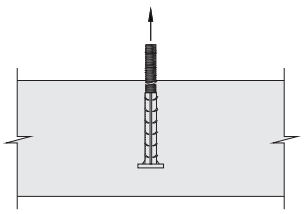
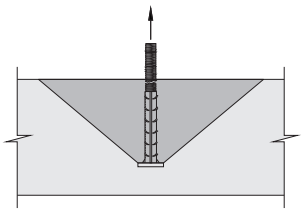
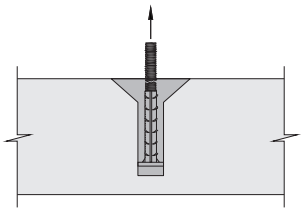
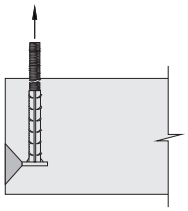
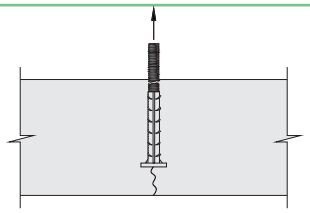
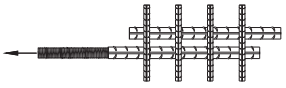
Check Failure	Anchor Bolt (NKP-L Type)	Anchor Bolt (NKP- P Type)	Figure
Steel Strength	Required	Required	
Concrete Cone Failure	Required	Not Required	
Pull-Out Failure	Required	Not Required	
Blow-Out Failure	Required	Not Required	
Concrete Splitting Failure	Required	Not Required	
Splicing Length	Required	Not Required	

Table 16. Design check for Compression:

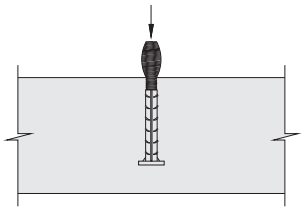
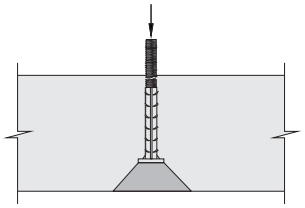
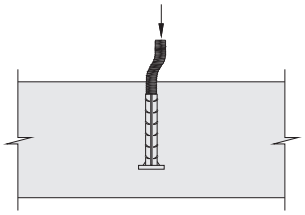
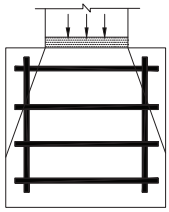
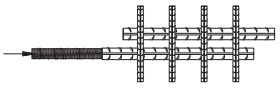
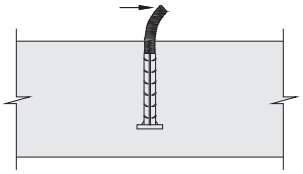
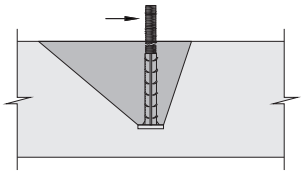
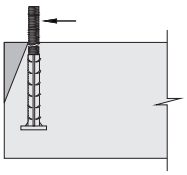
Check Failure	Anchor Bolt (NKP-L Type)	Anchor Bolt (NKP- P Type)	Figure
Steel Strength	Required	Required	
Punching Strength Under Anchor Head	Required	Not Required	
Buckling Strength	Required	Required	
Partially Loaded Area	Required (for base structure at final stage)	Required (for base structure at final stage)	
Splicing Length	Not Required	Required	

Table 17. Design check for Shear:

Check Failure	Anchor Bolt (NKP-L Type)	Anchor Bolt (NKP- P Type)	Figure
Steel Strength with Lever Arm	Required	Required	
Concrete Pry-Out Failure	Required	Not Required	
Concrete Edge Failure	Required	Required	

The following checks are carried out for Base bolts if SKP Type High Capacity Anchor Bolt is used:

Table 18. Design check for Tensile:

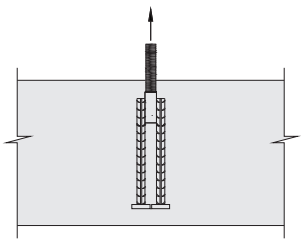
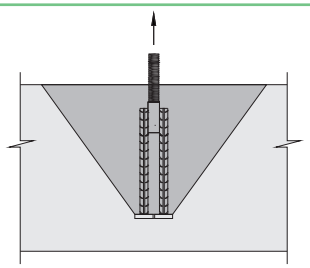
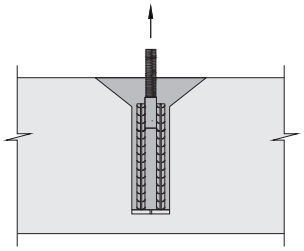
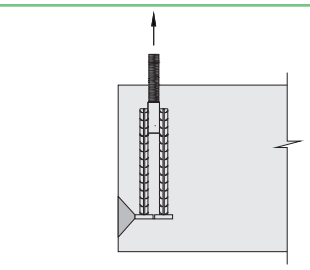
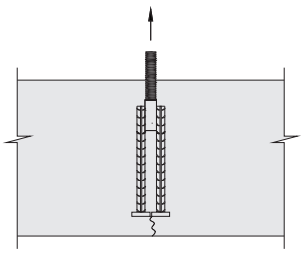
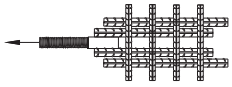
Check Failure	Anchor Bolt (SKP-L Type)	Anchor Bolt (SKP- P Type)	Figure
Steel Strength	Required	Required	
Concrete Cone Failure	Required	Not Required	
Pull-Out Failure	Required	Not Required	
Blow-Out Failure	Required	Not Required	
Concrete Splitting Failure	Required	Not Required	
Splicing Length	Not Required	Required	

Table 19. Design check for Compression:

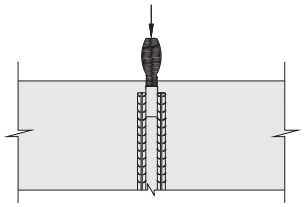
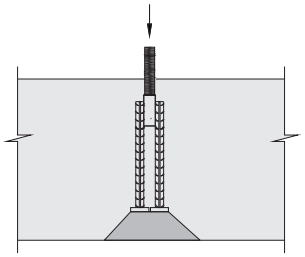
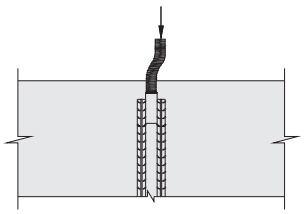
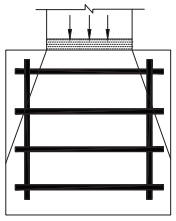
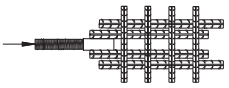
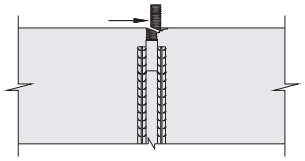
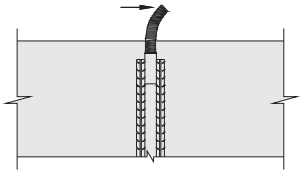
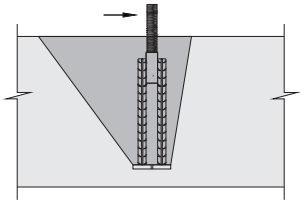
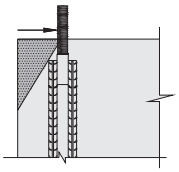
Check Failure	Anchor Bolt (SKP-L Type)	Anchor Bolt (SKP- P Type)	Figure
Steel Strength	Required	Required	
Punching Strength Under Anchor Head	Required	Not Required	
Buckling Strength	Required	Required	
Partially Loaded Area	Required (for base structure at final stage)	Required (for base structure at final stage)	
Splicing Length	Not Required	Required	

Table 20. Design check for Shear:

Check Failure	Anchor Bolt (SKP-L Type)	Anchor Bolt (SKP- P Type)	Figure
Steel Strength	Required	Required	
Steel Strength with Lever Arm	Required	Required	
Concrete Pry-Out Failure	Required	Not Required	
Concrete Edge Failure	Required	Required	

4.2 Combined Axial and Shear Load

The required verification's for steel and concrete failure are calculated separately:

For Steel Verification:

At Erection Stage:

$$\frac{N_{Ed.e}}{N_{Rd.e}} + (V_{Ed.e} + V_{Rd.e}) \leq 1 \quad \text{..... Based on EOTA TR-68, Eq. (1)}$$

At Final Stage:

$$\frac{N^1_{Ed}}{1.4N_{Rd}} + (V^1_{Ed} + V_{Rd}) \leq 1 \quad \text{..... Based on EOTA TR-68, Eq. (5)}$$

$$\frac{N^1_{Ed}}{N_{Rd}} \leq 1 \quad \text{..... Based on EOTA TR-68, Eq. (6)}$$

N^1_{Ed} = Shear resistance of bolt at Erection Stage (Absolute value)
N_{Rd} = Shear resistance of bolt at Final Stage
V^1_{Ed} = Axial resistance of bolt at Erection Stage (Absolute value)
V_{Rd} = Axial resistance of bolt at Final Stage
N^1_{Ed} = Shear load on single bolt at Erection Stage (Absolute value)
N_{Rd} = Shear load on single bolt at Final Stage
V_{Ed} = Axial load on single bolt at Erection Stage (Absolute value)
V_{Rd} = Axial load on single bolt at Final Stage

For Concrete verification (for NPK - L and SKP - L type only):

Bolts without supplementary reinforcement for tension and shear:

Either one, or both of the following conditions are to be satisfied for tensile and shear forces:

$$\left(\frac{N_{Ed}}{N_{Rd.i}}\right)^{1.5} + (V_{Ed} + V_{Rd.i})^{1.5} \leq 1 \quad \text{..... EN 1992-4:2018, Eq. 7.55}$$

$$\left(\frac{N_{Ed}}{N_{Rd.i}}\right)^{1.5} + (V_{Ed} + V_{Rd.i})^{1.5} \leq 1.2 \quad \text{..... EN 1992-4:2018, Eq. 7.56}$$

with $\frac{N_{Ed}}{N_{Rd.i}} \leq 1$ and $\frac{V_{Ed}}{V_{Rd.i}} \leq 1$ The largest value $\frac{N_{Ed}}{N_{Rd.e}}$ and $\frac{V_{Ed}}{V_{Rd.e}}$ for different failure.

Bolts with supplementary reinforcement for tension or shear:

$$\left(\frac{N_{Ed}}{N_{Rd.i}}\right)^{\frac{2}{3}} + (V_{Ed} + V_{Rd.i})^{\frac{2}{3}} \leq 1 \quad \text{..... EN 1992-4:2018, Eq. 7.57}$$

$\frac{N_{Ed}}{N_{Rd.i}}$ are resultant design tension and shear force

$\frac{V_{Ed}}{V_{Rd.i}}$ are resultant design resistance for different failuer.

Note 1: For verification's against tension and shear, N_{Ed} / $N_{Rd.i}$ for concrete cone failure mode and V_{Ed}/$V_{Rd.i}$ for concrete edge failure mode are both replaced by the corresponding values for failure of supplementary reinforcement.

Note 2: If we provided splitting supplementary reinforcement, then splitting failure shall not be considered for combined verification.

4.3 Fire Resistances:

The fire resistance occurs due to tension load. The fire resistances for bolted connection are designed according to EN 1992-1-2. If the fire resistance of the connection is insufficient, the concrete cover must be increased.

5. REINFORCEMENT

5.1 Splitting Reinforcement

Required reinforcement to resist splitting force and splitting cracks are shown in figure xx below and the quantity of reinforcement is provided in table 21, 22 respectively.

$$\Sigma A_{s,re} = k_4 \frac{\Sigma N_{ed}}{f_{yk,re} / \gamma M_{s,re}} \quad \text{..... EN 1992-4, (Eq. 7.22)}$$

ΣN_{Rd} = the sum of the design tensile force of the fasteners in tension under the design value of the actions

f_{yk} = nominal yield strength of the reinforcing steel ≤ 600 N/mm^2

$\gamma Ms_{.re}$ = partial safety factor for steel failure of supplementary reinforcement = 1.15

Placements of Reinforcement:

- Side face reinforcement (1) is provided for the critical edges
- Top face reinforcement (2) is provided for the critical edges
- Reinforcement provided for splitting should be placed inside the effective area.

Notes:

- *Spacing between the splitting reinforcement should be ≤ 150mm.*
- *Transverse edges must be considered separately. (provide splitting reinforcement in each direction)*
- *Required amount of splitting reinforcement can be taken 50% for the case when there is only one critical edge in the examined direction.*
- *Reinforcement (1) should be placed along the side face of member but should not go beyond 100mm in depth under the anchor head.*

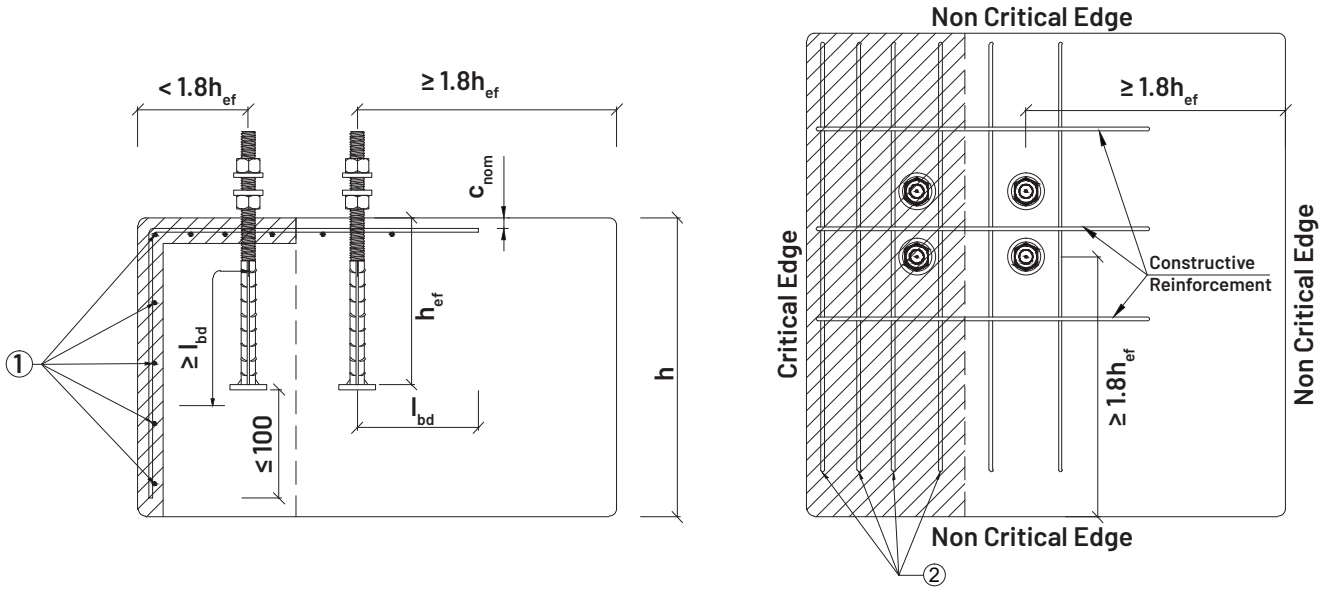


Table 21. Concrete Splitting Reinforcement for NKP - L Type

Anchor Bolt	Reinforcement, dia [mm]	A_{st} (1+2) [mm²]
NKP - L - M16	3 - 6Ø	71.5
NKP - L - M20	4 - 6Ø	111.6
NKP - L - M24	4 - 8Ø	160.1
NKP - L - M30	4 - 10Ø	255.5
NKP - L - M39	4 - 12Ø	444.5

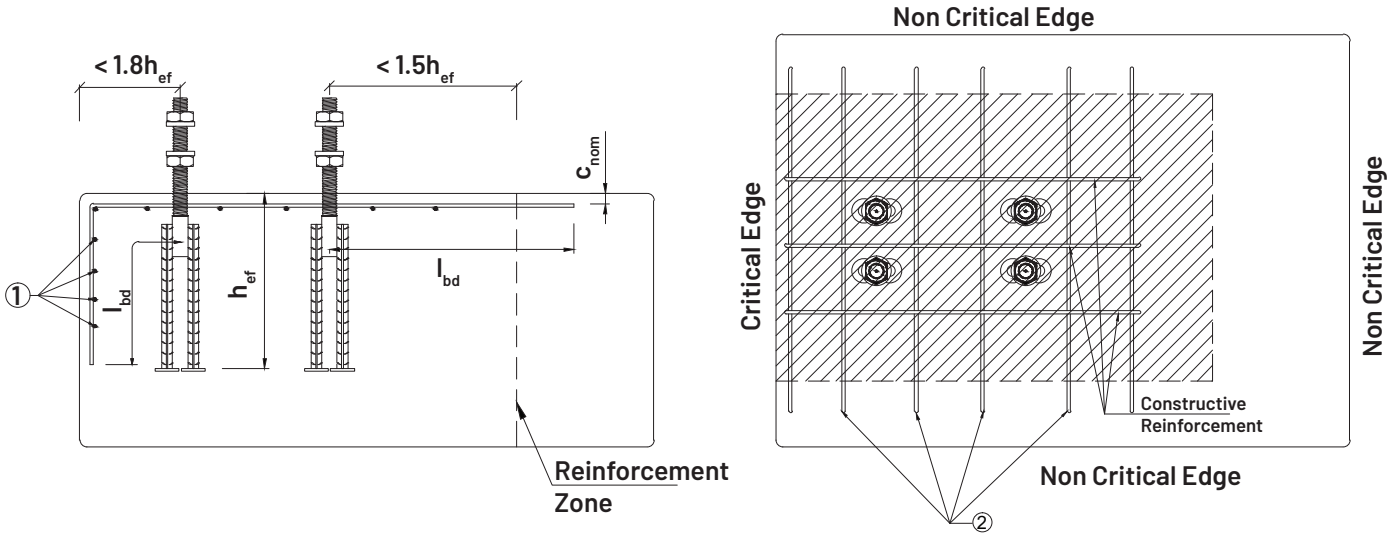
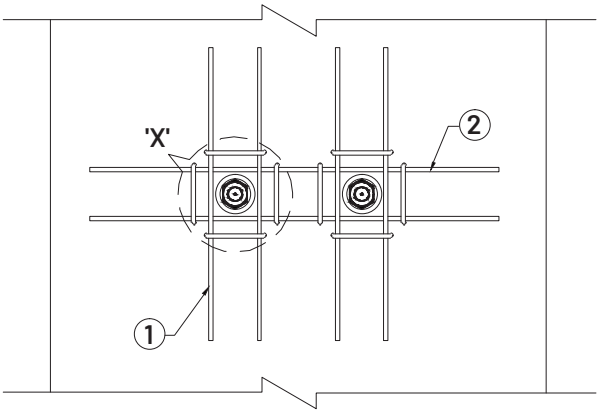


Table 22. Concrete Splitting Reinforcement for SKP - L Type for High Capacity Anchor Bar

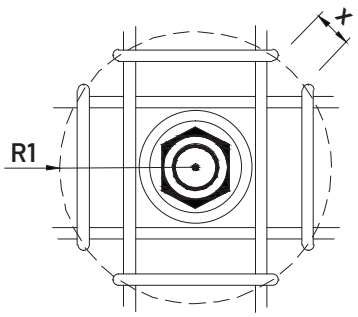
Anchor Bolt	Reinforcement, dia [mm]	A_{st} (1+2) [mm²]
SKP - L - M30	4 - 12Ø	344.08
SKP - L - M36	4 - 14Ø	501.09
SKP - L - M39	4 - 14Ø	598.61
SKP - L - M45	4 - 16Ø	801.01
SKP - L - M52	6 - 16Ø	1078.24
SKP - L - M60	8 - 16Ø	1448.69

5.2 Concrete Cone Reinforcement

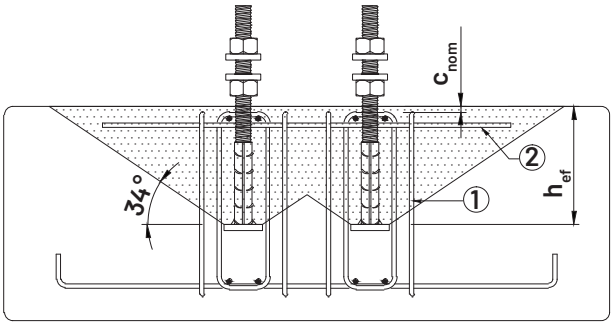
If the concrete cone resistance is exceed, required reinforcement to resist tension force should be provided as shown in figure 15,16 below and the quantity of reinforcement is provided in table 23, 24 respectively.



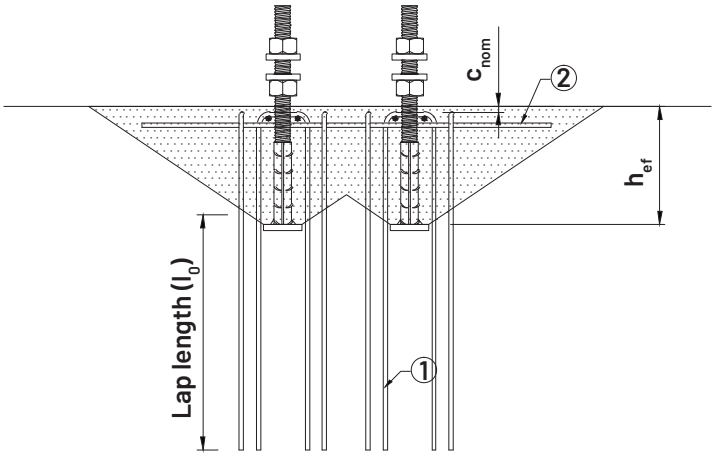
Top View



Detail 'X'



Closed Stirrups



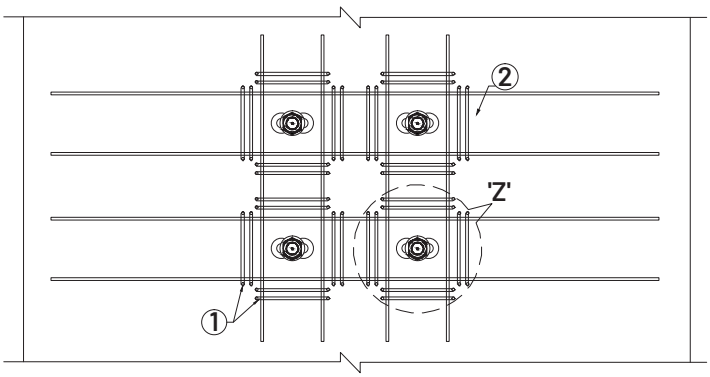
U-Stirrups

Table 23. Concrete Cone Reinforcement for NKP - L Type

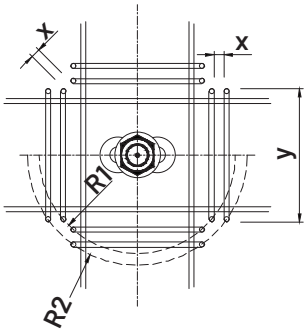
Anchor Bolt	Stirrups, (1) [mm]	Horizontal Bars, (2) (dia)	A_{st} [mm^2]	C_{nom} [mm]	h_{ef} [mm]	R1 [mm]	y (Stirrups width)
NKP - L - M16	2 - Ø8	Ø8	200	35	169	75	90
NKP - L - M20	3 - Ø8	Ø8	600	35	227	90	90
NKP - L - M24	4 - Ø8	Ø8	400	35	290	105	110
NKP - L - M30	4 - Ø10	Ø10	628	35	340	105	130
NKP - L - M39	4 - Ø12	Ø12	904	35	508	200	150

The reinforcement from table 21 can used without any further verification's if following conditions are met:

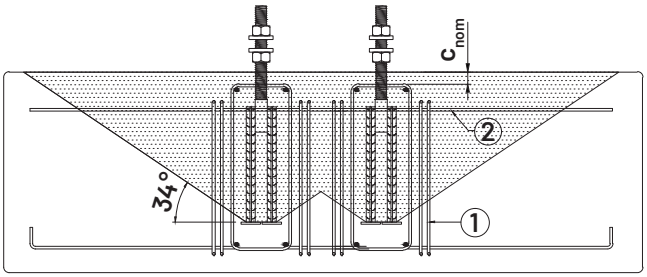
- Concrete cover ≤ 35mm
- Minimum distance between parallel stirrups > 21mm
- Concrete grade is ≥ C25/30



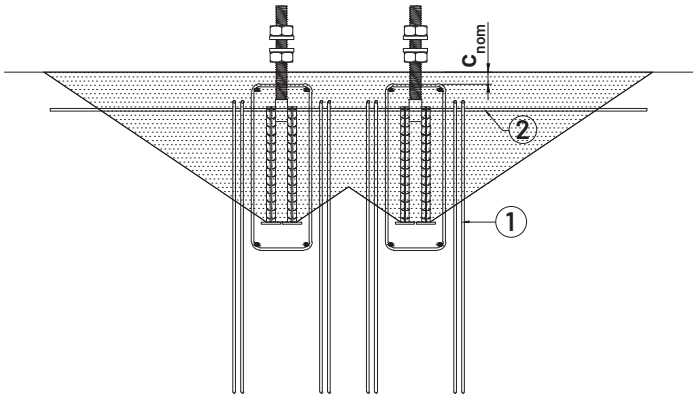
Top View



Detail 'Z'



Closed Stirrups



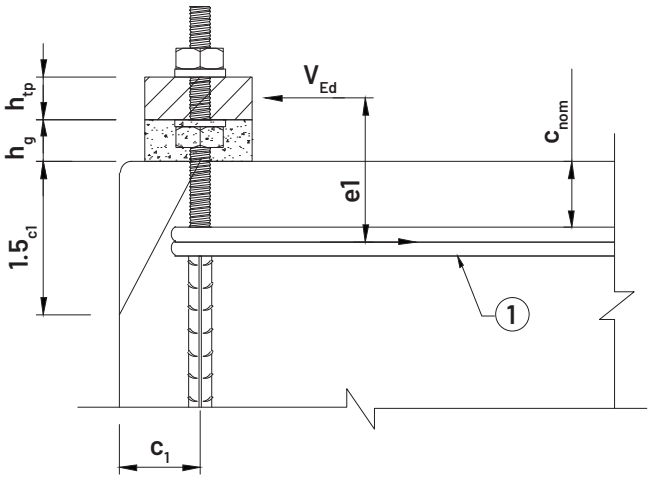
U-stirrups

Table 24. Concrete Cone Reinforcement for SKP - L Type High Capacity Anchor Bolt

Anchor Bolt	Stirrups, (1) [mm]	Horizontal Bars, (2)(dia)	A_{st} [mm^2]	C_{nom} [mm]	h_{ef} [mm]	R1 [mm]	R2 [mm]	y (Stirrups width)
SKP - L - M30	4 - Ø12	Ø8	904	35	505	170	-	180
SKP - L - M36	6 - Ø12	Ø10	1357	35	562	200	-	185
SKP - L - M39	6 - Ø12	Ø10	1357	35	680	225	-	195
SKP - L - M45	6 - Ø14	Ø12	1847	35	764	255	-	215
SKP - L - M52	6 - Ø16	Ø14	2412	35	892	285	320	255
SKP - L - M60	8 - Ø16	Ø16	3217	35	1057	300	320	255

5.3 Edge Reinforcement

If the edge resistance is exceeded, supplementary reinforcement should be provided based on the shear force applied. The quantity and arrangement of the edge reinforcement is described in fig 17,18 and table 25, 26.



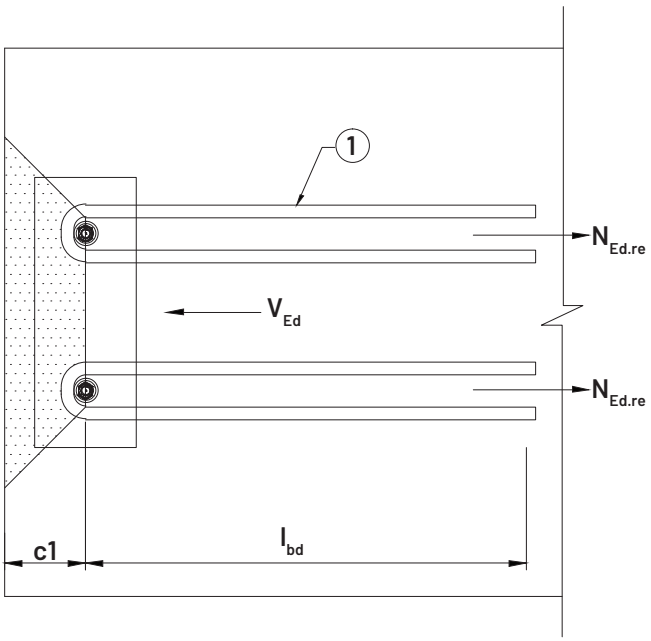


Table 25. Concrete Edge Reinforcement for NKP - L Type

Anchor Bolt	U - Bar, (1) [mm]	C1 (mm)	e1 (mm)	C_{nom} [mm]
NKP - L - M16	1 - Ø12	50	100	35
NKP - L - M20	1 - Ø14	70	105	35
NKP - L - M24	1 - Ø16	70	110	35
NKP - L - M30	2 - Ø16	100	125	35
NKP - L - M39	3 - Ø16	130	145	35

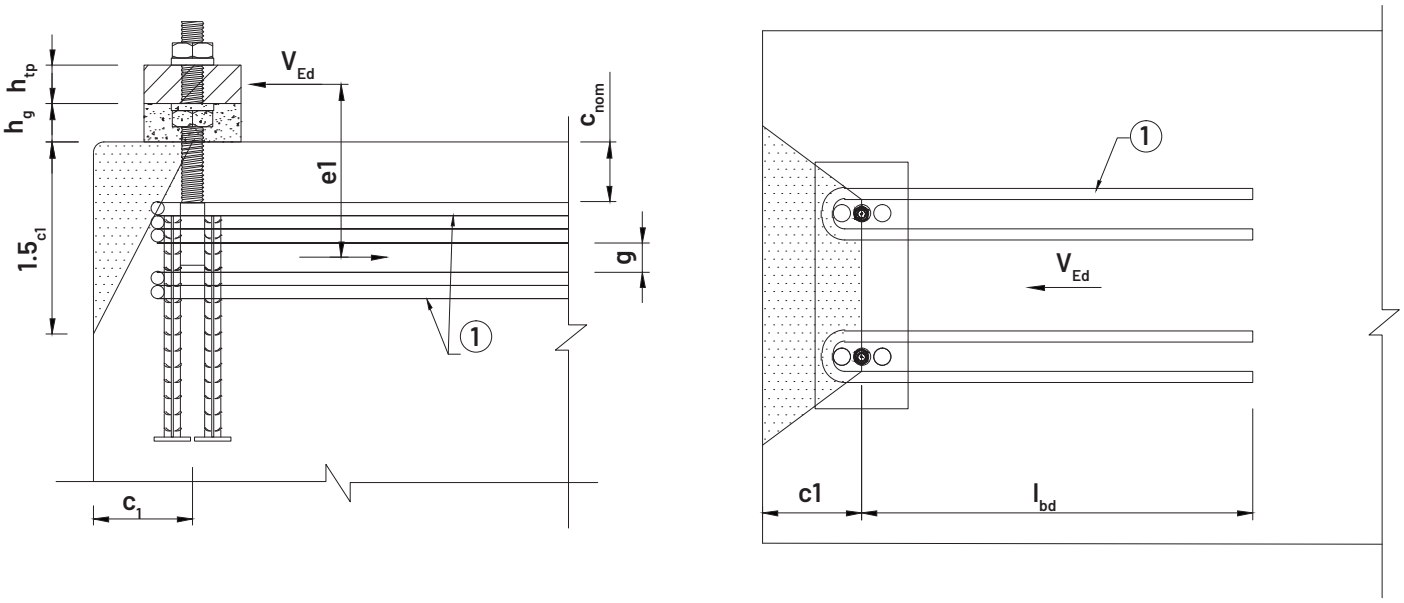


Table 26. Concrete Edge Reinforcement for SKP - L Type High Capacity Anchor Bolt

Anchor Bolt	U - Bar, (1) [mm]	C1 [mm]	e1 [mm]	a [mm]	C_{nom} [mm]	a [mm]
SKP - L - M30	4 - Ø12	120	170	-	35	-
SKP - L - M36	4 - Ø14	140	170	-	35	-
SKP - L - M39	4 - Ø14	150	180	-	35	-
SKP - L - M45	3 + 1 - Ø16	160	190	28	35	30
SKP - L - M52	3 + 2 - Ø16	180	230	28	35	30
SKP - L - M60	3 + 2 - Ø16	180	270	8	35	30

The reinforcement from table 23 and 24 can used without any further verification's if following conditions are met:

- c1 ≥ (Values from table 23)

- Reinforcement should be placed as close to the surface as possible with consideration of nominal cover. In any case, e1 should not be more than the value given in table 23.

The case mentioned above is for the most favourable condition (αv = 0°). If the applied load acts at and angle between 0° to 90°, then the force in the supplementary reinforcement can be reduced.

$$\Psi a,V = \sqrt{\frac{1}{(\cos \alpha_v)^2 + (0{,}5.\sin \alpha_v)^2}} \geq 1$$ ..... EN 1992-4:2018, Eq. 7.48

The reinforcement requirement based on the reduced force can be calculated by the coefficient above by multiplying the applied force by inverse of $\Psi_{a,V}$.

α_v = the angle between design shear load V_{Ed} and a line perpendicular to the verified edge,

$0° \leq \alpha_V \leq 90°$

5.4 Concrete Cone for Punching

Supplementary reinforcement needs to be provided under the bolt head in the event of punching resistance exceeding under the head of the bolt. The reinforcement given in the Table 27, 28 only needs to be considered if the thickness of concrete under the bolt head (h_{ud}) is less than the values given in the table below.

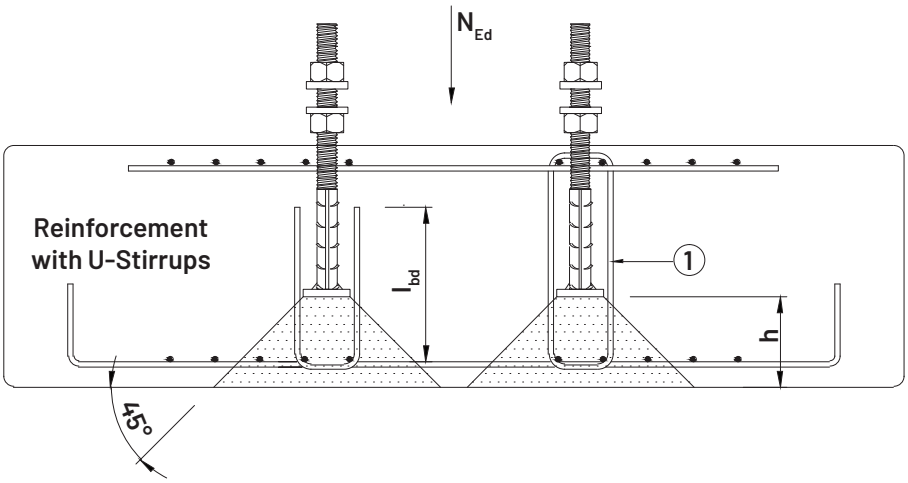


Table 27. Concrete Edge Reinforcement for NKP - L Type

Anchor Bolt	h_{ud} [mm]	A_s (mm)	Stirrups (1)
NKP - L - M16	80	100	2 - Ø6
NKP - L - M20	100	145	2 - Ø8
NKP - L - M24	115	200	2 - Ø8
NKP - L - M30	145	315	2 - Ø10
NKP - L - M39	190	530	2 - Ø14

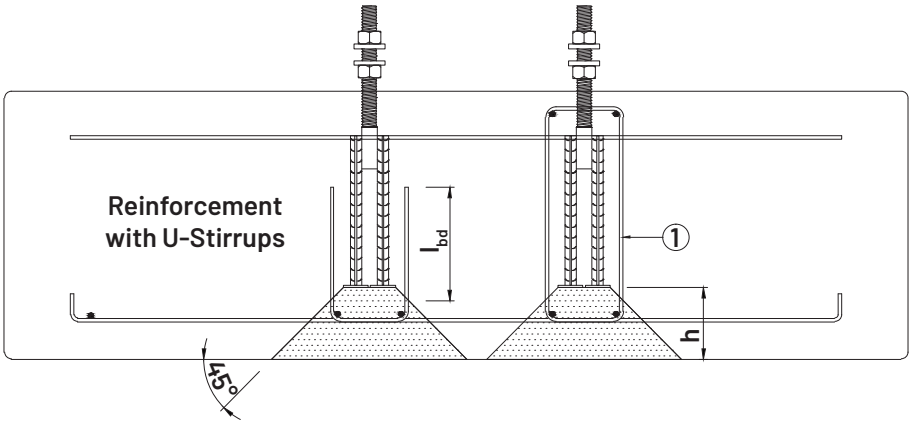
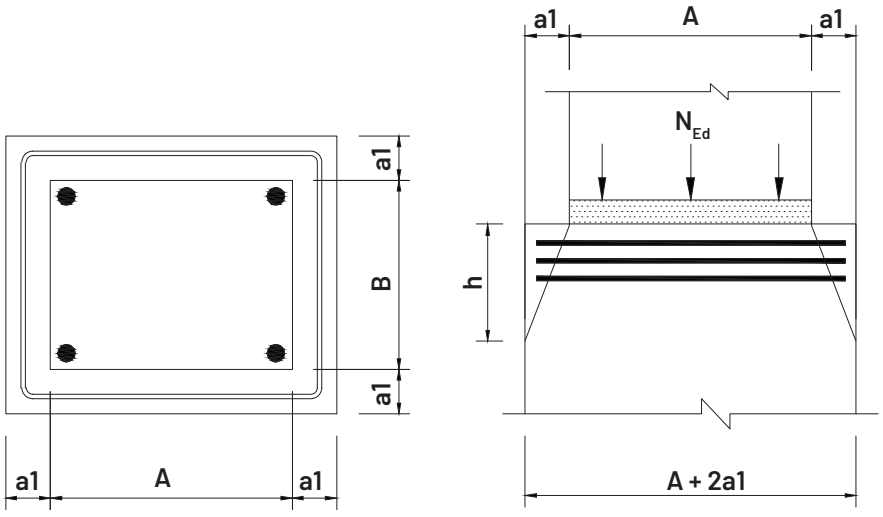


Table 28. Concrete Edge Reinforcement for SKP - L Type High Capacity Anchor Bolt

Anchor Bolt	h [mm]	A_s [mm]	Stirrups [1]
SKP - L - M30	90	201	2 - Ø8
SKP - L - M36	85	215	2 - Ø10
SKP - L - M39	75	180	2 - Ø8
SKP - L - M45	50	135	2 - Ø8
SKP - L - M52	105	385	2 - 12
SKP - L - M60	55	190	2 - Ø8

5.5 Partially Loaded Areas, Splitting Reinforcement

If the grade of concrete of the below column in a column-column connection is lower than the column above, localized crushing should be considered in the column below at connection location. The column below can be increased in size (cross-section) and additional reinforcement (distributed uniformly) be provided at the splitting edge location to prevent local crushing.



Design Example:

Concrete Column 500 x 500 (C35/45) bears on base column (C30/37), Calculate the minimum cross section and required splitting reinforcement of base structure to bears maximum compression force applied from the supported column.

The concentrated resistance force of partially loaded area:

$F_{Rd.p} = A_{c0} \cdot f_{cd.b} \cdot \sqrt{A_{c1}/A_{c0}} \leq 3.0 \cdot f_{cd.b} \cdot A_{c0}$

$F_{Rd.p}$ = Ultimate load capacity of an axial loaded column

A_{c0} = loaded area

A_{c1} = maximum design distribution area

$f_{cd.b}$ = design compressive strength of foundation / base structure (26.68 N/mm^2)

$f_{cd.c}$ = design compressive strength of column (40.0 N/mm^2)

Solution:

$A_{c0} = A \cdot B = 500x\,500 = 250000\ mm^2$

$A_{c1} = (A + 2.a_1) \cdot (B + 2.a_1) = (500 + 2.a_1) + (500 + 2.a_1) = (500 + 2.a_1)^2$

$F_{Rd.p}$ = Ultimate load capacity of an axial loaded column

$= Ac0 \cdot fcd.c = 250000 \cdot 40 = 10000\ kN$

$A \cdot B \cdot f_{cd.c} = A \cdot B \cdot f_{cd.b} \cdot \sqrt{((A + 2.a_1) \cdot (B + 2.a_1) / A \cdot B)}$

$40 = 26.68 \cdot \sqrt{((500 + 500.2a_1) \cdot (500 + 2.a_1) / 500/500)}$

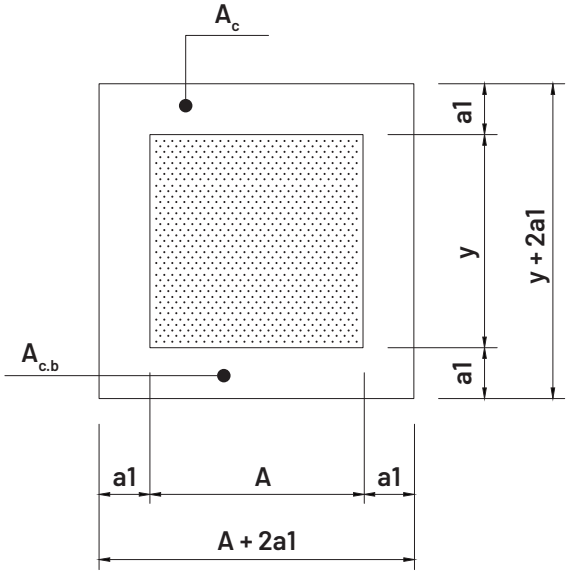
$a_1 = 125\ mm$

Minimum cross-section of base column:

$= (A + 2.a_1) \cdot (B + 2.a_1) / A \cdot B)$

$= (500 + 2 \times 125) \cdot (500 + 2 \times 125)$

$= 750\ mm \times 750\ mm$



Splitting Force

$F_{sp} = 0.25\ F_{Rdu} \cdot (1-B/B+2a_1)$

$= 0.25^* 10000 \cdot (1-500 / (500+2 \cdot 125))$

$= 833.3\ kN$

Required splitting reinforcement area

A_{sp} = F_{sp} /2.(f_{yk}/γ_s)

F_{yk} = 500 N/mm^2 (yield strength of reinforcement)

γ_s = 1.15 (partial safety factor for reinforcement)

= 833.33 / 2 /(500/1.15)

= 958.33 mm^2

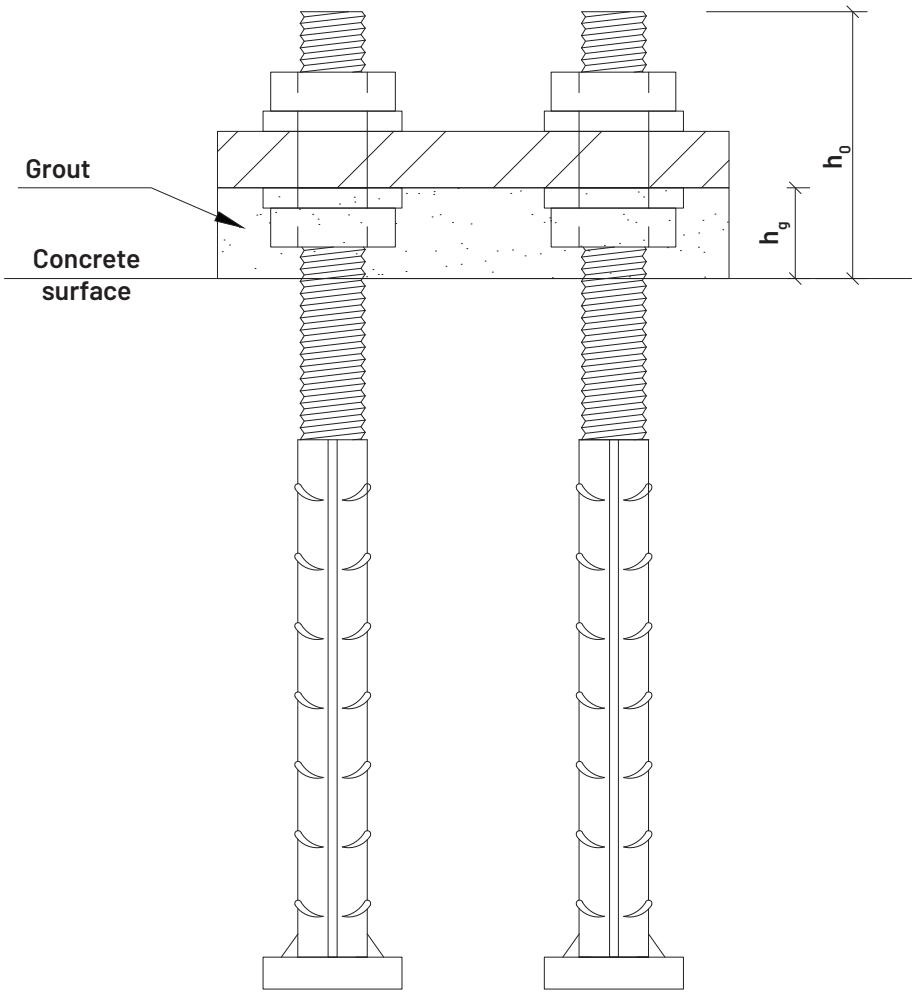
6. INSTALLATION OF COLUMN

Table 29. Minimum Tightened Torque Vale of the Nut:

Anchor Bolt	T_{min} [mm]
NKP - L - M16	120
NKP - L - M20	150
NKP - L - M24	200
NKP - L - M30	250
NKP - L - M39	350
SKP - L - M30	250
SKP - L - M36	300
SKP - L - M39	350
SKP - L - M45	400
SKP - L - M52	450
SKP - L - M60	500

Table 30. Bolt Height and Grout Position:

Anchor Bolt	Grout thickness, h_g [mm]	h_0 [mm]	Tolerance for bolt [mm]
NKP - L - M16	50	105	± 3
NKP - L - M20	50	115	± 3
NKP - L - M24	50	130	± 3
NKP - L - M30	50	150	± 3
NKP - L - M39	60	180	± 3
SKP - L - M30	50	150	± 4
SKP - L - M36	55	170	± 4
SKP - L - M39	60	190	± 4
SKP - L - M45	65	205	± 4
SKP - L - M52	70	235	± 5
SKP - L - M60	80	260	± 5



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