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ENDURA

Bolted Connections
REBAR ANCHOR BOLT EBB, ESB

TECHNICAL MANUAL

END/PALS/DC/001-

R0 - 09.06.2026

EBB and ESB Anchor Bolts

Endura's EBB and ESB rebar anchor bolts provide a cast-in-place bolted connection system for precast concrete construction. Each bolt comprises a deformed reinforcement bar with a machined threaded end, enabling connection through standard nuts and washers. The bolts are cast into the base structure - such as a foundation, a lower column, or a wall panel - using installation templates that ensure precise positioning relative to the main and supplementary reinforcement.

Once the precast element is placed over the projecting bolt group, it is fastened, aligned, and the joint grouted to achieve structural continuity. At the individual bolt level, applied connection forces are resolved into tension, compression, and shear in each bolt. At the connection level, the system of bolts, grout, and bearing surfaces collectively resists axial forces, shear forces, and bending moments - with moment resisted by a force couple across the bolt group (tension in some bolts, compression through concrete on the opposite side). Exposed threaded portions are wrapped with protective tape to prevent damage during subsequent construction activities. Both plain-finish and hot-dip galvanised variants are available to suit different exposure conditions.

The advantages of anchor bolts are as below:

- Provides moment-resisting bolted connections between structural elements - foundation to column, column to column, wall to foundation, and wall to wall.
- Eliminates the need for temporary bracing or propping on site.
- Enables rapid on-site positioning and alignment of precast elements.
- Integrates anchorage, threading, and load transfer into a single factory-manufactured component.

ENDURA

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1. PRODUCT DESCRIPTION AND PROPERTIES

EBB, ESB anchor bolts are generally used for connecting a column to its foundation. Anchor bolts are embedded into the base structure along with the primary and additional reinforcement.

1.1 EBB Anchor bolt

EBB anchor bolt are available in two types of anchor bolt EBB-S type and EBB-L type . These are normal capacity anchor bolt. These bolts are generally used in foundation, wall and other precast element.

1.1.1 EBB-S Anchor bolt

The EBB-S variant incorporates a headed anchor plate at the embedded end that transfers tensile loads into the concrete through mechanical bearing. This configuration is intended for structural members with limited depth — typically pad foundations, isolated footings, and ground slabs. The threaded portion at the top conforms to standard metric thread dimensions. Each bolt transfers tension, compression, and shear forces to the concrete.
Available sizes: M16, M20, M24, M30, M39.

1.1.2 EBB- L Anchor bolt

The EBB-L variant uses the full deformed-bar length to develop anchorage through bond with the surrounding concrete. It is designed for wall-to-wall and column-to-column connections where sufficient embedment depth is available. Each bolt transfers tension, compression, and shear forces to the concrete.
Available sizes: M16, M20, M24, M30, M39.

1.2 ESB Anchor bolt

ESB bolts employ high-strength threaded bars (Imacro M grade) and are specified where the design forces exceed the capacity of EBB bolts. They are available in a short-embedment (-S) and a long-embedment (-L) configuration.

1.2.1 ESB-S Anchor bolt

The ESB-S variant uses the same headed-anchor configuration as the EBB-S, but with larger bar diameters and high-strength threaded components for high-capacity loading conditions. Each bolt transfers tension, compression, and shear forces to the concrete.
Available sizes: M30, M36, M39, M45, M52, M60.

1.2.2 ESB-L Anchor bolt

The ESB-L variant provides full bond-length anchorage for high-capacity wall and column connections.
Each bolt transfers tension, compression, and shear forces to the concrete.
Available sizes: M30, M36, M39, M45, M52, M60. M36, M39, M45, M52, M60.

2. STRUCTURAL BEHAVIOR

Endura anchor bolts serve as the load-transfer mechanism within bolted precast connections. The applied forces on the connection - axial load, shear, and bending moment - are resolved at the bolt group level into statically equivalent tension, compression, and shear forces in each individual bolt. Bending moment on the connection is not carried by any single bolt; instead, it is resisted by a force couple - tension in the bolts on one side and compression through the concrete and grout on the other. Based on the forces applied to the group, certain bolts will be in tension while others will be in compression. The bolts are designed exclusively for quasi-static loading conditions.

2.1 Erection stage

Before the joint grout has cured, the bolt group alone resists all applied actions - principally element self-weight and wind loads during erection. Shear in this stage is resisted solely through bolt bending across the lever arm, resulting in significantly reduced capacity compared to the final condition. Individual bolts must be checked for buckling under compression if the unsupported length across the open joint is excessive. The connection must not receive loading beyond element self-weight and construction-stage wind until the grout achieves its specified design strength.

Erection Stage

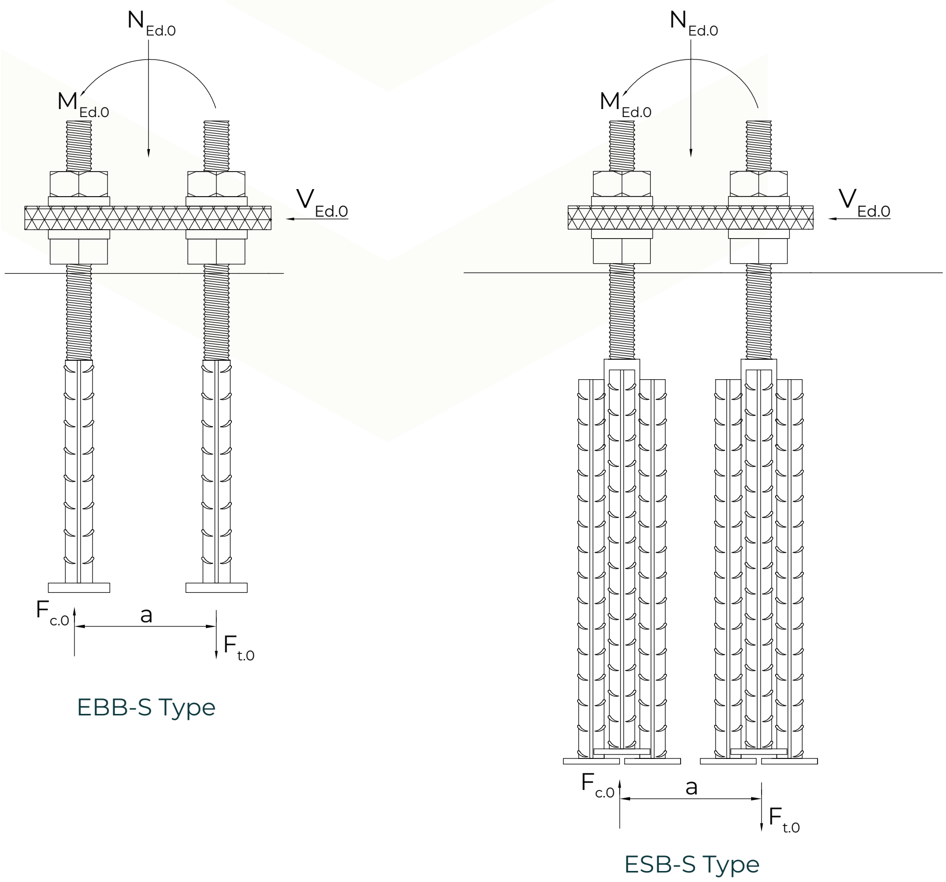


Figure – 2

2.2 Final stage

Once the joint grout has hardened to its characteristic strength, the assembly behaves as a composite reinforced concrete connection. Tensile forces are carried through the bolt steel in direct pull. Compressive forces are transmitted by direct bearing through the grout and concrete. Shear is primarily resisted by friction along the compressed face of the joint. Bending moment continues to be resolved via the force couple across the bolt group. The bolted connection will work when the concrete of foundation and grouting of gap have hardened.

Final Stage

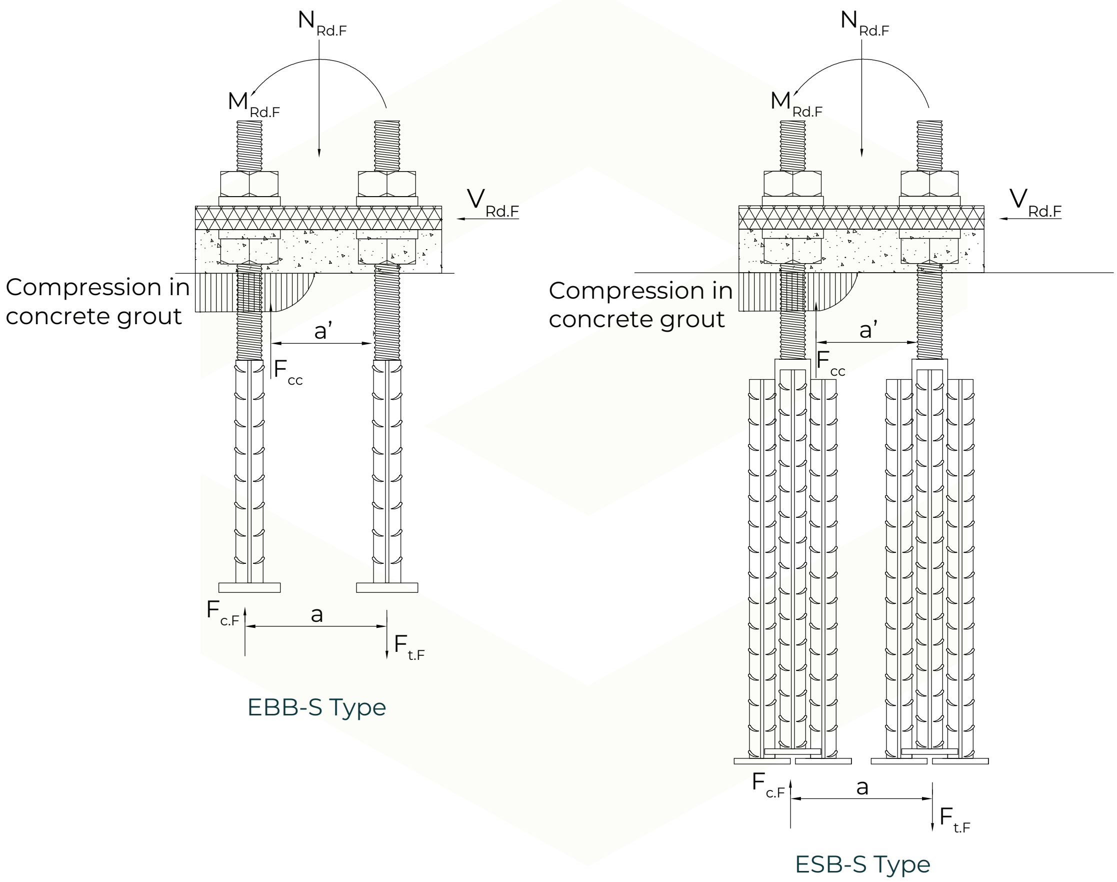


Figure – 3

2.3 Application conditions

Endura anchor bolts are designed for quasi-static loads. They are suitable for all standard climatic environments - dry, humid, cold, and hot — provided the appropriate surface treatment and concrete cover are specified.

2.4 Environmntal conditions

The primary corrosion protection for embedded bolt steel is the surrounding concrete cover. For enhanced durability, Endura offers factory-applied epoxy coating, hot-dip galvanising per EN ISO 1461, and site-applied anti-corrosion treatments as supplements.

Table 1: Concrete cover for Anchor Bolt for different exposure

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

2.5 Arrangement of Anchor bolts

Anchor bolts are arranged as per the minimum edge distance and the minimum centre-to-centre spacing of anchor bolts. Anchor bolts will be placed in a base element in that manner, and the minimum criteria will be fulfilled. Following placement of anchor bolts in the base element are as below:

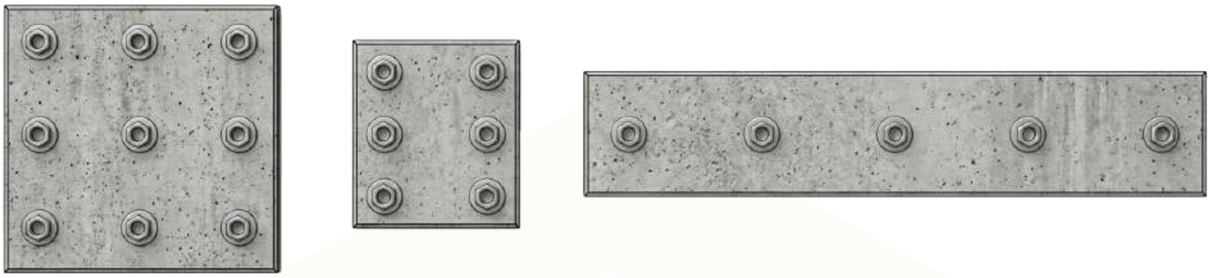


Figure – 4

Minimum edge distance and minimum center-to-center spacing of anchor bolt are shown in below table:

Table: 2 Arrangement of EBB-S TYPE Anchor Bolt see figure: 5

Anchor Bolt	h_{min} [mm]	h_{ef} [mm]	c_{nom} [mm]	c [mm]	s [mm]	k [mm]
EBB-S-M16	270	169	85	50	80	6
EBB-S-M20	330	227	85	70	100	8
EBB-S-M24	395	290	85	70	100	10
EBB-S-M30	445	340	85	100	130	10
EBB-S-M39	610	508	85	130	150	12

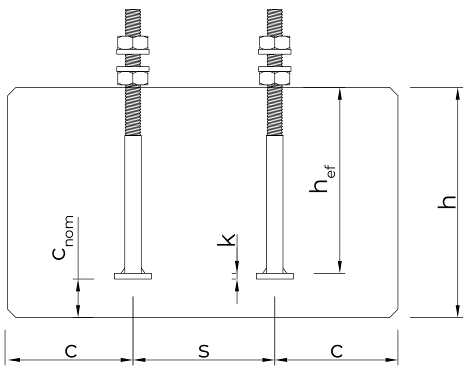


Figure – 5

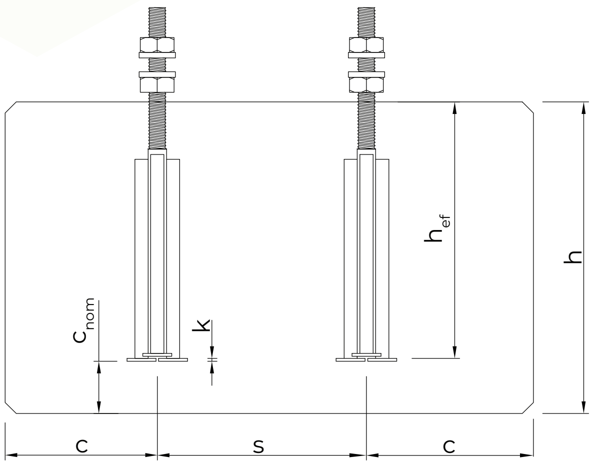


Figure – 6

Table: 3 Positioning of ESB-S High Strength Anchor bolt see figure: 6

High Strength Anchor Bolt	hmin [mm]	hef [mm]	cnom [mm]	c [mm]	s [mm]	k [mm]
ESB-S-M30	600	505	35	120	130	13
ESB-S-M36	655	562	35	140	160	12
ESB-S-M39	755	680	35	150	180	12
ESB-S-M45	865	764	35	160	200	12
ESB-S-M52	990	892	35	180	280	15
ESB-S-M60	1155	1057	35	180	280	15

2.6 Materials

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

Table: 4 Materials of Anchor Bolt

Component	Material	Material Type	Standard
Ribbed Bars	B500B Grade 60 HRB 500	Electro-Zinced	EN 10080 ASTM A706M GB 1499
Washers	S355J2 + N Grade 50 Q345	Electro-Zinced	EN 10025-2 ASTM A572M GB/T 1591
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 Grade 50 Q345	Electro-Zinced	EN 10025-2 ASTM A572M GB/T 1591

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

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

3. MANUFACTURING

3.1 Marking

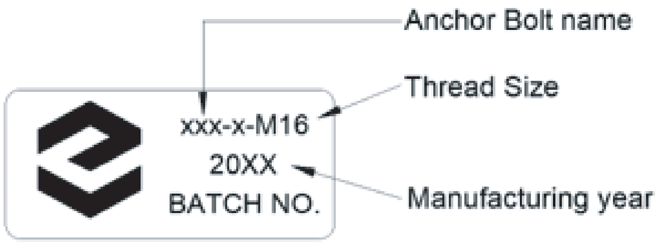


Figure – 7

3.2 Colour Scheme

Table 5. Color Scheme for Anchor bolt

Anchor Bolt	EBB-M16	EBB-M20	EBB-M24	EBB-M30	EBB-M39	ESB-M30	ESB-LM36	ESB-M39	ESB-M45	ESB-M52	ESB-M60
Colour	Yellow	Blue	Grey	Green	Orange	Black	Red	Brown	Purple	White	Pink

3.3 Manufacturing Tolerances

Table: 6 Manufacturing tolerances are provided as given below: -

Bolt Length	Thread Length
± 10	+ 5, -0

3.4 Manufacturing Method

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

3.5 Quality Control

Quality Control is in accordance with EN 1090-2.

3.6 Product Dimensions

3.6.1 EBB — Product Dimensions

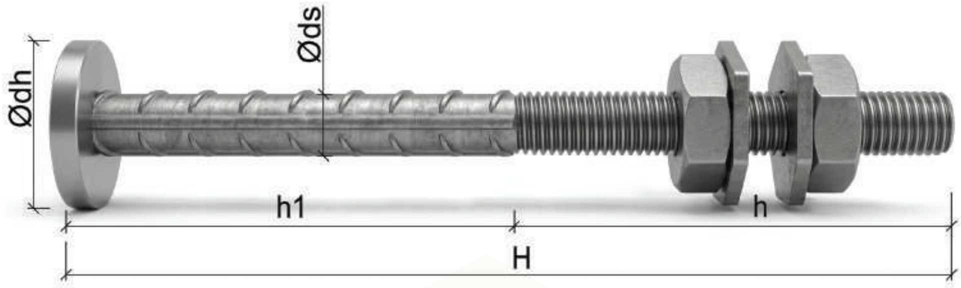


Figure - 8

Table 7. EBB-S Type - Anchor Bolt

Anchor Bolt	H [mm]	h [mm]	h1 [mm]	øds [mm]	ødh [mm]
EBB-S-M16	280	140	140	16	36
EBB-S-M20	350	140	210	20	46
EBB-S-M24	430	170	260	25	55
EBB-S-M30	500	190	310	32	70
EBB-S-M39	700	200	500	40	90

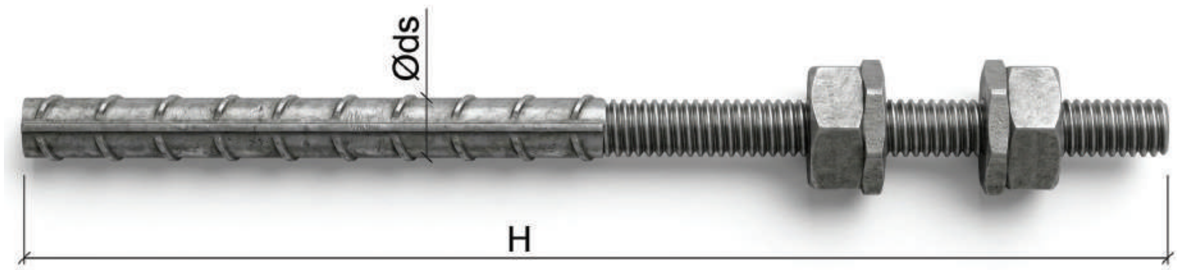


Figure - 9

Table 8. EBB-L-Type - Anchor Bolt

Anchor Bolt	H [mm]	h [mm]	øds [mm]
EBB-L-M16	810	140	16
EBB-L-M20	960	140	20
EBB-L-M24	1160	170	25
EBB-L-M30	1460	190	32
EBB-L-M39	2000	200	40

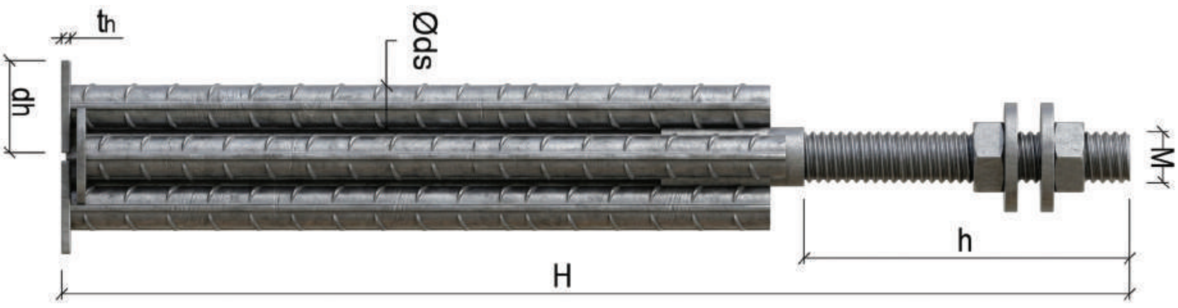


Figure - 10

Table 9. EBB-L Type - High Strength Anchor Bolt

High Strength Anchor Bolt	H [mm]	h [mm]	øds [mm]	ødh [mm]	th [mm]
ESB-S-M30	670	190	2 - 25	55	13
ESB-S-M36	740	190	4 - 20	46	12
ESB-S-M39	880	200	3 - 25	55	12
ESB-S-M45	990	220	4 - 25	55	12
ESB-S-M52	1140	250	4 - 32	70	15
ESB-S-M60	1330	310	4 - 32	70	15

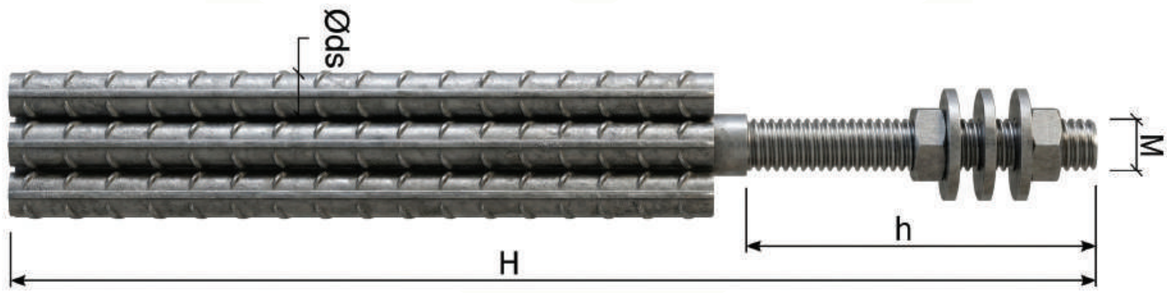


Figure - 11

Table 10. ESB-L Type - High Strength Anchor Bolt

High Strength Anchor Bolt	H [mm]	h [mm]	øds [mm]
ESB-S-M30	1705	190	2 - 25
ESB-S-M36	1370	190	4 - 20
ESB-S-M39	1710	200	3 - 25
ESB-S-M45	1720	220	4 - 25
ESB-S-M52	1860	250	4 - 32
ESB-S-M60	2390	310	4 - 32

4. RESISTANCES

4.1 Tensile, Compressive and Shear Resistances

The design calculation of EBB-S and EBB-L anchor bolt are based on European and American standard. European standards are : EN1991-1-1-2004, EN- 1992-2: 2018, EN 1993-1-8: 2005.
American Standards are : ACI 318M-19, ANSI/AISC 360-10, AWS D1.1/D1.1M 2006, IBC 2021

ds = diameter of stress area in thread

hg = Grout thickness

htp = Plate thickness

hnut = thickness of nut

hs = Equal span of anchor bolt

= hg - hnut + ds / 2

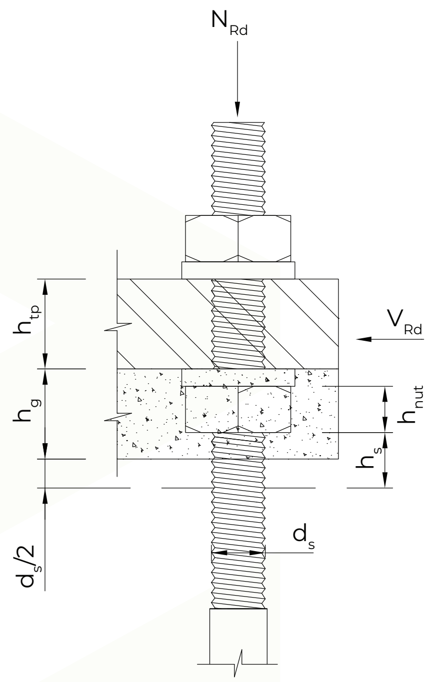


Figure - 12: Loads and parameters

The capacities are calculated is based on the standards. Supplementary reinforcement is also used to prevent failure of the bolt. The main reinforcement is calculated as per design requirements. The following design capacities are given below:

Table: 11 Design values for Shear and Tensile Resistances for EBB Anchor Bolt at erection stage:

Anchor Bolt	NRd,0 [kN]	VRd,0 [kN]
EBB-S/L -M16	62.17	5,04
EBB-S /L-M20	97.02	10,10
EBB-S/L -M24	139.79	17,99
EBB-S/L -M30	222.16	38,09
EBB-S/L -M39	386.50	73,79

Table: 12 Design values for Shear and Tensile Resistances for EBB Anchor Bolt at the final stage:

Anchor Bolt	NRd [kN]	VRd [kN]	Area [mm2]	Lever arm ls [mm]
EBB-S/L -M16	62.17	20.02	157	64.57
EBB-S /L-M20	97.02	31.23	245	68.83
EBB-S/L -M24	139.79	45.00	352	75.60
EBB-S/L -M30	222.16	71.52	561	85.86
EBB-S/L -M39	386.50	124.43	976	102.63

Table: 13 Design values for Shear and Tensile Resistances for ESB TYPE High strength Anchor Bolt at erection stage:

High Strength Anchor Bolt	NRd1 [kN]	VRd1 [kN]
ESB-S/L- M30	299.20	48,76
ESB-S/L- M36	435.73	80,07
ESB-S/L- M39	520.53	94,45
ESB-S/L- M45	696.53	138,02
ESB-S/L- M52	937.60	206,10
ESB-S/L- M60	1259.73	279,03

Table: 14 Design values for Shear and Tensile Resistances during installation for ESB TYPE High strength Anchor Bolt at final stage:

High Strength Anchor Bolt	NRd [kN]	VRd [kN]	Area [mm2]	Lever arm ls [mm]
ESB-S/L- M30	299.20	71.23	561	83.50
ESB-S/L- M36	435.73	103.74	817	96.50
ESB-S/L- M39	520.53	123.93	976	107.50
ESB-S/L- M45	696.53	165.83	1306	115.50
ESB-S/L- M52	937.60	223.22	1758	128.75
ESB-S/L- M60	1259.73	299.92	2362	142.50

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

Table: 15 Design check for Tension:

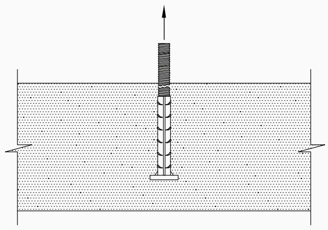
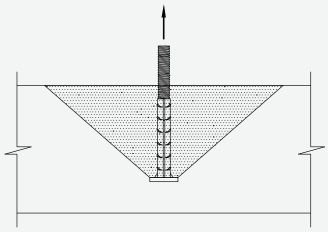
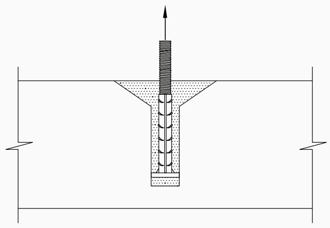
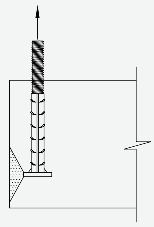
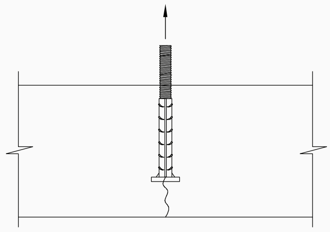
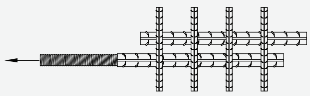
Check Failure	Anchor Bolt (EBB-S Type)	Figure
Steel Strength	Required	
Concrete cone failure	Required	
Pull-out failure	Required	
Blow-out Failure	Required	
Concrete splitting failure	Required	
Splicing Length	Required	

Table: 16 Design check for Compression :

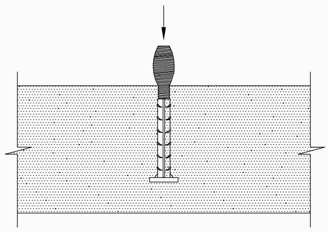
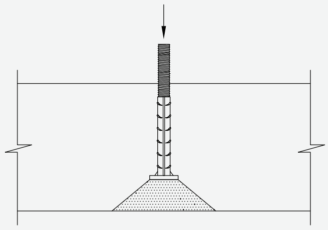
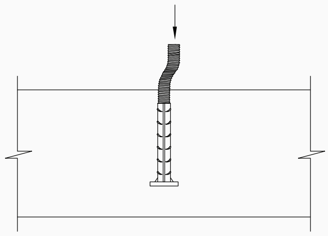
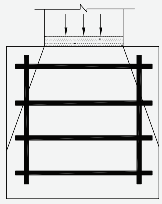
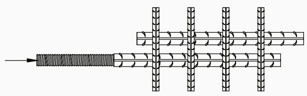
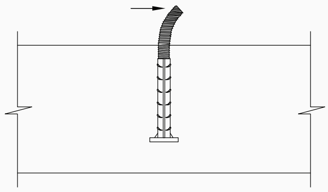
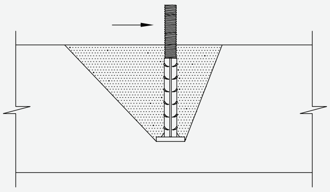
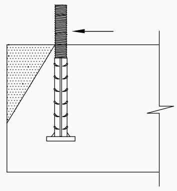
Check Failure	Anchor Bolt (EBB-S Type)	Figure
Steel Strength	Required	
Punching Strength under anchor head	Required	
Buckling Strength	Required	
Partially loaded area	Required (for base structure at final stage)	
Splicing Length	Not Required	

Table: 17 Design check for Shear:

Check Failure	Anchor Bolt (EBB-S Type)	Figure
Steel Strength with lever arm	Required	
Concrete pry-out failure	Required	
Concrete Edge failure	Required	

The following checks are carried out for ESB Type High Strength Anchor bolts

Table: 18 Design check for Tensile for High Strength Anchor Bolt:

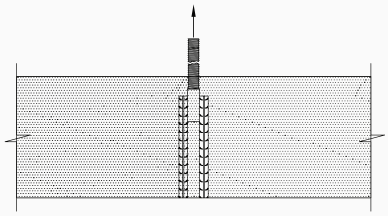
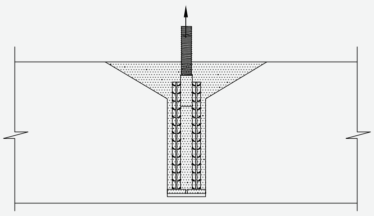
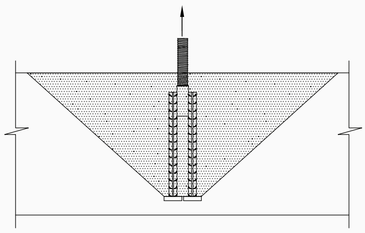
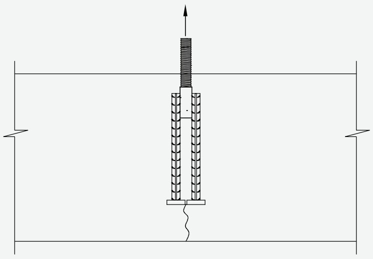
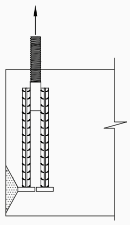
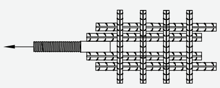
Check Failure	Anchor Bolt (EBB-L-Type)	Figure
Steel Strength	Required	
Pull-out failure	Required	
Concrete cone failure	Required	
Concrete splitting failure	Required	
Blow-out Failure	Required	
Splicing length	Not Required	

Table: 19 Design check for Compression for High Strength Anchor Bolt:

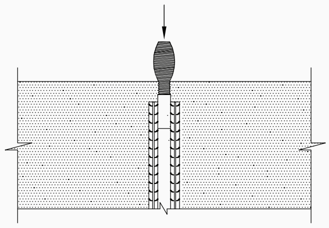
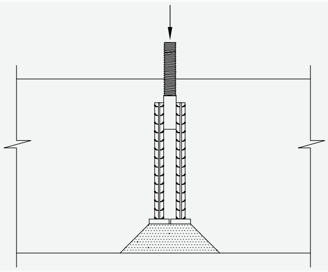
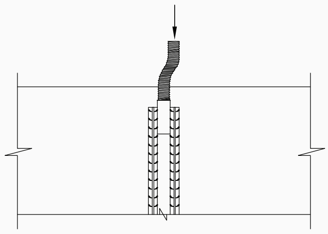
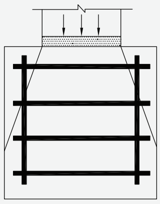
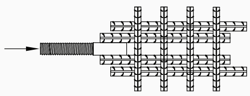
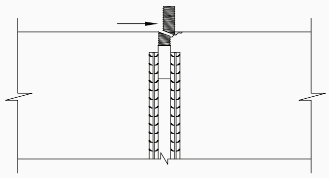
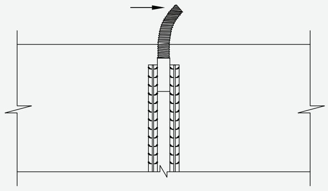
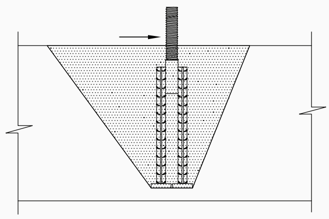
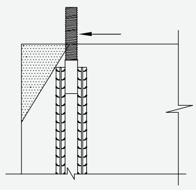
Check Failure	High strength Anchor Bolt (EBB-L-Type)	Figure
Steel Strength	Required	
Punching Strength under anchor head	Required	
Buckling Strength	Required	
Partially loaded area	Required (for base structure at final stage)	
Splicing Length	Not Required	

Table: 20 Design check for Shear for High Strength Anchor Bolt:

Check Failure	High strength Anchor Bolt (EBB-L-Type)	Figure
Steel Strength	Required	
Steel Strength with lever arm	Required	
Concrete pry-out failure	Required	
Concrete Edge failure	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:

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

At Erection Stage:

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

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

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

For Concrete verification (for EBB and ESB 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:

$(N_{Ed} / N_{Rd.i})1.5 + (V_{Ed} + V_{Rd.i})1.5 \leq 1$ EN 1992-4:2018, Eq. 7.55

$(N_{Ed} / N_{Rd.i}) + (V_{Ed} + V_{Rd.i}) \leq 1.2$ EN 1992-4:2018, Eq. 7.56

with $N_{Ed} / N_{Rd.i} \leq 1$ and $V_{Ed} / V_{Rd.i} \leq 1$

The largest value $N_{Ed} / N_{Rd.e}$ and $V_{Ed} / V_{Rd.e}$ for different failure modes shall be taken.

Bolts with supplementary reinforcement for tension or shear:

$(N_{Ed} / N_{Rd.i})2/3 + (V_{Ed} + V_{Rd.i})2/3 \leq 1$ EN 1992-4:2018, Eq. 7.57

with NEd / NRd.i ≤ 1 and VEd / VRd.i ≤ 1

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

$V_{Ed} / V_{Rd.i}$ are resultant design resistance for different failure.

Note 1: For verifications 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:- Splitting will not be taken into account for combined verification, if we If we provided splitting supplementary reinforcement.

4.3 Fire Resistances

En 1992-1-2 is Europeon standard for fire resistance is also be considered for anchor bolt design. Concrete cover must be increased for achieved the fire resistance connection

5. REINFORCEMENT

5.1 Splitting Reinforcement

Splitting reinforcement is calculated as per below calculation and required reinforcement is also show in table 21, 22 respectively

$$\sum A_{s,re} = k_4 \frac{\sum N_{Ed}}{f_{yk,re} / \gamma_{Ms,re}}$$

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

fyk = nominal yield strength of the reinforcing steel ≤ 600 N/mm2

$\gamma M_{s.re}$ = 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:

Maximum splitting reinforcement should not be more than 150mm.

Reinforcement should be positioned adjacent the side face of member but should be less than 100mm in depth below the head of the anchor.

Reinforcement must be place in each ways. Give individually observation for transverse edges.

Required amount of splitting reinforcement can be taken 50% for the case when there is only one critical edge in the examined direction.

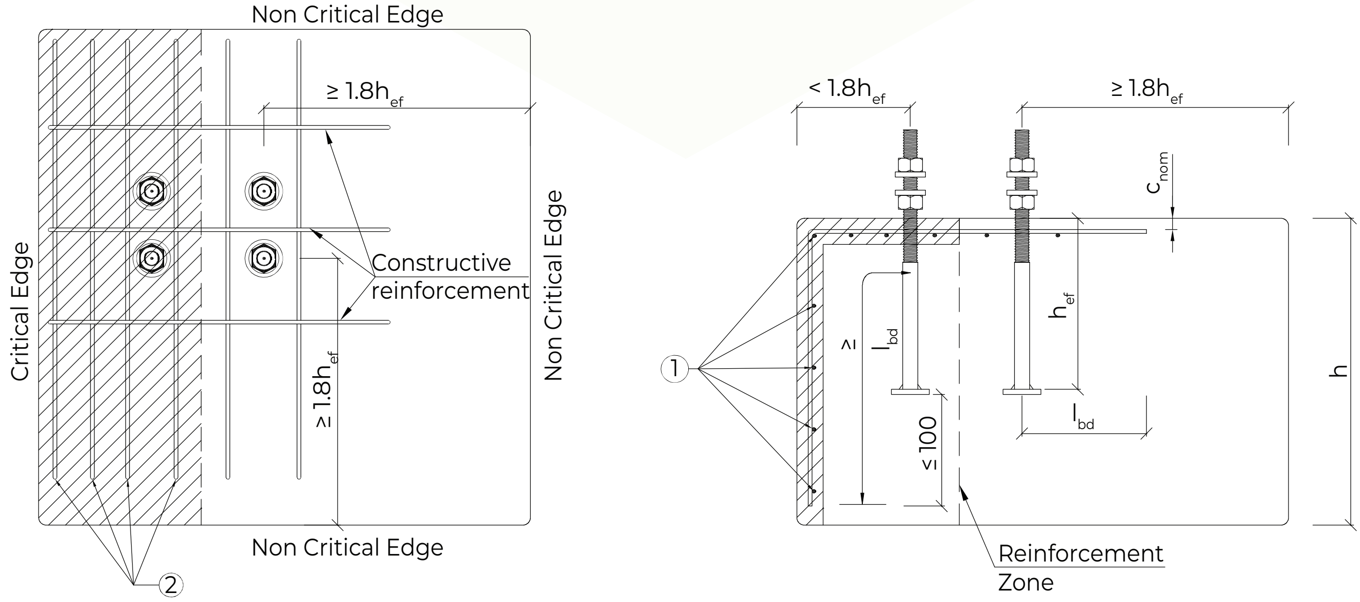


Figure - 13 (Concrete Splitting Reinforcement for EBB-S)

Table 21: Concrete Splitting reinforcement for EBB-S Type

Anchor Bolt	Reinforcement, dia [mm]	Ast (1+2) [mm2]
EBB-S-M16	3 - 6Ø	71.5
EBB-S-M20	4 - 6Ø	111.6
EBB-S-M24	4 - 8Ø	160.1
EBB-S-M30	4 - 10Ø	255.5
EBB-S-M39	4 - 12Ø	444.5

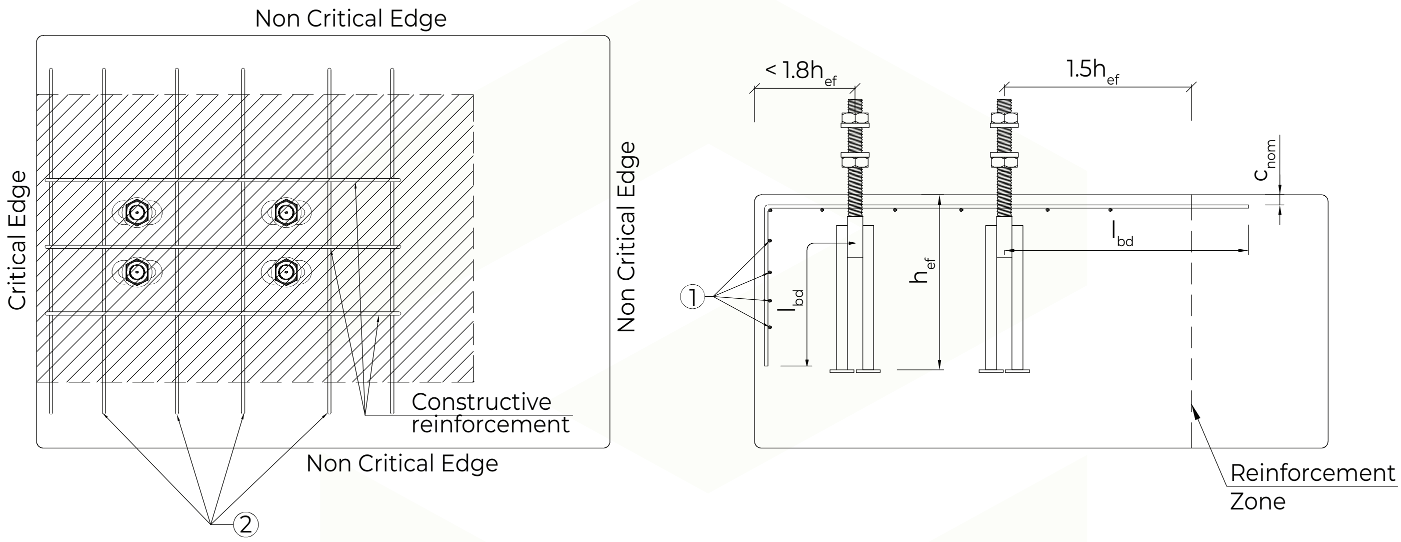


Figure - 14 (Concrete Splitting Reinforcement for ESB-S)

Table 22: Concrete Splitting reinforcement for ESB-S Type for High strength anchor bar

Anchor Bolt	Reinforcement, dia [mm]	Ast (1+2) [mm2]
ESB-S-M30	4 - Ø12	344.08
ESB-S-M36	4 - Ø14	501.09
ESB-S-M39	4 - Ø14	598.61
ESB-S-M45	4 - Ø16	801.01
ESB-S-M52	6 - Ø16	1078.24
ESB-S-M60	8 - Ø16	1448.69

5.2 Concrete Cone Reinforcement

If concrete cone failure is is exist in element, so we have to provide additional reinforcement for concrete cone failure as below figure 15,16 and table 23-24.

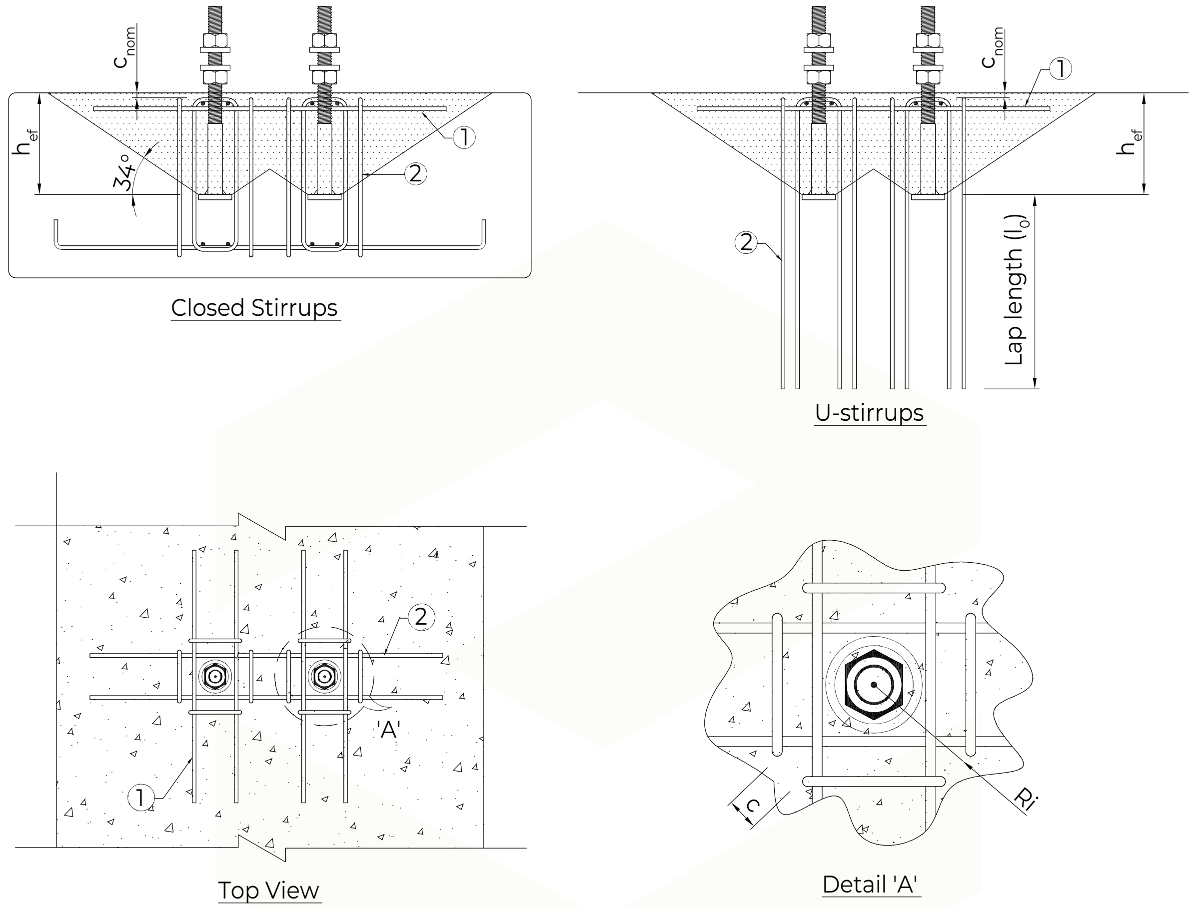


Figure - 15 (Concrete Cone Reinforcement for EBB-S)

Table 23: Concrete Cone reinforcement for EBB-S Type

Anchor Bolt	Stirrups, (1) [mm]	Horizontal Bars, (2) (dia)	Ast [mm2]	Cnom [mm]	hef [mm]	y (Stirrups width)	R1 [mm]
EBB-S-M16	2 - Ø8	Ø8	200	35	169	90	75
EBB-S-M20	3 - Ø8	Ø8	600	35	227	90	90
EBB-S-M24	4 - Ø8	Ø8	400	35	290	110	105
EBB-S-M30	4 - Ø10	Ø10	628	35	340	130	105
EBB-S-M39	4 - Ø12	Ø12	904	35	508	150	200

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

Concrete cover ≤ 35mm

Minimum distance between parallel stirrups > 21mm

Concrete grade is ≥ C25/30

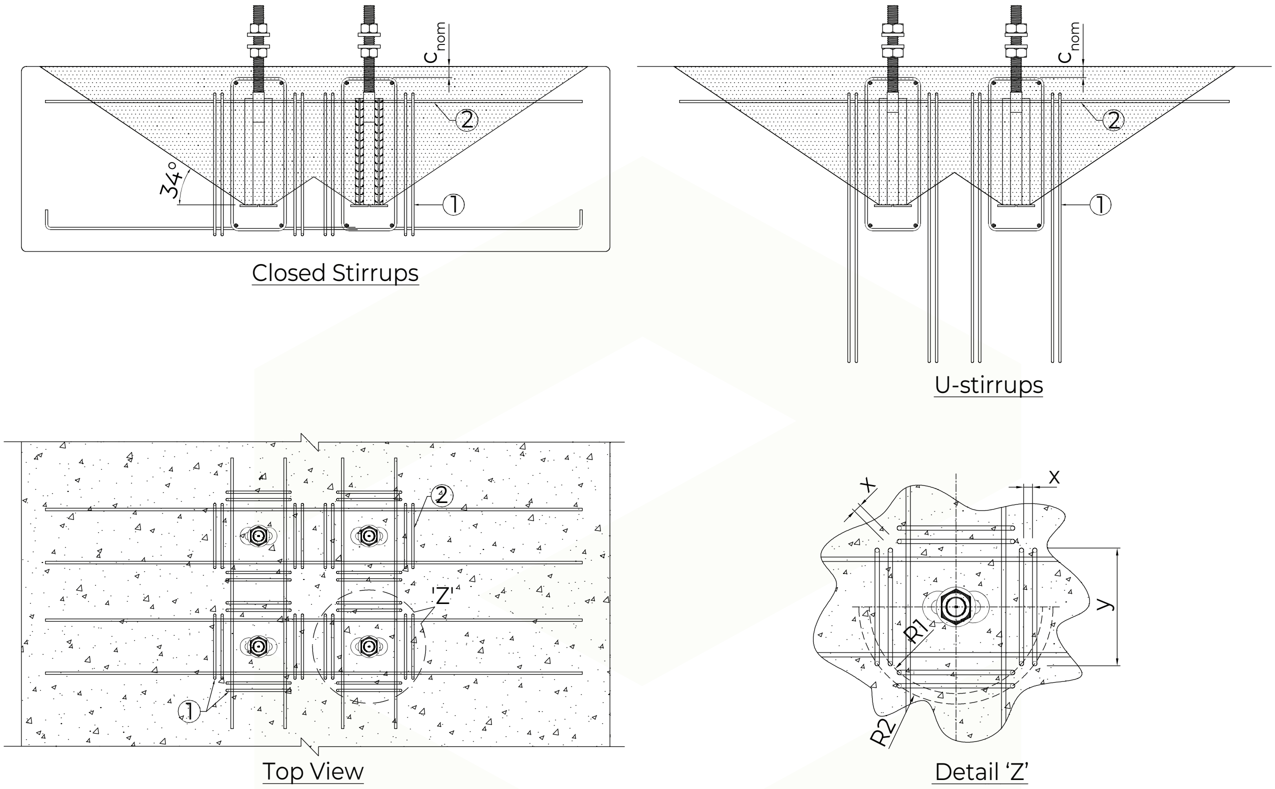


Figure - 16 (Concrete Cone Reinforcement for ESB-S)

Table 24: Concrete Cone reinforcement for ESB-S Type (High Strength anchor bolt)

Anchor Bolt	Stirrups, (1) [mm]	Horizontal Bars, (2) (dia)	Ast [mm2]	Cnom [mm]	hef [mm]	y (Stirrups width)	R1 [mm]	R2 [mm]
ESB-S-M30	4- 12Ø	8Ø	904	35	505	180	170	-
ESB-S-M36	6 - 12Ø	10Ø	1357	35	562	185	200	-
ESB-S-M39	6 - 12Ø	10Ø	1357	35	680	195	225	-
ESB-S-M45	6 - 14Ø	12Ø	1847	35	764	215	255	-
ESB-S-M52	6 - 16Ø	14Ø	2412	35	892	255	285	320
ESB-S-M60	8 - 16Ø	16Ø	3217	35	1057	255	300	320

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

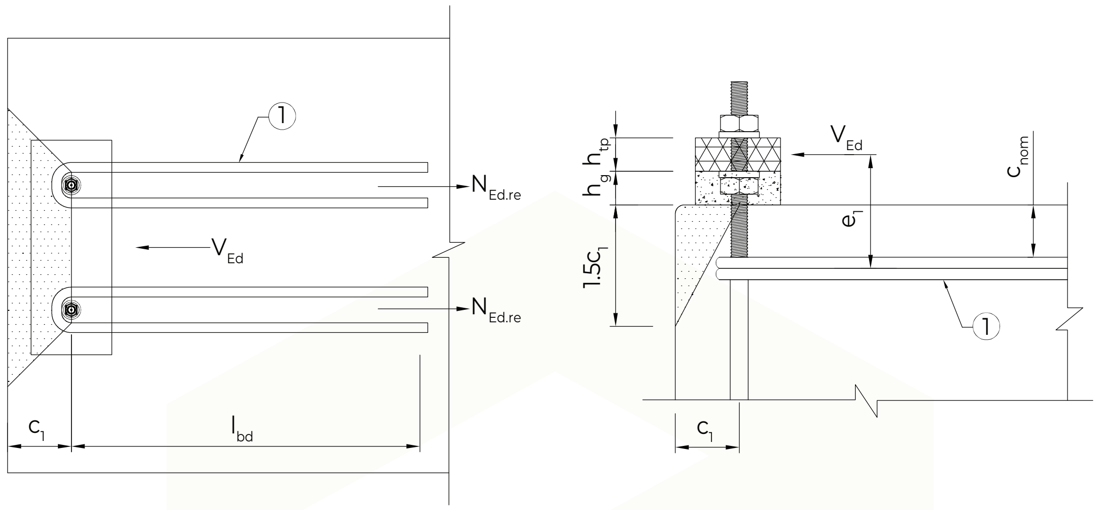


Figure - 17 (Concrete Edge Reinforcement for EBB-S)

Table 25: Concrete Edge reinforcement for EBB-S Type

Anchor Bolt	U - Bar, (1) [mm]	C1 (mm)	e1 (mm)	Cnom (mm)
EBB-S-M16	1 - Ø12	50	100	35
EBB-S-M20	1 - Ø14	70	105	35
EBB-S-M24	1 - Ø16	70	110	35
EBB-S-M30	2 - Ø16	100	125	35
EBB-S-M39	3 - Ø16	130	145	35

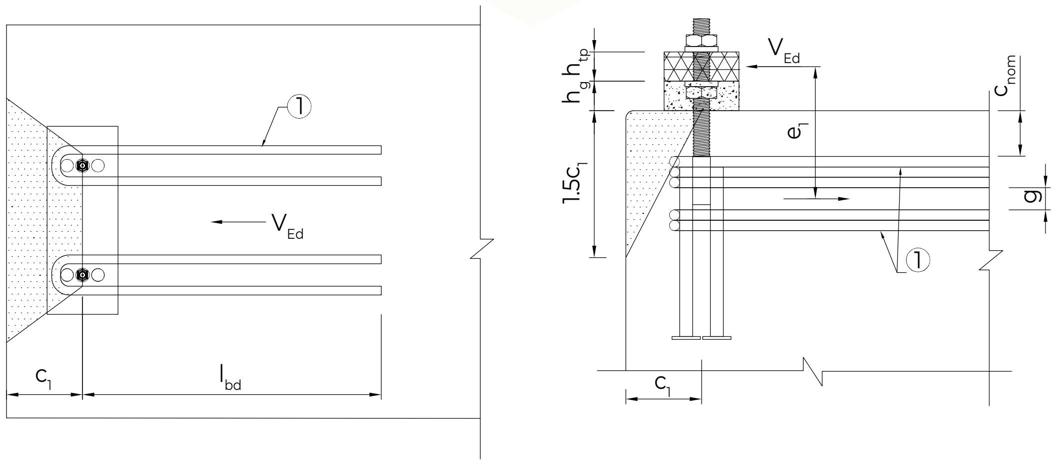


Figure - 18 (Concrete Edge Reinforcement for ESB-S)

Table 26: Concrete Edge reinforcement for ESB-S Type for high strength anchor bolt

High strength Anchor Bolt	U - Bar, (1) [mm]	C1 (mm)	e1 (mm)	a (mm)	Cnom (mm)	a [mm]
ESB-S-M30	4 - Ø12	120	170	-	35	-
ESB-S-M36	4 - Ø14	140	170	-	35	-
ESB-S-M39	4 - Ø14	150	180	-	35	-
ESB-S-M45	3+1 - Ø16	160	190	28	35	30
ESB-S-M52	3+2 - Ø16	180	230	28	35	30
ESB-S-M60	3+2 - Ø16	180	270	28	35	30

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

c1 ≥ (Values from table 23)

b) 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.

$$\psi_{\alpha,V} = \sqrt{\frac{1}{(\cos\alpha_V)^2 + (0{,}5 \cdot \sin\alpha_V)^2}} \geq 1$$

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 Ψa,V.

αv = the angle between design shear load VEd and a line perpendicular to the verified edge, 0° ≤ αV ≤ 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 (hud) is less than the values given in the table below.

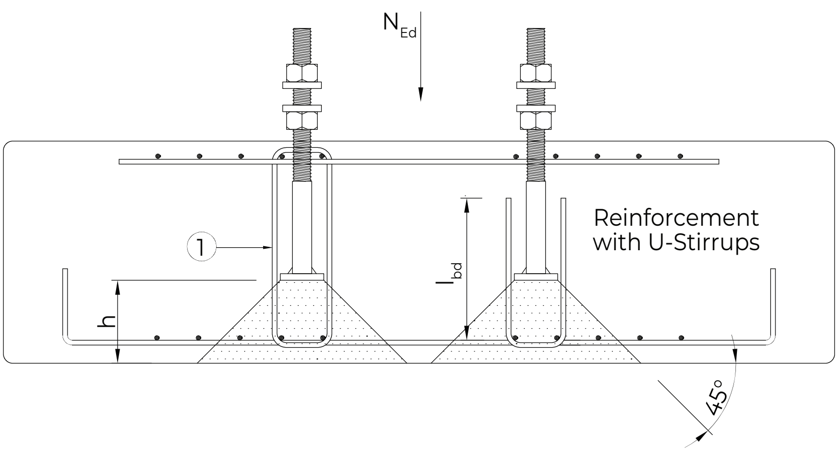


Figure - 19 Reinforcement of Concrete cone for punching

Table 27: Concrete Edge reinforcement for EBB-S Type for normal strength anchor bolt

Normal strength Anchor Bolt	l_{bd} [mm]	As (mm)	Stirrups (1)
EBB-S-M16	80	100	2-Ø6
EBB-S-M20	100	145	2-Ø8
EBB-S-M24	115	200	2-Ø8
EBB-S-M30	145	315	2-Ø10
EBB-S-M39	190	530	2-Ø14

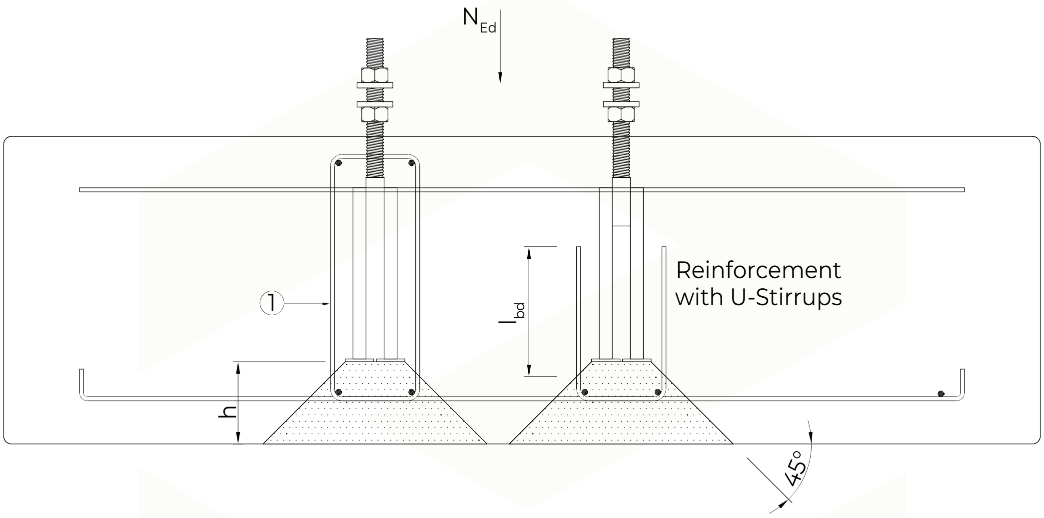


Figure 20: Reinforcement of Concrete cone for punching

Table 28 : Concrete Edge reinforcement for ESB-S Type for high strength anchor bolt

High strength Anchor Bolt	h [mm]	As (mm)	Stirrups (1)
ESB-S-M30	90	201	2-Ø8
ESB-S-M36	85	215	2-Ø10
ESB-S-M39	75	180	2-Ø8
ESB-S-M45	50	135	2-Ø8
ESB-S-M52	105	385	2-Ø12
ESB-S-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.

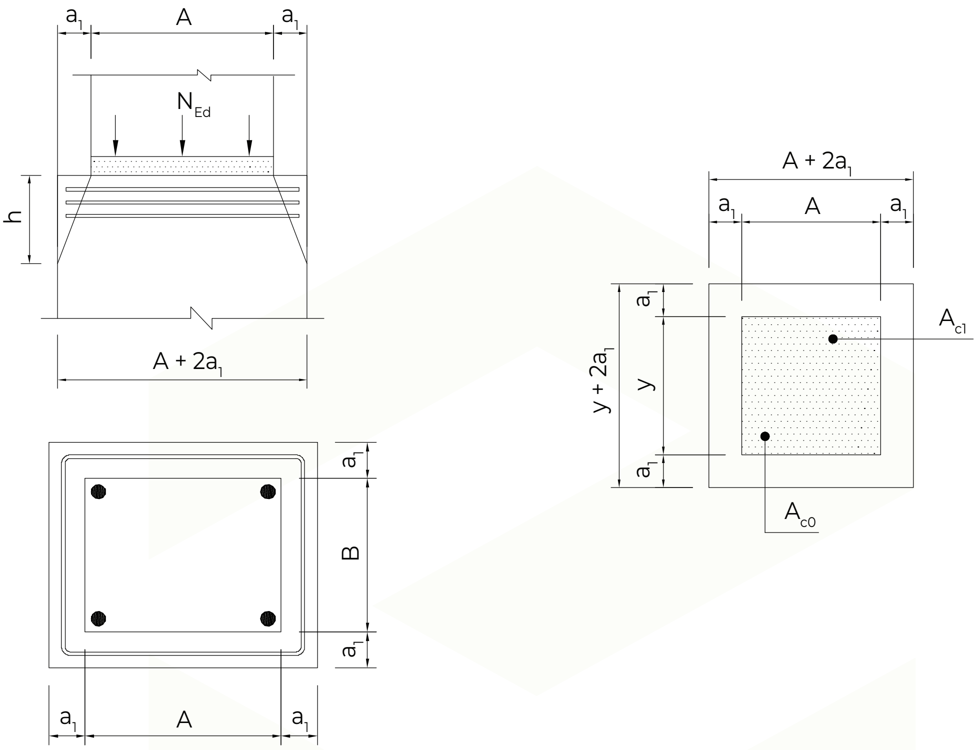


Figure 21: Column connection with different section and required splitting Reinforcement in base column.

Design Example:
Concrete Column 600 x 600 (C40/50) 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:

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

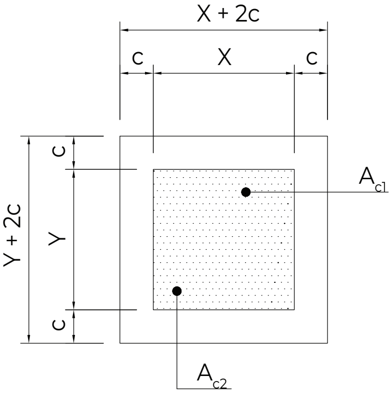
$F_{Rd.p}$ = Ultimate load capacity of an axial loaded column

A_{c0} = loaded area

A_{c1} = maximum design distribution area

$f_{cd.b}$ = design compressive strength of foundation / base structure (20.0 N/mm2)

$f_{cd.c}$ = design compressive strength of column (26.68 N/mm2)



Solution :

A_{c1} = X . Y = 600x 600 = 360000 mm2

A_{c2} = (X + 2.c) . (Y + 2.c) = (600 + 2.c) + (600 + 2.c)

= (600 + 2.c)2

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

= $A_{c1} . f_{cd.c}$ = 360000 x 26.68 = 9604.8 kN

$X . Y . f_{cd.c}$ = $X . Y . f_{cd.b}$. √((A + 2.a1) . (B + 2.a1) / A . B)

= 20.0 . √((600 + 600.2x) . (600 + 2.x) / 600/600)

x = 125 mm

Minimum cross-section of base column:

= (X + 2.x) . (Y + 2.x) / X . Y)

= (600 + 2 x 125) . (600 + 2 x 125)

= 850 mm x 850 mm

Splitting force

Fsp = 0.25 FRdu . (1-Y/Y+2x)

= 0.25* 9604.8 x (1-600 / (600+2 .125))

= 706.23 kN or 706235 N

Required splitting reinforcement area

A_{sp} = Fsp /2.(f_{yk}/γ_s)

F_{yk} = 500 N/mm2 (yield strength of reinforcement)

γ_s = 1.15 (partial safety factor for reinforcement)

= 706235 /[2 . (500/1.15)]

= 812.2 mm2

6. INSTALLATION OF COLUMN

The process requires special technique and materials.To ensure a secure installation, it is crucial to understand the correct methods of installation anchor bolt. The bolts are installed into the group by using the frame. The frame ensures that each bolt is correctly positioned and aligned, have to protect the thread during casting. After installation of frame, washer will be placed over the anchor bolt and the bolt is tightened. The gap between the column and base structure will be grout for further installation. Ensure that, since the grout has not been reached our design strength, precast element must not be installed.

Table 29. Minimum tightened torque vale of the nut:

Anchor Bolt	Tmin [mm]
EBB-S-M16	120
EBB-S-M20	150
EBB-S-M24	200
EBB-S-M30	250
EBB-S-M39	350
ESB-S-M30	250
ESB-S-M36	300
ESB-S-M39	350
ESB-S-M45	400
ESB-S-M52	450
ESB-S-M60	500

Installation deviation (tolerance) of Base Bolt

The permissible positional deviation for installing the precast concrete elements in the bolt group is ±10 mm. Permissible deviation for the elevation of the top of the base bolt is ±20 mm

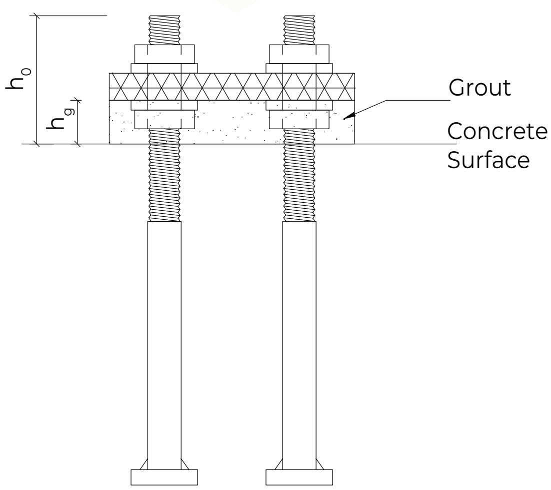


Figure: 22

Table 30. Bolt height and grout position :

Anchor Bolt	Grout thickness, hg [mm]	h0 [mm]	Tolerance for bolt [mm]
EBB-S-M16	50	105	± 3
EBB-S-M20	50	115	± 3
EBB-S-M24	50	130	± 3
EBB-S-M30	50	150	± 3
EBB-S-M39	60	180	± 3
ESB-S-M30	50	150	± 4
ESB-S-M36	55	170	± 4
ESB-S-M39	60	190	± 4
ESB-S-M45	65	205	± 4
ESB-S-M52	70	235	± 5
ESB-S-M60	80	260	± 5

SUPERVISON OF INSTALLATION

Before casting :

- Conduct a visual checking for anchor bolt positioned, distance and correct installation.
- Check the installation frame will be horizontal to the base structure.
- Check the tolerances of the top of the anchor bolt.
- Check the thread it will not be damaged untill the grouting is not done.
- Check that the reinforcement is places as per design consideration.
- Joint filler with high strength free flow cementitious grout.

After casting :

- Check the correct position of bolt as per drawing.
- Check the thread it will not be damaged.

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