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ESC
Column Shoes

TECHNICAL MANUAL

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Column Shoe System

Endura Global's ESC Column Shoes and EBB Anchor Bolts provide a reliable bolted connection system for precast concrete columns, enabling moment-resisting, near-monolithic performance after grouting. The matched design ensures balanced capacity and predictable behaviour, simplifying structural design and on-site assembly.

- **Fast, Simple Installation:** Columns are quickly secured by tightening nuts, eliminating the need for welding or complex formwork.
- **Immediate Load Transfer:** The column can resist axial and moment forces instantly after nut tightening, allowing crane release.
- **No Temporary Bracing Required:** The bolted moment connection provides immediate stability without additional props.
- **Adjustability:** Column position and vertical alignment can be easily fine-tuned before final tightening.
- **Fast Erection and Alignment:** Bolted connections reduce crane time and accelerate the overall construction schedule.
- **High Stiffness After Grouting:** The grouted base achieves near-monolithic stiffness, stronger than the column itself.
- **Potential for Reuse:** Connections can be demounted for future disassembly or reuse, supporting sustainable construction.

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1. ESC Column Shoes and EBB Bolts

1.1. Introduction

Endura Global's ESC Column Shoes and EBB Anchor Bolts form a complete bolted connection system for precast concrete columns. Designed for simple on-site bolting, the system provides moment-resisting connections between columns and foundations (or column splices). Once the gap is grouted and hardened, the joint achieves near-monolithic stiffness, resisting axial and bending forces like cast-in-place connections.

The EBB bolts are manufactured in multiple strength categories and are matched with the ESC column shoes to ensure balanced performance. This compatibility allows both components to reach capacity simultaneously, simplifying design and providing predictable behaviour. While high-strength EBB bolts are available, the system's overall capacity is governed by the ESC shoe, maintaining safety and consistency.

Drawing from proven global systems, Endura's ESC/EBB solution incorporates lessons from competitors while offering its own refinements. With standard design tools and BIM components, the system streamlines engineering workflows and site execution. Once grouted, connections achieve or exceed column capacity, ensuring the connection is never the weak link—making Endura a robust, efficient, and competitive solution for precast construction.

1.2. Material

Endura ESC column shoes and EBB Anchor Bolts are composed of high-quality structural steel components and reinforcing bars, all meeting international standards for structural use. Each ESC shoe consists of a base anchor plate (base plate + side plate) and integrated anchor bars (rebar), which are welded together to form a rigid shoe unit. The materials used are chosen to ensure both high load capacity and weldability:

Component	International Standard	Indian Equivalent	Key Properties
Anchor Plate (Base Plate)	S355J2+N Structural Steel (~355 MPa yield)	IS 2062 E350 Grade	High ductility, weldability, toughness
Anchor Bars (Reinforcement)	B500B Ribbed Rebar (500 MPa yield)	IS 1786 Fe500 / Fe500D	High strength, bond with concrete, weldable
Anchor Bolt (Reinforcement)	B500B Ribbed Rebar (500 MPa yield)	IS 1786 Fe500 / Fe500D	High strength, bond with concrete, weldable
Nuts (EBB Anchor Bolts)	High-grade Steel (Grade 8.8)	IS 1367 Grade 8.8	Supplied with nuts/washers, corrosion protection options
Washers (EBB Anchor Bolt)	S355J2+N Structural Steel (~355 MPa yield)	IS 2062 E350 Grade	High ductility, weldability, toughness

1.3. Markings

Each ESC column shoe is fitted with an identification tag showing product type, size (e.g., M16, M20), year of manufacture, and batch number. This ensures full traceability and helps site teams quickly verify the correct shoe size.

Along with tags, Endura uses a durable color-coding system for quick visual identification after casting.

ESC Column Shoe Type	Thread Size	Color Code
ESC M16	16 mm	Yellow (paint mark)
ESC M20	20 mm	Blue
ESC M24	24 mm	Grey
ESC M30	30 mm	Green
ESC M39	39 mm	Orange

These markings ensure that even if tags are hidden or removed, workers can still identify shoe sizes immediately, improving accuracy and site efficiency.

By using both tags and colour markings, Endura ensures proper identification during storage, installation, and even after the components are embedded in concrete. This reduces the risk of mix-ups (such as using the wrong bolt with a shoe) and simplifies the inspection process for quality control.

1.4. Production Tolerance

Endura ESC column shoes are manufactured to precise dimensions with a tolerance of ±10 mm on anchor bar length, ensuring proper overlap and anchorage in concrete.

Critical steel dimensions like base plate size and bolt hole positions are kept within +2 / -1 mm, following EN 1090 standards for consistent fit and alignment with foundation bolts.

Each shoe undergoes strict quality checks for hole spacing, plate geometry, welding accuracy, and bar positioning, ensuring smooth on-site assembly and reliable installation.

1.5. Environmental Conditions

Endura's standard ESC column shoes and EBB bolts are designed for dry indoor conditions, offering 50+ years of service life with minimal maintenance. Standard products operate down to –20 °C, making them suitable for cold climates.

For harsher environments (outdoor, marine, chemical), durability is ensured through concrete cover, hot-dip galvanizing, or protective coatings options. These measures protect exposed steel parts while maintaining fit and performance.

Exposure Class	Concrete Cover (Δ) – EN 1992-1-1	Cover at Base Plate (Δ)	Surface Treatment
X0	20 mm	0 mm	No surface treatment
XC1	25 mm	25 mm	None (inwards) / Hot-dip galvanised (edge)
XC2	35 mm	35 mm	None (inwards) / Hot-dip galvanised (edge)
XC3	35 mm	35 mm	None (inwards) / Hot-dip galvanised (edge)
XC4	40 mm	40 mm	Hot-dip galvanised
XD1 / XS1	45 mm	45 mm	Hot-dip galvanised
XD2 / XS2	50 mm	50 mm	Hot-dip galvanised
XD3 / XS3	55 mm	55 mm	Hot-dip galvanised

Most of the shoe and bolt are naturally encased in concrete, with only minor exposed areas protected by grout, coatings, or additional cover. Designers must specify protective finishes as per exposure class, ensuring long-term reliability.

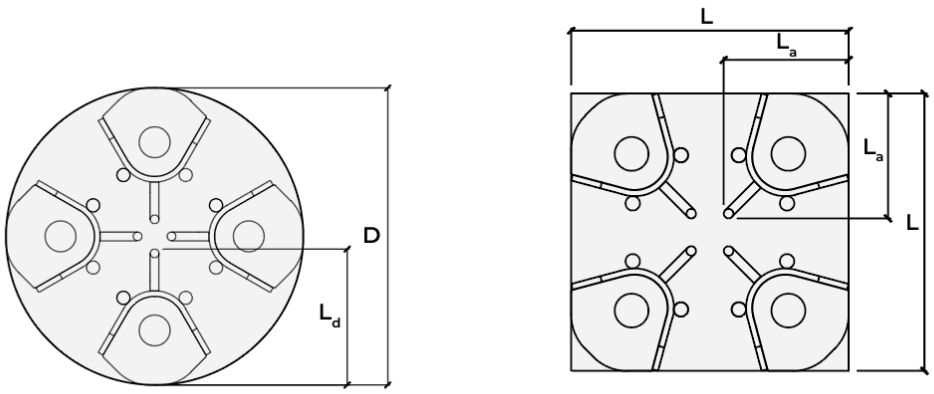
2. Product Dimensions

2.1. Column Dimensions and Layouts

To properly accommodate ESC column shoes, the precast column must have sufficient cross-sectional dimensions. Each shoe occupies a certain space within the column's base, and there are minimum column width/thickness requirements so that the shoes (and their reinforcement) fit without clashing and with adequate concrete around them for load transfer.

Table 2 below summarizes basic dimensions of ESC column shoes and the corresponding minimum column size for use:

Column Shoe Type	**Anchor Bolt (EBB)**	**Min. Column Section L/D** (mm)	L_d (mm)
ESC M16 (2.3 kg)	M16 bolt	Square ~ 200 × 200 Circular ~ ⌀230	Square - 104 Circular – 135
ESC M20 (4.2 kg)	M20 bolt	Square ~ 240 × 240 Circular ~ ⌀280	Square - 108 Circular – 145
ESC M24 (6.7 kg)	M24 bolt	Square ~ 300 × 300 Circular ~ ⌀350	Square - 116 Circular – 150
ESC M30 (12.2 kg)	M30 bolt	Square ~ 350 × 350 Circular ~ ⌀410	Square - 137 Circular – 175
ESC M39 (26.7 kg)	M39 bolt	Square ~ 450 × 450 Circular ~ ⌀520	Square - 177 Circular - 225

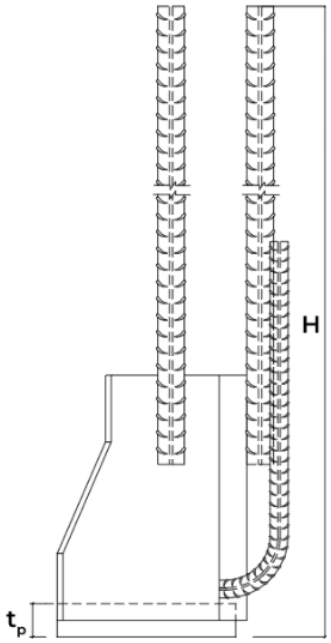


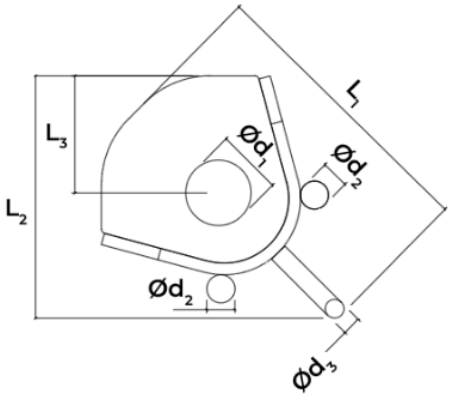
Minimum Column Sizes

2.2. Column Shoe and Anchor Bolt Dimensions

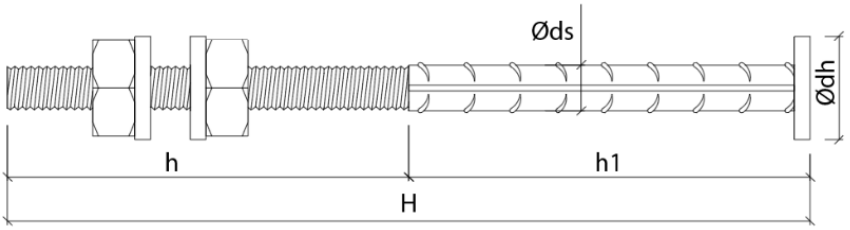
NKK Column Shoe Product Dimensions

Column Shoe	H [mm]	L1 [mm]	L2 [mm]	L3 [mm]	⌀d1 [mm]	⌀d2 [mm]	⌀d3 [mm]	t_p [mm]	Weight [kg]
ESC-M16	597	124	104	50	28	12	8	15	2.23
ESC-M20	820	130	108	50	31	16	10	20	4.12
ESC-M24	1185	140	116	50	35	16	12	30	6.67
ESC-M30	1390	169	137	50	40	20	16	45	12.21
ESC-M39	1910	221	177	60	55	25	20	50	26.84

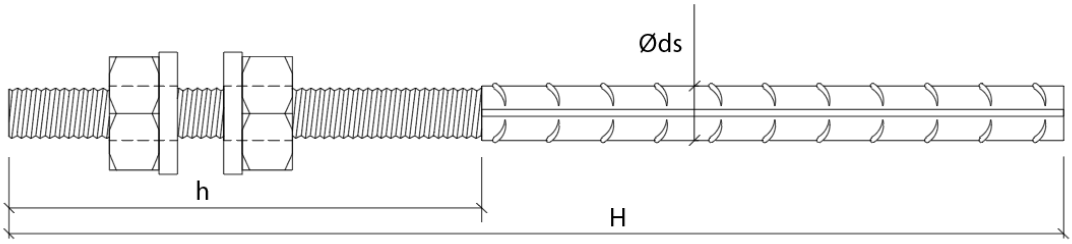




EBB Anchor Bolt Product Dimensions



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

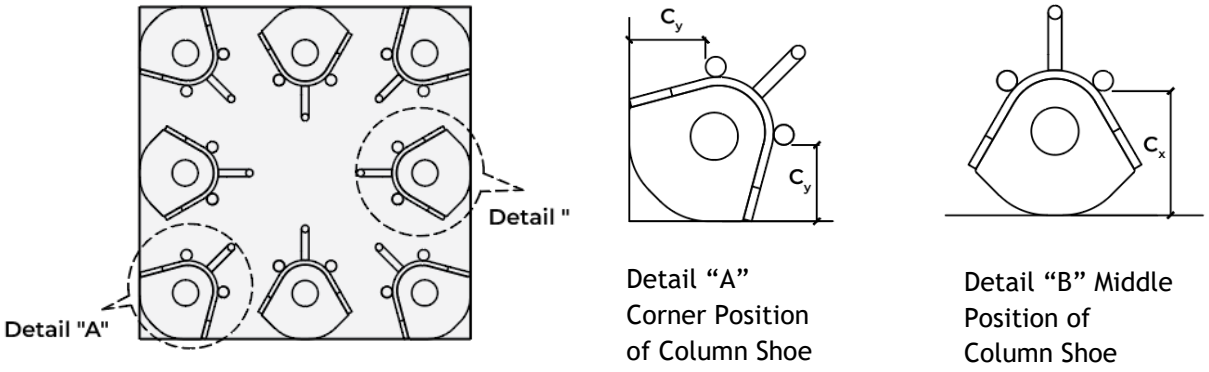


Anchor bolt	H [mm]	h [mm]	Øds [mm]
EBB-P-M16	810	140	16
EBB-P-M20	960	140	20
EBB-P-M24	1160	170	25
EBB-P-M30	1460	190	32
EBB-P-M39	2000	200	40

2.3. Concrete Cover Requirements

Each ESC column shoe is fitted with an identification tag showing product type, size (e.g., M16, M20), year of manufacture, and batch number. This ensures full traceability and helps site teams quickly verify the correct shoe size.

Proper concrete cover over steel components is not only a durability concern (as discussed in Environmental Conditions) but also a structural requirement for fire protection and to ensure the development of the rebar forces. For the ESC column shoe, there are two critical cover considerations:

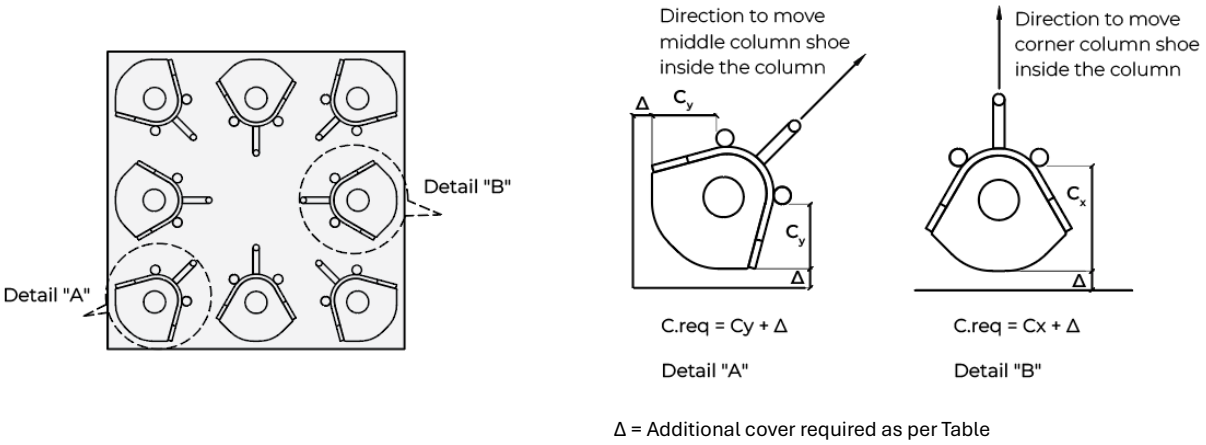


Detail “A” Corner Position of Column Shoe

Detail “B” Middle Position of Column Shoe

Concrete Cover for Main Bar of Column Shoe

Column Shoe	Middle Concrete Cover , Cx [mm]	Corner Concrete Cover , Cy [mm]
ESC-M16	73	45
ESC-M20	76	45
ESC-M24	82	45
ESC-M30	89	45
ESC-M39	109	45



Δ = Additional cover required as per Table

Required Concrete Cover for Main Bar of Column Shoe

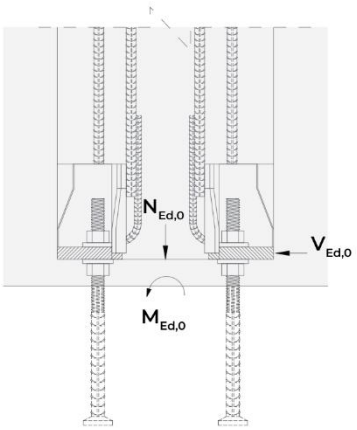
If a standard shoe cannot achieve the needed cover in a particular column (for instance, a very thin column where even a small shoe is near the surface), then solutions include increasing the column dimensions slightly, using additional protective measures (like a fireproof mortar over the face where the plate sits), or using a different connection approach. Endura's team can advise if such cases arise.

3. Resistances

3.1. Structural Behaviour

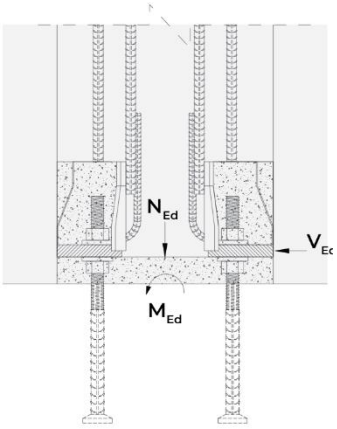
The Endura ESC/EBB bolted system transfers axial loads, shear forces, and bending moments between precast columns and foundations, functioning much like a rigid cast-in-place base connection. Four or more shoes and bolts create a couple to resist moment and provide direct tension/compression for axial forces.

At erection stage, tightened bolts alone carry column self-weight, wind, and temporary loads, allowing crane release. Shear is initially resisted by bolt bearing with minor slip possible.



Erection Stage

After grouting, the base plate bears fully on grout, friction and bearing dominate shear transfer, and the connection achieves near-monolithic stiffness.



Final Stage

Torsion is resisted by the bolt pattern and grout; for higher torsional demands, six-bolt layouts or structural bracing may be used. The connection is generally considered rigid in structural analysis, though pinned-type behaviour is possible with special arrangements.

Overall, Endura's ESC/EBB system ensures reliable, moment-resisting performance in both temporary and permanent stages, meeting Eurocode requirements for strength and stiffness in precast column bases.

The resistances are calculated according to the following standards:

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

3.2. Tensile Resistance

The tensile resistance of the connection refers to its ability to carry uplift forces or overturning tension in one or more anchor bolts. In an Endura bolted connection, tension is primarily taken by the anchor bolts (EBB) in conjunction with the column shoes (ESC) which transfer the force to the precast concrete. The design of ESC shoes intentionally matches the tensile capacity of the corresponding EBB bolt of the same size. This means, for example, an ESC M20 shoe used with an EBB M20 anchor bolt will not be the limiting factor – the pair will have a known capacity and generally the bolt steel will govern the tension capacity.

Shoe & Bolt Size	Grout Thick. (mm)	Lever Arm la (mm)	N_Rd,s (kN) (Final Tensile)
ESC M16 + EBB M16	50	65	62.1
ESC M20 + EBB M20	50	79	97.0
ESC M24 + EBB M24	50	76	139.7
ESC M30 + EBB M30	50	86	222.1
ESC M39 + EBB M39	60	103	386.5

Tensile resistance (N_{Rd}) is calculated based on the below equation:

$$N_{Rd} = \frac{0.9 f_{uk} * A}{\gamma_{Ms}}$$

$\gamma_{Ms} = 1.25$

$f_{uk} = 550$ MPa

3.3. Shear Resistance

The shear resistance refers to how much horizontal load (shear force at the column base) the connection can carry. In the ESC/EBB system, shear is transferred by a combination of steel dowel action (anchor bolts in shear) and friction/bearing at the interface once grouted.

Shoe & Bolt Size	Grout Thick. (mm)	Lever Arm la (mm)	V_Rd0,s (kN) (Inst. Shear)	V_Rd,s (kN) (Final Shear)
ESC M16 + EBB M16	50	65	5.0	20.0
ESC M20 + EBB M20	50	79	10.1	31.2
ESC M24 + EBB M24	50	76	17.9	45.0
ESC M30 + EBB M30	50	86	38.0	71.5
ESC M39 + EBB M39	60	103	73.7	124.4

Shear Resistance for Installation Stage is calculated based on below equations:

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

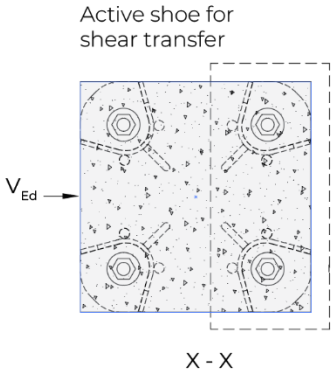
$V_{Rk} = \alpha_{M} * M_{Rk} / l_a$

$M_{Rk} = M^0_{Rk} (1- N_{Ed} / N_{Rd})$; ($N_{Ed} = 0$, shear only)

$M^0_{Rk} = 1.2\, W_{ef} * f_{uk}$

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

$\alpha_M = 2.0$



Shear Resistances

Shear Resistance for Final Stage is calculated based on below equations:

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

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

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

$f_{bolt.u} = 550$ N/mm2

$f_{ub} = 640$ N/mm2

$\gamma_{M2} = 1.25$

$\alpha_v = 0.5$

3.4. Combined Loading

For Steel Components:

At Erection Stage:

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

At Final 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 Related Checks (for stud bolts):

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

$N_{Ed} / N_{Rd.i}$ 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:- If we provided splitting supplementary reinforcement, then splitting failure shall not be considered for combined verification.

3.5. Fire Resistance

Fire resistance of columns shall be designed in accordance with EN 1992-1-2. With the concrete cover values specified in Table 3 (Clause 1.2.3), a fire resistance rating of R90 to R120 can be achieved. If higher resistance is required, the column shoes should be embedded deeper to increase the effective cover.

4. Installation Guidelines

4.1. Preparation and Placement

Proper installation of ESC column shoes and EBB anchor bolts is critical to achieve the intended performance. The process involves preparation at both the precast factory (for the column) and on site (for the foundation):

In the Precast Plant (Column Preparation):

- **Shoe Positioning:** Place ESC shoes in formwork as per drawings, aligned so bolt holes match anchors; use jigs/templates for accuracy.
- **Securing Shoes:** Fix shoes firmly to formwork with screws, tack welds, or installation plates to prevent movement during pouring.
- **Reinforcement Integration:** Tie shoe anchor bars to vertical rebars with proper lap; use stirrups/U-bars for confinement, avoid welding main bars.
- **Concrete Casting:** Pour and compact concrete carefully without displacing shoes; once hardened, shoes are embedded with plates exposed for bolting.

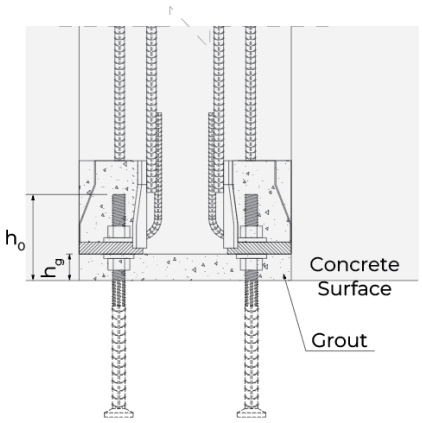
On Site (Foundation Preparation):

- **Anchor Bolt Installation:** Set EBB bolts with templates for correct spacing, alignment, and projection height.
- **Levelling & Surface Prep:** Use levelling nuts, shims, or plates to set column height and maintain the grout gap.
- **Bolt Condition:** Ensure threads are clean, nuts run freely, and bolts are upright before erection.

4.2. Bolt Projection and Grouting

- **Lifting & Placing:** Lift column with crane, align shoe holes with anchor bolts, keeping crane load until bolts pass through.
- **Initial Alignment:** Adjust base elevation with levelling nuts/shims; ensure plan position within ±2 mm and uniform grout gap.
- **Plumbing:** Check column verticality with level/instrument; correct tilt and hand-tighten nuts.
- **Tightening Nuts:** Torque nuts to specified range using calibrated wrench, tightening in crisscross sequence.
- **Grouting:** Fill the base gap with high-strength non-shrink grout, ensuring complete contact and no voids.

Bolt Type (EBB)	Column Shoe (ESC)	Bolt Projection h_0 (mm)	Joint (Grout) Thickness h_g (mm)	Tolerance for bolt (mm)
EBB-L/P M16	ESC M16	105	50	± 3
EBB-L/P M20	ESC M20	115	50	± 3
EBB-L/P M24	ESC M24	130	50	± 3
EBB-L/P M30	ESC M30	150	50	± 3
EBB-L/P M39	ESC M39	180	60	± 3



- **Final Checks:** After grout cures, recheck nut tightness and connection stability.

4.3. Torque Application and Stabilization

- **Nut Tightening:** Apply torque of Endura's T_min using a calibrated wrench.

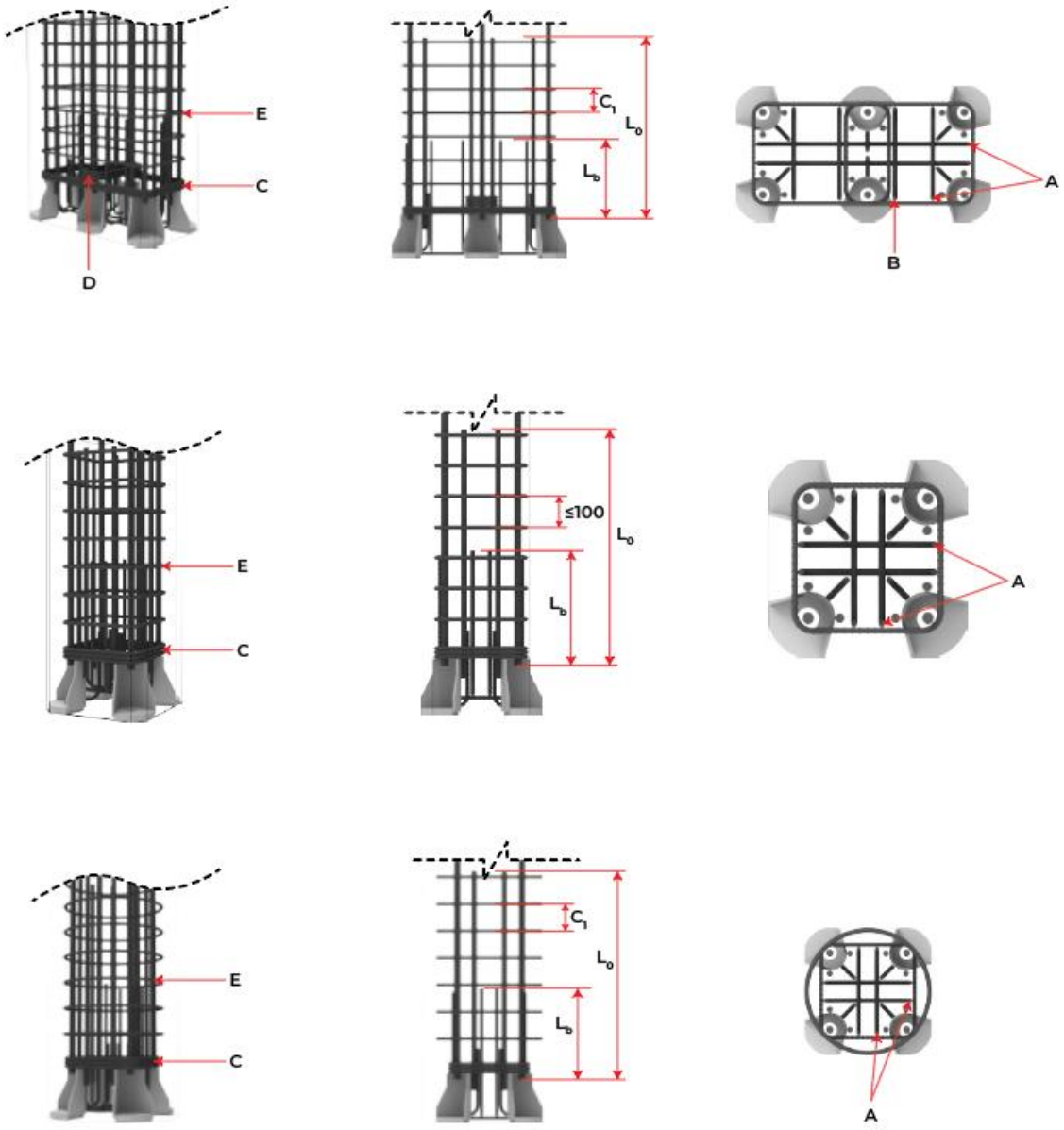
Anchor Bolt Size	Minimum Torque T_min (Nm)
M16	120
M20	150
M24	200
M30	250
M39	350

- **Pretension Benefits:** Bolt pretension clamps shoe to foundation, maintaining compression, stiffness, and shear resistance.
- **Rechecking Torque:** Re-check after grout curing to account for relaxation or shrinkage.
- **Dynamic Loads:** For cyclic loads, pretension is critical; use two-nut or locknut systems to prevent loosening.
- **Precautions:** Ensure proper alignment, avoid overloading before grout hardens, and correct misalignments carefully within tolerance.

5. Appendix A: Reinforcement

To fully realize the capacity of the bolted connection, additional reinforcement is often needed in the adjoining concrete elements. Endura provides typical details for this reinforcement.

5.1. Column Shoe Additional Reinforcement Requirements



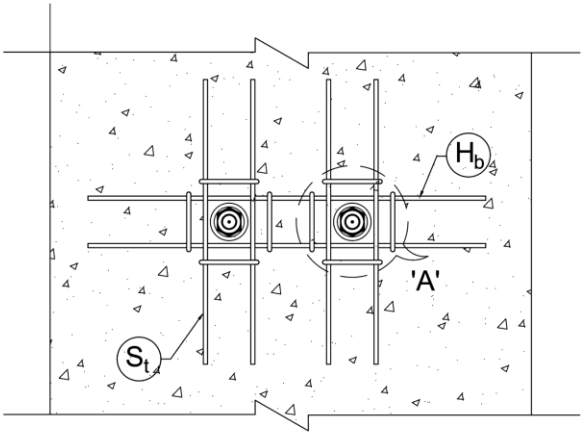
C1 ≤ 100mm

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

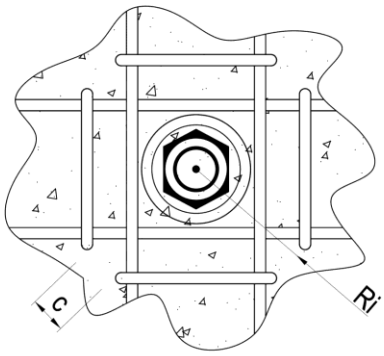
Column Shoe	(A) U-Stirrup [mm]	(B) U-Stirrup [mm]	(C) Stirrup [mm]	(D) Stirrup [mm]	(E) Stirrup [mm]	L_b [mm]
ESC-M16	4-T6	2-T6	2-T8	2-T8	T8	500
ESC-M20	4-T6	2-T6	2-T8	2-T8	T8	500
ESC-M24	4-T6	2-T6	3-T8	3-T8	T8	500
ESC-M30	4-T6	2-T6	3-T8	3-T8	T8	500
ESC-M39	4-T6	2-T6	3-T10	3-T10	T10	500

5.2. Anchor Bolt Additional Reinforcement Requirements

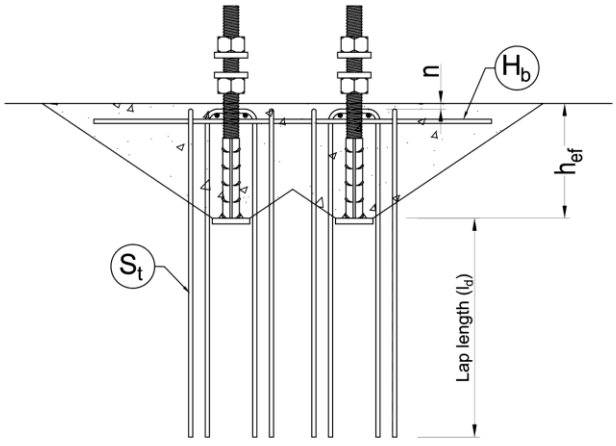
5.2.1. Concrete Cone Reinforcement



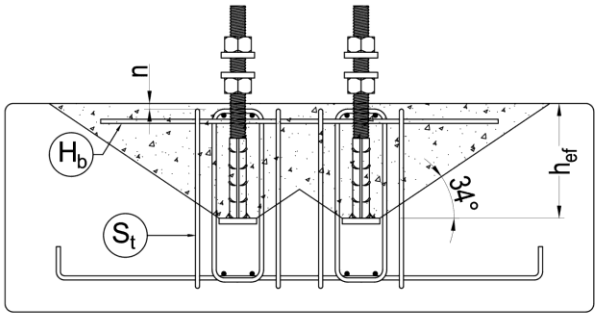
Top View



Detail 'A'



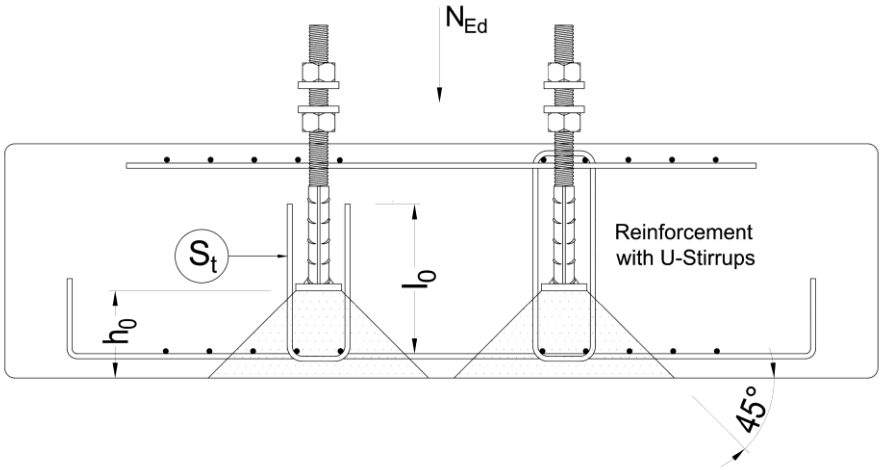
U-stirrups



Closed Stirrups

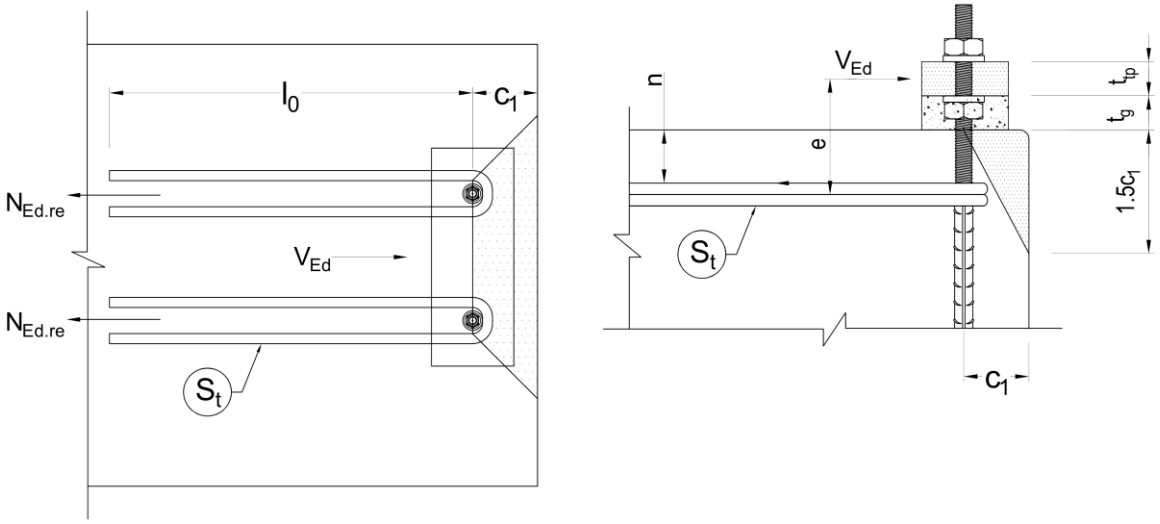
Anchor Bolt	Stirrups, (S_t) [mm]	Horizontal Bars, (H_b) (dia)	A_{st} [mm^2]	n [mm]	h_{ef} [mm]	c (Stirrups width)	Ri [mm]
EBB-L M16	2 - Ø8	Ø8	200	35	169	90	75
EBB-L M20	3 - Ø8	Ø8	600	35	227	90	90
EBB-L M24	4 - Ø8	Ø8	400	35	290	110	105
EBB-L M30	4 - Ø10	Ø10	628	35	340	130	105
EBB-L M39	4 - Ø12	Ø12	904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

5.2.2. Concrete Cone for Punching



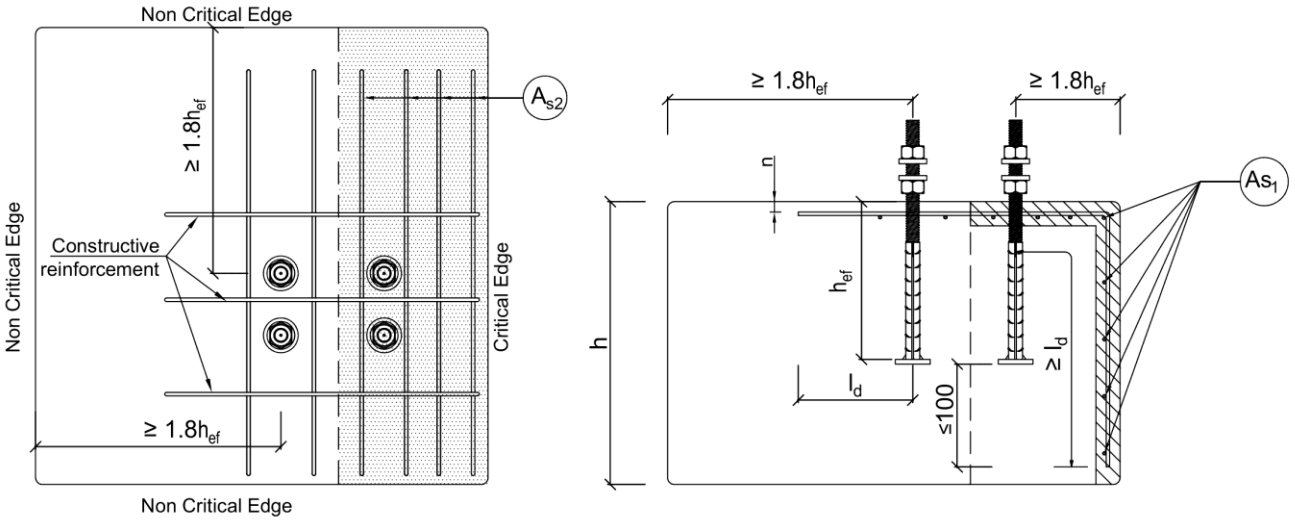
Normal strength Anchor Bolt	h_0 [mm]	A_s (mm)	Stirrups (S_t)
EBB-L M16	80	100	2-Ø6
EBB-L M20	100	145	2-Ø8
EBB-L M24	115	200	2-Ø8
EBB-L M30	145	315	2-Ø10
EBB-L M39	190	530	2-Ø14

5.2.3. Edge Failure



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

5.2.4. Splitting Reinforcement



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

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