MEMO 526 BSF - DESIGN OF REINFORCEMENT, T-CONNECTION BEAM-BEAM DESIGN	Dato: 21.10.2013 Siste rev.: 24.05.2016 Dok. nr.: K4-10/526E	Sign.: sss Sign.: sss Control: ps

BSF – DESIGN OF REINFORCEMENT, T-CONNECTION BEAM-BEAM

CONTENT

PART 1 BASIC ASSUPTIONS

1.1 GENERAL

This memo deals with BSF used in beam-beam connections where a secondary beam is connected to the side of a main beam. Standard beam-box is embedded in the side of the main beam. Reinforcement of the secondary beam with the BSF knife is found in Memo 521. Therefore, only reinforcement related to the BSF beam-box is discussed.

Cross sections of the two connected beams, and the point along the main beam where the secondary beam is connected, will vary. This may lead to different load bearing mechanisms in the main beam. Thus, the final load bearing mechanism is to be evaluated in each case. The mechanism will depend upon the geometry in the connection, and there may be issues with the local force transfer that is not covered by the examples given in this Memo.

Therefore, the following selected load bearing model, calculations on anchorage of the unit, and the resulting reinforcement is only examples meant to illustrate *one* possible load bearing model and *one* way to arrange the reinforcement.

If other reinforcement arrangements are used, observe the following:

- The number and size of vertical anchoring bars must be as indicated in this memo.
- The position of bars at the point of contact with the bearing block on the BSF BB unit must be as indicated in this memo. This to ensure the centre of gravity of the bars is identical to the centre of the load from the knife onto the bearing block.
- Bars should be detailed so as to transfer load from the bearing block up to the upper part of the beam.
- At the upper end, anchorage and bends should comply with National Regulations to ensure full anchorage.

Beyond these observations, EC2 shall as always be applied as the governing design document when detailing the beam reinforcement. The information found here and in the memos assumes that the design of the elements and the use of the units in structural elements are carried out under the supervision of a structural engineer with knowledge about both the relevant standards, and the structural behavior of concrete and steel structures.

1.2 STANDARDS

The calculations are in accordance with:

- Eurocode 2: Design of concrete structures. Part 1-1: General rules and rules for buildings.
- Eurocode 3: Design of steel structures. Part 1-1: General rules and rules for buildings.
- Eurocode 3: Design of steel structures. Part 1-8: Design of joints.

The selected values for the NDP's in the following calculations are:

Parameter	γ_c	γ_s	α_{cc}	α_{ct}
Value	1,5	1,15	0,85	0,85

Table 1: NDP-s in EC2.

Parameter	γ_{M0}	γ_{M1}	γ_{M2}
Value	1,1	1,1	1,25

Table 2: NDP-s in EC3.

1.3 QUALITIES

Concrete C35/45: $f_{ck} = 35,0$ MPa — EC2, Table 3.1

$f_{cd} = \alpha_{cc} \times f_{ck}/\gamma_c = 0,85 \times 35/1,5 = 19,8$ MPa — EC2, Clause 3.15

$f_{ctd} = \alpha_{ct} \times f_{ctk,0,05}/\gamma_c = 0,85 \times 2,2/1,5 = 1,24$ MPa — EC2, Clause 3.16

$f_{bd} = 2,25 \times \eta_1 \times \eta_2 \times f_{ctd} = 2,25 \times 1,0 \times 1,0 \times 1,24 = 2,79$ MPa — EC2, Clause 8.4.2

Note: For simplicity, good bond conditions are assumed when calculating f_{bd}. This assumption may not be correct in all situations and has to be evaluated in each case. EC2 indicates poor bond conditions for anchoring in top of the beam.

Reinforcement 500C (EN 1992-1-1, Annex C): $f_{yd} = f_{yk}/\gamma_s = 500/1,15 = 435$ MPa — EC2, Clause 3.2.

Note: *Reinforcement steel of different qualities may be chosen provided that the calculations take into account the actual yield strength ($f_y \leq 500$ MPa) and that the bendability is sufficient for fitting the vertical suspension reinforcement to the half round steel.*

Steel Sxxx (EN 10025-2):

Steel S355:
- Tension: $f_{yd} = f_y/\gamma_{M0} = 355/1,1 = 322$ MPa
- Compression: $f_{yd} = f_y/\gamma_{M0} = 355/1,1 = 322$ MPa
- Shear: $f_{sd} = f_y/(\gamma_{M0} \times \sqrt{3}) = 355/(1,1 \times \sqrt{3}) = 186$ MPa

Weld S355: $$f_{w,d} = \frac{f_u}{\gamma_{M2}\sqrt{3}} \times \frac{1}{\beta_w} = \frac{510}{1{,}25 \times \sqrt{3}} \times \frac{1}{0{,}9} = 262 MPa$$

Threaded bars/nut:

8.8 quality steel: $f_{yd} = 0{,}9 \times f_u / \gamma_{M2} = 0{,}9 \times 800/1{,}25 = 576$ MPa

1.4 DIMENSIONS AND CROSS-SECTION PARAMETERS

UNIT	HALF ROUND STEEL			HORIZONTAL ANCHORING[1]	INTERNAL OPENING BEAM BOX (WIDTH×HEIGHT×DEPTH)
	D [mm]	L [mm]	Steel grade		
BSF225 BEAM BOX	Ø76	100	S355	2×M12, 8.8+ nut, L=to be decided & st.pl.50×50×8, S355	30mm×215mm×80mm
BSF300 BEAM BOX	Ø76	100	S355	2×M12, 8.8+ nut, L= to be decided & st.pl.50×50×8, S355	30mm×255mm×80mm
BSF450 BEAM BOX	Ø76	100	S355	1×M20, 8.8+ nut, L= to be decided & st.pl.90×90×12, S355	40mm×270mm×92,5mm
BSF700 BEAM BOX	Ø175	140	S355	2×M20, 8.8+ nut, L= to be decided & st.pl.160×90×12, S355	50mm×310mm×105mm

Table 3: Dimensions – BSF beam box.

[1] ***See also Table 4. Note: The steel plate anchoring both the M20 bars for the BSF700 is designed only for the actual design force of 210kN, not the tensile capacity of two M20 bars.***

NOMINAL DIAMETER	M12	M16	M20
Equivalent diameter: $\varnothing_{eq}$ [mm]	10,4	14,1	17,7
Stress area: A_s [mm^2]	84	157	245
Tensile capacity (8.8): $F_{cap}= f_{yd} \times A_s$ [kN]	48	90	141
With across flats: NV [mm]	19	24	30
Required dim. of square steel plate anchoring F_{cap}[2] $b_{req} \geq [F_{cap}/f_{cd}+\pi \times \varnothing^2_{nom}/4]^{0.5}$ [mm] Select b×b	≈50,4 Select 50×50	69 Select 70×70	86 Select 90×90
Net area for compression anchorage: $A_{net}=A_{steel\ plate}-\pi \times \varnothing^2_{nom}/4$ [mm^2]	2387	4699	7786
Concrete stress: $\sigma_c=F_{cap}/A_{net}$ [MPa]	20,1	19,1	18,1
Required thickness of steel plate, S355:[2] $a=(2^{0.5} \times b\text{-NV})/2$ -> $t_1 \geq a \times (\sigma_c/f_{yd})^{0,5}$[mm] $c=b/2\text{-NV}/2$ -> $t_2 \geq 3^{0,5} \times c \times (\sigma_c/f_{yd})^{0,5}$[mm] $t>[t_1, t_2]$	a=25,9 t_1=6,5 c=15,5 t_2=6,7 Select t=8mm	a=37,5 t_1=9,1 c=23 t_2=9,7 Select t=10mm	a=48,6 t_1=11,5 c=30 t_2=12,3 Select t=12mm
Standard height of nut: (H) [mm]	10,0	13,0	16,0
Required thread length in blind holes: S355	18mm	24mm	30mm

Table 4: Dimensions - threaded bars and anchoring steel plates.

[2] ***An illustration, and background for the formulas, can be found in the Memo "BSF-Design of steel units". The listed dimensions are based on the concrete quality and parameters given in Section 1.2 and Section 1.3.***
Note: The steel plate anchoring both the M20 bars for the BSF700 is designed only for the actual design force of 210kN, not the tensile capacity of two M20 bars.

1.5 LOADS

Vertical ultimate limit state load: F_V= According to Table 5.
Horizontal ultimate limit state load - in axial direction: F_H=0kN (see notes below)
Horizontal ultimate limit state load - in transverse direction: F_T=0kN

***Note on loads:**

- The BSF beam box is a product designed to transfer primarily vertical load.

- Significant horizontal loading on the unit may also occur if imposed deformation (shrinkage, temperature differences etc.) in the pre-cast element is resisted. When the occurring horizontal force exceeds the potential friction force the knife will slide and the force will be partly relieved. The static friction factor steel-steel at support is assumed to be within the range (0,2-0,5). The maximum friction force due to gradually increasing imposed deformations will however be associated with vertical service loads. The steel parts of the unit, and anchoring of these parts into the concrete are designed for the following unfavorable load combination:

  Vertical force 1,0F_v + Horizontal force 0,3F_v

- In some cases transfer of static global horizontal load via the unit may be requested. The magnitude of this force would be limited by the minimum friction factor at the support and vertical load present at the same time. This will imply uncertainty in resistance, and it's recommended to transfer the horizontal forces by proper reinforcement through the joint. In case of dynamic loads, the horizontal resistance should always be assumed to be zero.

- Horizontal anchoring of the steel parts assumes minimum concrete grade C35 in column and beam.

UNIT	VERTICAL ULTIMATE LIMIT STATE LOAD F_v [kN]	LOAD BEAM BOX	
		VERT. 1,0F_v [kN]	HOR. 0,3F_v [kN]
BSF225	225	225	67,5
BSF300	300	300	90
BSF450	450	450	135
BSF700	700	700	210

Table 5: Design loads

1.6 TOLERANCES

The design nominal gap between two beams is 20mm, with a tolerance of ±10mm.The tolerances are handled with the cantilevering of the knife from the beam. If the gap is 30mm, the knife is pushed out an extra 10mm and vice versa if the gap is only 10mm. Thus, the load point in the beam box will always be the same. The knife shall always be pushed out until it bottoms against the back of the beam box.
The tolerance on location of the reinforcement for the beam box is ±2mm.

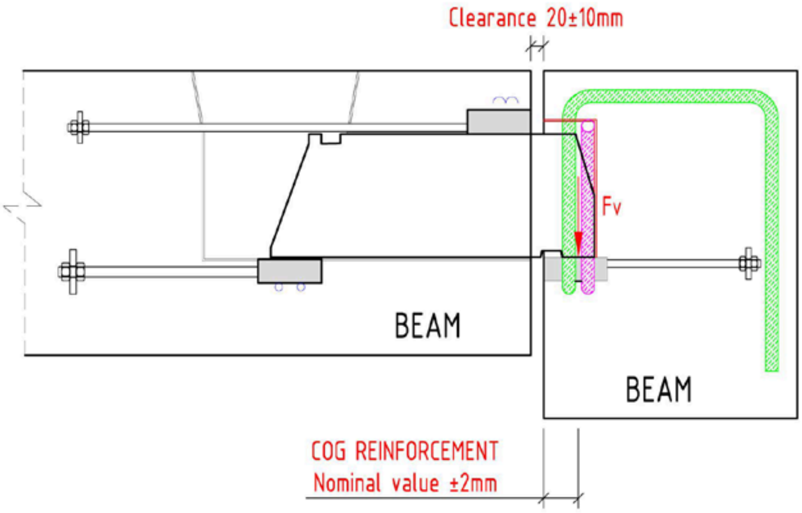

Figure 1: Tolerances.

PART 2 PRINCIPAL DESIGN OF REINFORCEMENT - BSF BEAM BOX

2.1 BEAM BOX - EQUILIBRIUM

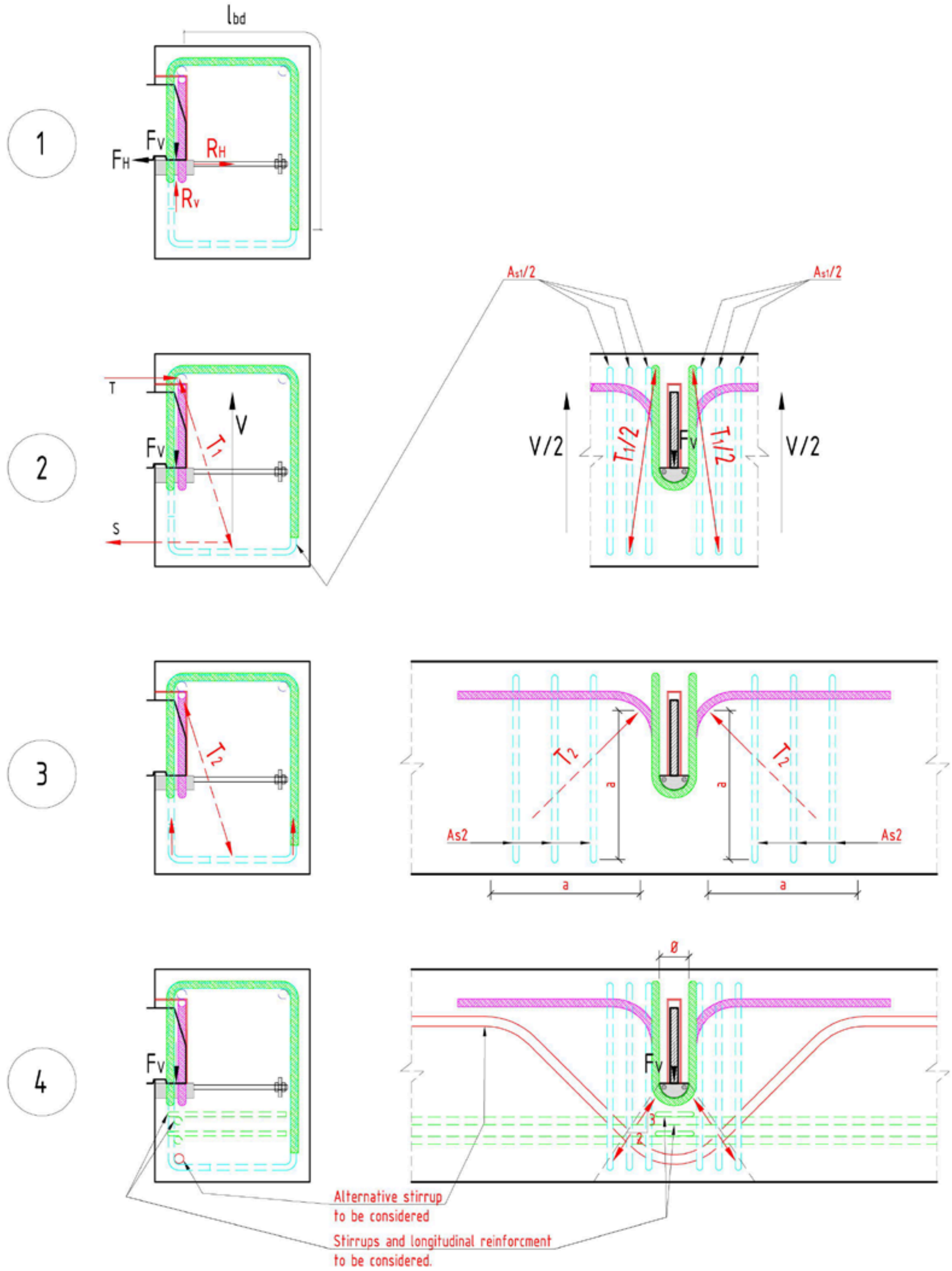

Figure 2: Equilibrium.

The assumed flow of forces is illustrated in Figure 2:

1) Vertical force: Suspension reinforcement designed for the load is to be placed at the load point$\Rightarrow$ $R_V=F_V$. The suspension reinforcement is anchored both inwards in the cross section, and in the longitudinal direction of the main beam.
Horizontal force: Anchored with threaded bars. The bending moment associated with the small vertical shift in the horizontal force is neglected. The length of the threaded bar is to be decided in each case. Proper depth of the anchoring must be ensured.

2) The assumed flow of forces for the beam section in order to transfer the load F_v into the shear center of the beam (drawing two in fig. 2) shows a compression strut (T_1) directed from the upper left corner towards the center of the beam. Proper reinforcement in order to take the horizontal force S in this strut is required at the bottom of the beam. Reasonableness of this force model must be controlled in each case. In normal beams, the horizontal force will be less than the vertical force. However, in low/wide beams the horizontal force will exceed the vertical force and the strut and tie model should be revised.
Depending on the ratio of suspension reinforcement anchored inwards in the cross section, an equal ratio of the compression strut (T_1) will be anchored towards the bend of these bars. Thus, the anchor length for the suspension reinforcement bent inwards shall be measured from the end of the upper left bend. The remaining part of the diagonal force will be anchored towards the bend of the shear stirrups.

3) Suspension reinforcement anchored in the longitudinal direction of the beam will cause a compression strut (T_2). Sufficient vertical reinforcement A_{s2} within a distance, a, to each side of the beam must be ensured. Normally the shear stirrups designed for the occurring shear force in the beam will be sufficient for this purpose.

4) In high beams a part of the vertical force may spread into the concrete below the unit. Stirrups within a distance 2/3H (H=height below unit) to both sides of the unit will contribute to collect this force. (Note: only one leg per stirrup is active). Alternatively, a stirrup shaped as illustrated red in the figure may be used.

Based on the issued mentioned in above clauses 2-4 it is recommended to always include extra stirrups close to the unit. These stirrups shall have a total cross-section (Note: only on leg per stirrup to go into the summation) equal to the calculated required amount of suspension reinforcement. The reinforcement is to be placed with one half on each side of the unit.

Use of horizontal stirrups and longitudinal reinforcement to safeguard splitting forces below the unit must be considered.

2.2 BEAM BOX – ANCHORING REINFORCEMENT

1) Required cross section area of suspension reinforcement (and stirrups close to the unit):

$$A_s = \frac{F_V}{f_{yd}}$$

2) Mandrel diameter – Bending of reinforcement- EC2, clause 8.3:

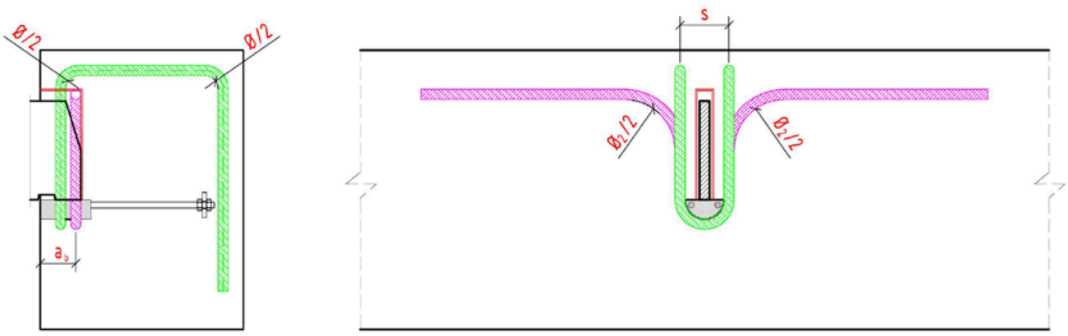

Figure 3: Bending of reinforcement.

Reinforcement anchored inwards in the cross section: $Ø = F \times \left[\frac{1/(s/2) + 1/(2Ø)}{f_{cd}} \right]$

Reinforcement anchored in the longitudinal direction: $Ø_2 = F \times \left[\frac{1/a_b + 1/(2Ø)}{f_{cd}} \right]$

In addition: EC2, clause.8.3: $Ø_{min}$=64mm for Ø16mm og 175mm for Ø>25mm

$\Rightarrow$ Select mandrel diameter

3) Anchoring of reinforcement - EC2, clause. 8.4.3 and 8.4.4:

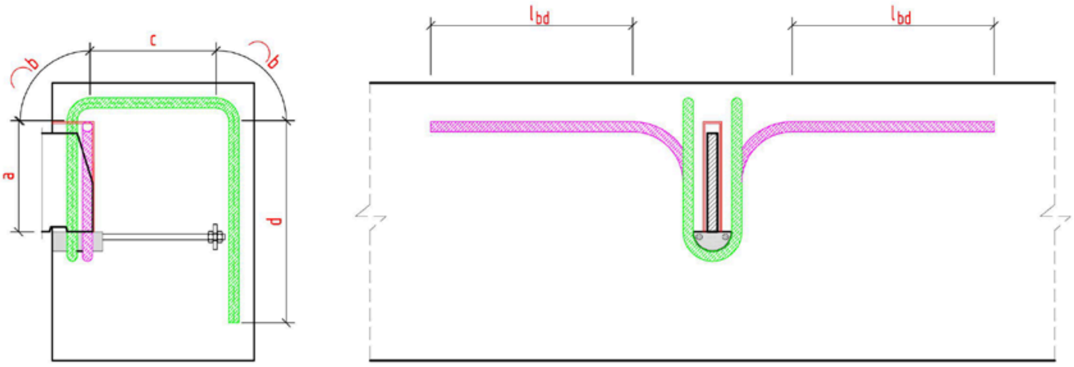

Figure 4: Anchoring of reinforcement

$l_{bd} = \alpha_1 \times \alpha_2 \times \alpha_3 \times \alpha_4 \times \alpha_5 \times l_{b,reqd} \geq l_{b,min}$

Assume: $\alpha_1 \times \alpha_2 \times \alpha_3 \times \alpha_4 \times \alpha_5 = 1{,}0$

$$l_{bd} = l_{b,reqd} = \frac{\varnothing}{4} \times \frac{\sigma_{sd}}{f_{bd}}$$

For the reinforcement anchored inwards in the cross-section, the anchoring length is: l_{bd}=c+b+d, see Figure 4 and the evaluations in section 2.1. Transverse reinforcement in the anchoring zone must be specified in accordance with EC2.

2.3 BEAM BOX – HORIZONTAL ANCHORING

The beam box is anchored for a total horizontal load of $F_H=0{,}3F_V$. The knife will be in contact with the half round steel and the horizontal force is transferred by friction between the two steel parts. The half round steel is anchored with threaded bars.

The required dimension of threaded bar and machined thread lengths in the half round steel is found from Table 4. The length of the threaded bars shall be adapted to the width of the beam. Proper depth of the anchoring must be ensured.

2.4 MAIN BEAM -TORSION

Due to the short length of the beam box, the secondary beam will probably never transfer the load to the center of gravity of the main beams cross section. Thus, it is recommended to always establish connections between the main- and the secondary beam to lock the torsion caused by the eccentric loading. If this is not done, the main beam and its supports have to be designed for the torsion. In addition, the force must be followed all the way through the rest of the construction.

The required tension/compression force in the joint between the secondary and main beam to lock the torsion becomes (see Figure 5):

$$S=T=F_v \times a/h$$

Detailing of the connections must be done in each case based on the geometry and magnitude of the forces. There are several possible solutions. Figure 5 illustrates a solution with steel plates embedded in both beams, connected with a welded steel plate. The compression force at top of the beam goes through the concrete in the joint. (Note: The figure is an illustration, no calculations has been carried out)

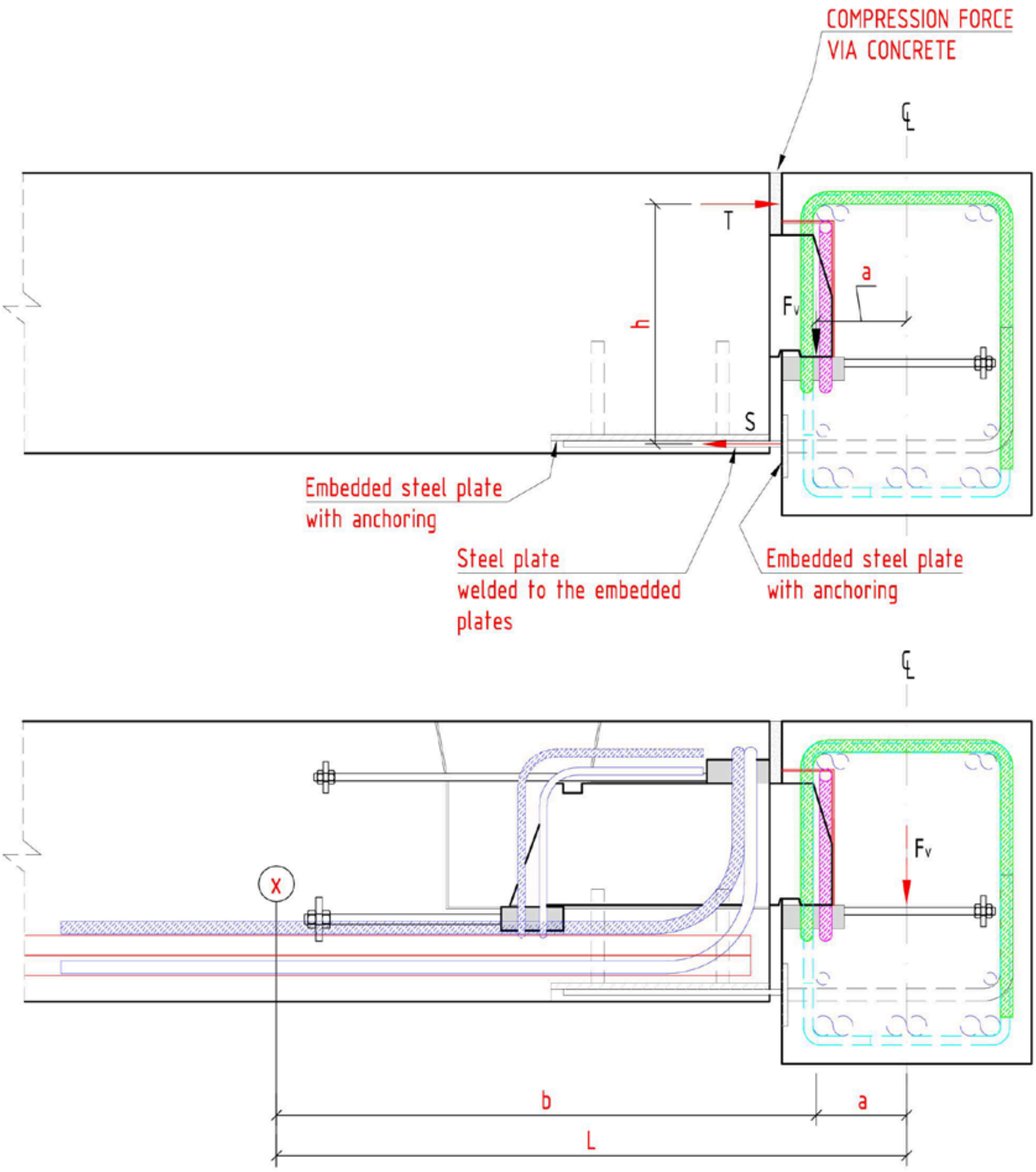

Figure 5: Lock of torsion –main beam.

Note:

- The theoretical span for the secondary beam increases when the lock of torsion is included. The span will continue to the center of the main beam. Alternatively, a bending moment may be applied to the end of the secondary beam in the calculations, see Figure 5: $M = F_v \times a$

- Following from the first note: The anchoring in the main reinforcement in every point (x) along the secondary beam, shall be designed for a tension force, see Figure 5:

  $S = M/z = F_v \times L/z$ (not only $F_v \times b/z$)

  (Example of anchoring of reinforcement for the normal situation is found in Memo 521.)

PART 3 BSF 225

3.1 BEAM BOX – ANCHORING REINFORCEMENT

1) Required cross section for reinforcement:

$$A_s = \frac{F_V}{f_{yd}} = \frac{225kN}{435MPa} = 517mm^2$$

2Ø16 stirrups= $201mm^2$x4=$804mm^2$

Capasity of selected reinforcement: $804mm^2$×435MPa=349kN

Compression strut T_1:

$A_{s1}=A_s$

Extra stirrups in the main beam close to the unit: 3+3 stirrups Ø12=$113mm^2$x6=$678mm^2$

Compression strut T_2:

$$A_{s2} = \frac{F_V/4}{f_{yd}} = \frac{225kN}{435MPa \times 4} = 130mm^2$$

Control: shear reinforcement within distance a > $130mm^2$

2) Mandrel diameter – Bending of reinforcement - EC2, clause 8.3:

Reinforcement anchored inwards in the cross section:

$$Ø = F \times \left[\frac{1/(s/2) + 1/(2Ø)}{f_{cd}} \right] = 225000N/4 \times \left[\frac{1/(96/2) + 1/(2 \times 16)}{19.8} \right] = 148mm$$

Minimum: 4×Ø=4×16=64mm

⇒ Select: Ø=80mm and bend around reinforcement in top of beam (minimum Ø16 in top of beam)

Reinforcement anchored in the longitudinal direction of the beam:

$$Ø_2 = F \times \left[\frac{1/a_b + 1/(2Ø)}{f_{cd}} \right] = 225000N/4 \times \left[\frac{1/70 + 1/(2 \times 16)}{19.8} \right] = 130mm$$

⇒ Select: $Ø_2$=200mm

3) Anchoring of reinforcement, EC2 clause 8.4.3 and 8.4.4:

$l_{bd} = \alpha_1 \times \alpha_2 \times \alpha_3 \times \alpha_4 \times \alpha_5 \times l_{b,reqd} \geq l_{b,min}$

$l_{b,reqd} = \frac{Ø}{4} \times \frac{\sigma_{sd}}{f_{bd}}$

Stress in reinforcement: $\sigma_{sd} = \frac{225kN}{804mm^2} = 280MPa$

$l_{b,reqd} = \frac{16}{4} \times \frac{280}{2,79} = 401mm$

$l_{b,min}$ = max(0,3×$l_{b,reqd}$; 10×Ø; 100mm)=160mm

l_{bd} = 1,0×1,0×1,0×1,0×1,0×401mm=401mm

⇒Reinforcement bent in longitudinal direction: Select: l=400mm

⇒Reinforcement bent inwards: 220mm+141mm+385mm=746mm>401mm ⇒OK!

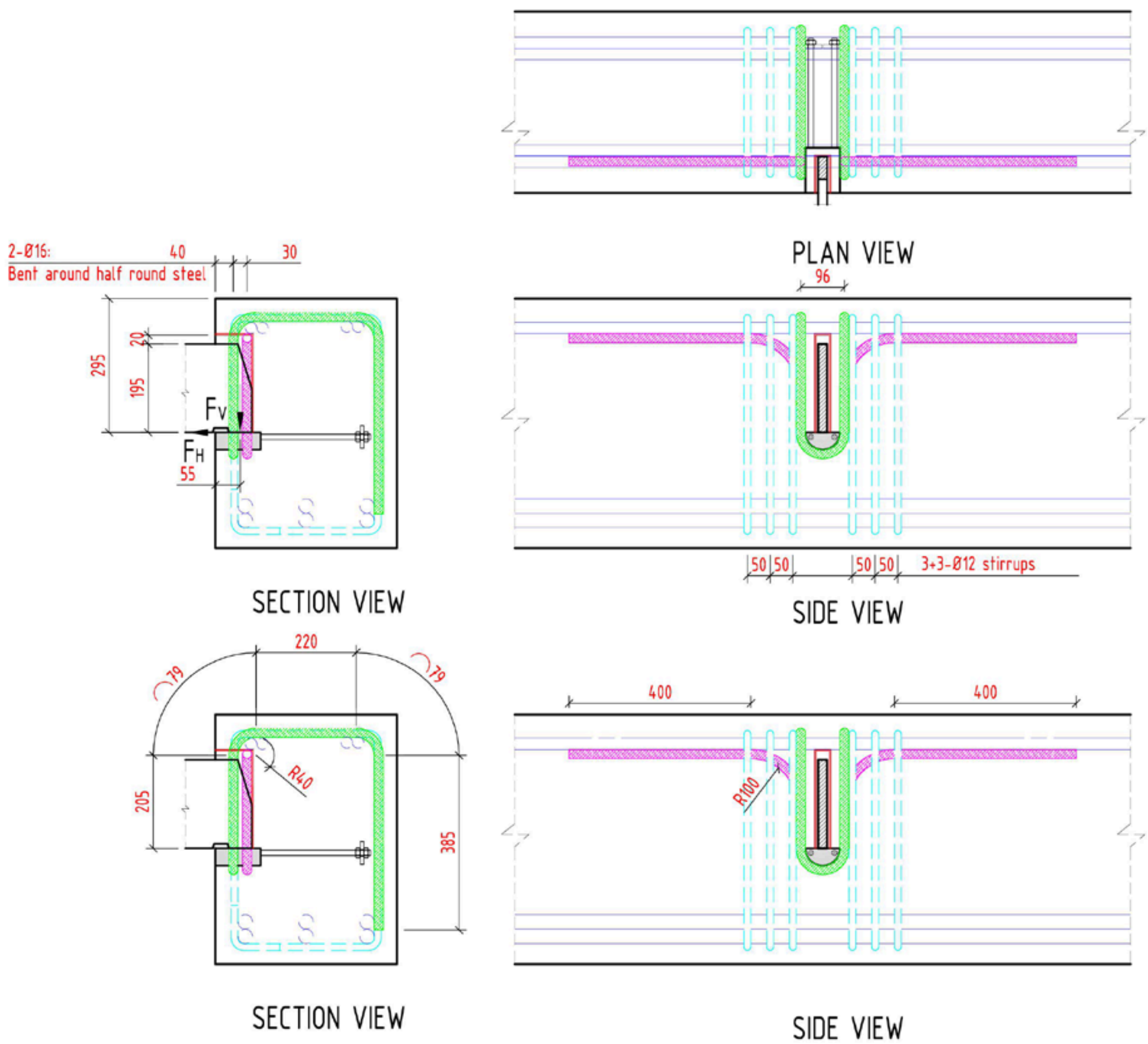

Figure 6: Illustration.

Note: The figure illustrates only the calculated suspension reinforcement and the extra stirrups close to the unit. The beam shall of cause have proper shear reinforcement/stirrups in every point, also in-between the illustrated stirrups. The other issues mentioned in chapter 2.1 (transverse reinforcement, stirrups below the unit, longitudinal reinforcement along beam edge, etc.) has not been evaluated. These issues must be addressed in each case by qualified engineer.

3.2 BEAM BOX – HORIZONTAL ANCHORING

Horizontal anchoring of half round steel: R_H=0,3×F_V=67,5kN:

Select: 2×M12 threaded bars, 8.8 with nut & steel plate = 48kN×2=96kN

Proper anchoring depth to avoid tearing of concrete cone must be ensured.

PART 4 BSF 300

4.1 BEAM BOX – ANCHORING REINFORCEMENT

1) Required cross section for reinforcement:

$$A_s = \frac{F_V}{f_{yd}} = \frac{300kN}{435MPa} = 689mm^2$$

2Ø16 stirrups= 201mm^{2}x4=804mm^2

Capasity of selected reinforcement: 804mm^2×435MPa=349kN

Compression strut T_1:

A_{s1}=A_s

Extra stirrups in the main beam close to the unit: 3+3 stirrups Ø12=113mm^{2}x6=678mm^2 (≈689mm^2 ok)

Compression strut T_2:

$$A_{s2} = \frac{F_V/4}{f_{yd}} = \frac{300kN}{435MPa \times 4} = 172mm^2$$

Control: shear reinforcement within distance a > 172mm^2

2) Mandrel diameter – Bending of reinforcement - EC2, clause 8.3:

Reinforcement anchored inwards in the cross section:

$$\varnothing = F_V \times \left[\frac{1/(s/2) + 1/(2\varnothing)}{f_{cd}} \right] = 300000N/4 \times \left[\frac{1/(96/2) + 1/(2\times16)}{19.8} \right] = 197mm$$

Minimum: 4×Ø=4×16=64mm

⇒ Select: Ø=80mm and bend around reinforcement in top of beam (minimum Ø16 in top of beam)

Reinforcement anchored in the longitudinal direction of the beam:

$$\varnothing_2 = F_V \times \left[\frac{1/a_b + 1/(2\varnothing)}{f_{cd}} \right] = 300000N/4 \times \left[\frac{1/70 + 1/(2\times16)}{19.8} \right] = 174mm$$

⇒ Select: $\varnothing_2$=200mm

3) Anchoring of reinforcement, EC2 clause 8.4.3 and 8.4.4:

$l_{bd} = \alpha_1 \times \alpha_2 \times \alpha_3 \times \alpha_4 \times \alpha_5 \times l_{b,reqd} \geq l_{b,min}$

$$l_{b,reqd} = \frac{\varnothing}{4} \times \frac{\sigma_{sd}}{f_{bd}}$$

Stress in reinforcement: $\sigma_{sd} = \dfrac{300kN}{804mm^2} = 373MPa$

$$l_{b,reqd} = \frac{16}{4} \times \frac{373}{2,79} = 535\text{mm}$$

$l_{b,min}$ = max(0,3×$l_{b,reqd}$; 10×Ø; 100mm)=160mm

l_{bd} = 1,0×1,0×1,0×1,0×1,0×535mm=535mm

⇒Reinforcement bent in longitudinal direction: Select: l=550mm

⇒Reinforcement bent in longitudinal direction:220mm+141mm+385mm=746mm>535mm ⇒OK!

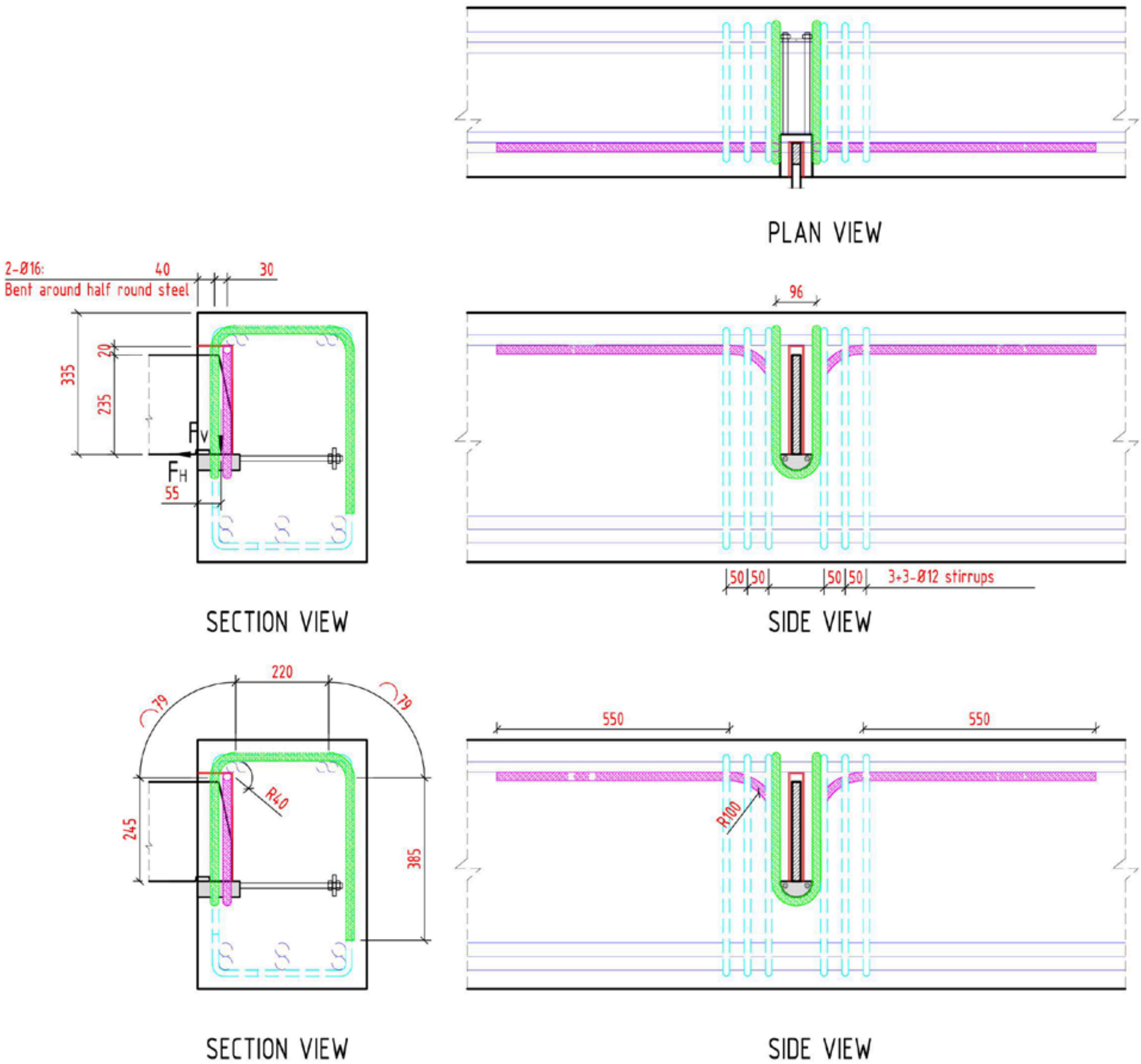

Figure 7: Illustration.

Note: The figure illustrates only the calculated suspension reinforcement and the extra stirrups close to the unit. The beam shall of cause have proper shear reinforcement/stirrups in every point, also in-between the illustrated stirrups. The other issues mentioned in chapter 2.1 (transverse reinforcement, stirrups below the unit, longitudinal reinforcement along beam edge, etc.) has not been evaluated. These issues must be addressed in each case by qualified engineer.

4.2 BEAM BOX – HORIZONTAL ANCHORING

Horizontal anchoring of half round steel: R_H=0,3×F_V=90kN:

Select: 2×M12 threaded bars, 8.8 with nut & steel plate= 48kN×2=96kN

Proper anchoring depth to avoid tearing of concrete cone must be ensured.

PART 5 BSF 450

5.1 BEAM BOX – ANCHORING REINFORCEMENT

1) Required cross section for reinforcement:

$$A_s = \frac{F_V}{f_{yd}} = \frac{450kN}{435MPa} = 1035mm^2$$

3Ø16 stirrups= 201mm^{2}x6=1206mm^2

Capasity of selected reinforcement: 1206mm^2×435MPa=524kN

Compression strut T_1:

A_{s1}=A_s

Extra stirrups in the main beam close to the unit: 3+3 double stirrups Ø12=113mm^2×6×2=1356mm^2

Compression strut T_2:

$$A_{s2} = \frac{F_V/6}{f_{yd}} = \frac{450kN}{435MPa \times 6} = 172mm^2$$

Control: shear reinforcement within distance a > 172mm^2

2) Mandrel diameter – Bending of reinforcement - EC2, clause 8.3:

Reinforcement anchored inwards in the cross section:

$$Ø = F_V \times \left[\frac{1/(s/2) + 1/(2Ø)}{f_{cd}} \right] = 450000N/6 \times \left[\frac{1/(90/2) + 1/(2\times16)}{19.8} \right] = 202mm$$

Minimum: 4×Ø=4×16=64mm

⇒ Select: Ø=320mm for one of the bars.

⇒ Select: Ø=80mm and bend around reinforcement in top of beam (minimum Ø16 in top of beam)

Reinforcement anchored in the longitudinal direction of the beam:

$$\O_2 = F_V \times \left[\frac{1/a_b + 1/(2\O)}{f_{cd}} \right] = 450000N/6 \times \left[\frac{1/62.5 + 1/(2\times16)}{19.8} \right] = 179mm$$

$\Rightarrow$ Select: $\O_2$=200mm

3) Anchoring of reinforcement, EC2 clause 8.4.3 and 8.4.4:

$l_{bd} = \alpha_1\times\alpha_2\times\alpha_3\times\alpha_4\times\alpha_5\times l_{b,reqd} \geq l_{b,min}$

$l_{b,reqd} = \dfrac{\O}{4} \times \dfrac{\sigma_{sd}}{f_{bd}}$

Stress in reinforcement: $\sigma_{sd} = \dfrac{450kN}{1206mm^2} = 373MPa$

$l_{b,reqd} = \dfrac{16}{4} \times \dfrac{373}{2{,}79} = 535$mm

$l_{b,min} = \max(0{,}3\times l_{b,reqd};\ 10\times\O;\ 100mm) = 160$mm

$l_{bd} = 1{,}0\times1{,}0\times1{,}0\times1{,}0\times1{,}0\times535mm = 535mm$

$\Rightarrow$Reinforcement bent in longitudinal direction: Select: l=550mm

$\Rightarrow$Reinforcement bent in longitudinal direction: 330mm+365mm=695mm>535mm $\Rightarrow$OK!

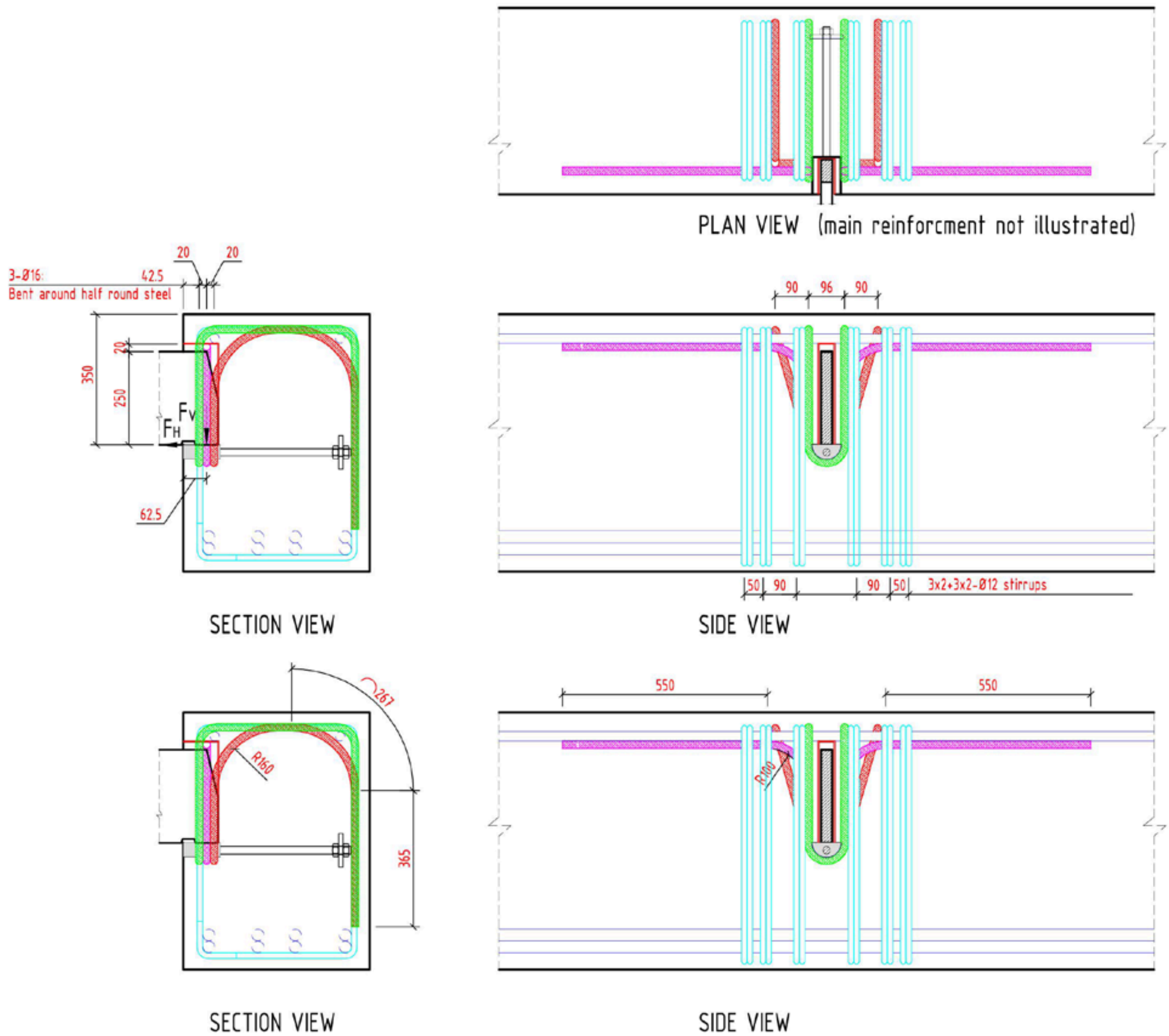

Figure 8: Illustration

Note: The figure illustrates only the calculated suspension reinforcement and the extra stirrups close to the unit. The beam shall of cause have proper shear reinforcement/stirrups in every point, also in-between the illustrated stirrups. The other issues mentioned in chapter 2.1 (transverse reinforcement, stirrups below the unit, longitudinal reinforcement along beam edge, etc.) has not been evaluated. These issues must be addressed in each case by qualified engineer.

5.2 BEAM BOX – HORIZONTAL ANCHORING

Horizontal anchoring of half round steel: R_H=0,3×F_V=135kN:

Select: 1×M20 threaded bars, 8.8 with nut & steel plate= = 141kN

Proper anchoring depth to avoid tearing of concrete cone must be ensured.

PART 6 BSF 700

6.1 BEAM BOX – ANCHORING REINFORCEMENT

1) Required cross section for reinforcement:

$$A_s = \frac{F_V}{f_{yd}} = \frac{700kN}{435MPa} = 1609mm^2$$

2Ø25 stirrups= 490mm^{2}x4=1960mm^2

Capasity of selected reinforcement: 1960mm^2×435MPa=852kN

Compression strut T_1:

A_{s1}=A_s

Extra stirrups in the main beam close to the unit: 4+4 double stirrups Ø12=113mm^2×8×2=1808mm^2

Compression strut T_2:

$$A_{s2} = \frac{F_V/4}{f_{yd}} = \frac{700kN}{435MPa \times 4} = 402mm^2$$

Control: shear reinforcement within distance a > 402mm^2

2) Mandrel diameter – Bending of reinforcement - EC2, clause 8.3:

Reinforcement anchored inwards in the cross section:

$$Ø = F_V \times \left[\frac{1/(s/2) + 1/(2Ø)}{f_{cd}} \right] = 700000N/4 \times \left[\frac{1/(232/2) + 1/(2 \times 25)}{19.8} \right] = 252mm$$

Minimum:=7×Ø=7×25mm=175mm

⇒ Select: Ø=320mm

Reinforcement anchored in the longitudinal direction of the beam:

$$Ø_2 = F_V \times \left[\frac{1/a_b + 1/(2Ø)}{f_{cd}} \right] = 700000N/4 \times \left[\frac{1/91mm + 1/(2 \times 25mm)}{19.8MPa} \right] = 274mm$$

$\Rightarrow$ Select: $Ø_2$=320mm

3) Anchoring of reinforcement, EC2 clause 8.4.3 and 8.4.4:

$l_{bd} = \alpha_1 \times \alpha_2 \times \alpha_3 \times \alpha_4 \times \alpha_5 \times l_{b,reqd} \geq l_{b,min}$

$$l_{b,reqd} = \frac{Ø}{4} \times \frac{\sigma_{sd}}{f_{bd}}$$

Stress in reinforcement: $\sigma_{sd} = \frac{700kN}{1960mm^2} = 357MPa$

$$l_{b,reqd} = \frac{25}{4} \times \frac{357}{2,79} = 800\text{mm}$$

$l_{b,min}$ = max(0,3×$l_{b,reqd}$; 10×Ø; 100mm)=250mm

l_{bd} = 1,0×1,0×1,0×1,0×1,0×800mm=800mm

$\Rightarrow$ Reinforcement bent in longitudinal direction: Select: l=800mm

$\Rightarrow$ Reinforcement bent in longitudinal direction: 198mm+278mm+496mm=972mm>800mm $\Rightarrow$OK!

Stirrups in the anchoring zone of the bar bent inwards shall always be included, see also EC2 clause. 8.7.4

$\sum A_{st} = A_s$=490mm^2 $\Rightarrow$ 4Ø10=4×2×78mm^2= 624mm^2

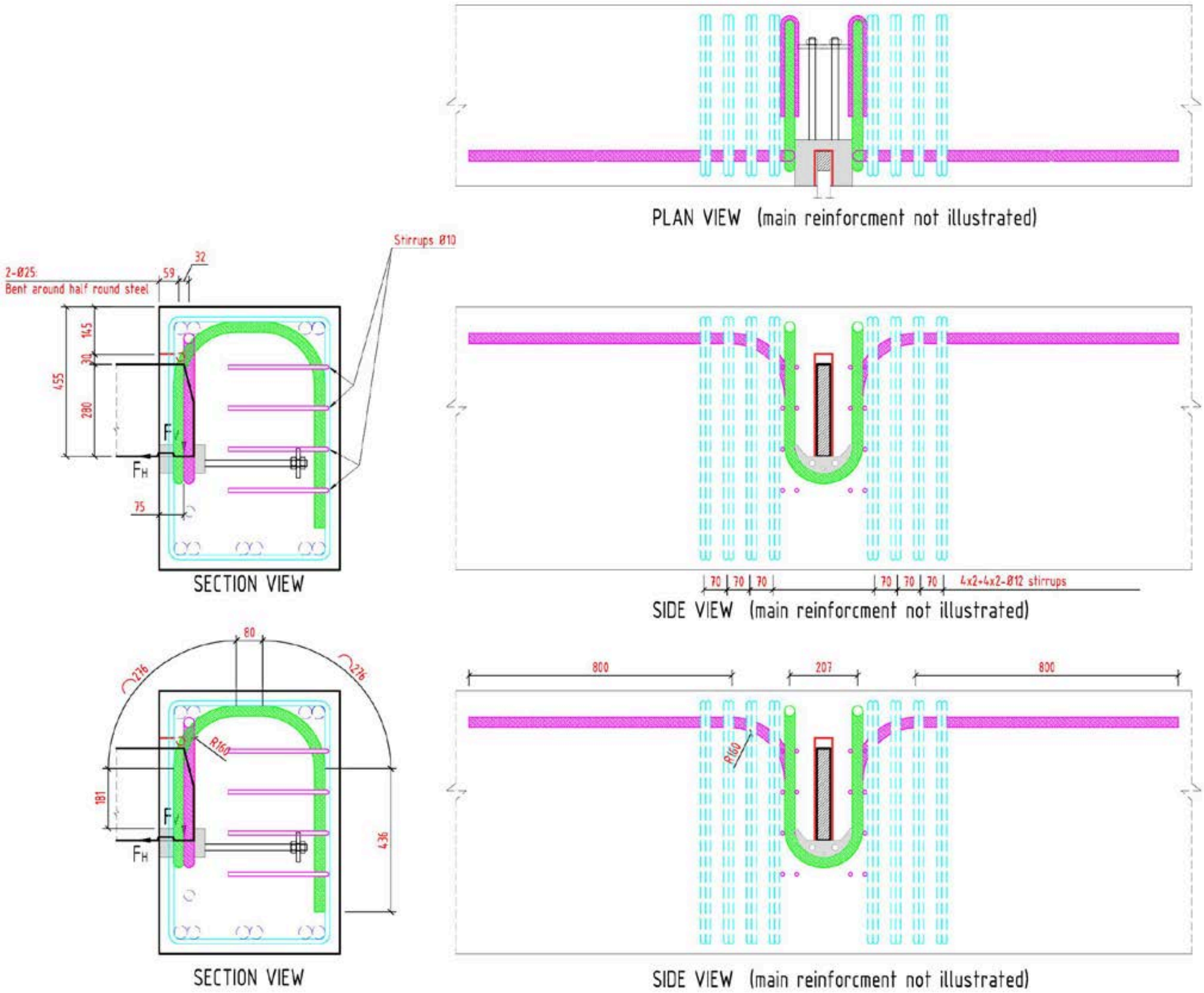

Figure 9: Illustration.

Note: The figure illustrates only the calculated suspension reinforcement and the extra stirrups close to the unit. The beam shall of cause have proper shear reinforcement/stirrups in every point. Transverse stirrups in the anchoring length of the Ø25 bar bent inwards shall always be included for this unit. The other issues mentioned in chapter 2.1 (stirrups below the unit, longitudinal reinforcement along beam edge, etc.) has not been evaluated. These issues must be addressed in each case by qualified engineer.

6.2 BEAM BOX – HORIZONTAL ANCHORING

Horizontal anchoring of half round steel: R_H=0,3×F_V=210kN:

Select: 2×M20 threaded bars, 8.8 with nut & steel plate = 210kN (limited by selected steel-plate)

Proper anchoring depth to avoid tearing of concrete cone must be ensured.

REVISION	
Date:	**Description:**
21.10.2013	First edition.
30.06.2014	Changed the half round steel on the BSF700 unit. Updated Table 1.
20.08.2014	Changed position of the M20 threaded bars in the half round steel BSF 700 unit. Changed steel plate anchoring M20 threaded bars BSF 700 unit.
13.01.2015	Updated Table 4. Required thread length in blind holes.
23.01.2015	Specified in Section 1.1 that this Memo only give an example with respect to load bearing model, calculations and reinforcement detailing. Corrected figure 6, 7, 8 & 9.
27.02.2015	Included a nut on the front side of the steel plate anchoring the threaded bars. (To ensure correct position of the plate when casting the concrete).
24.05.2016	New template.