MEMO 54d

MEMO TSS 101 REINFORCEMENT DESIGN DESIGN	Dato: 26.04.2011 Siste rev.: 25.05.2016 Dok. nr.: K3-10/54dE	Sign.: sss Sign.: sss Control: ps

REINFORCEMENT DESIGN FOR TSS 101

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PART 1 – BASIC ASSUMTIONS

GENERAL

The following calculations of anchorage of the units and the corresponding reinforcement must be considered as an example illustrating the design model.

It must always be checked that the forces from the anchorage reinforcement can be transferred to the main reinforcement of the concrete components. The recommended reinforcement includes only the reinforcement necessary to anchor the unit to the concrete.

In the vicinity of the unit the element must be designed for the force R_1.

STANDARDS

The calculations are carried out 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.
- EN 10080: Steel for the reinforcement of concrete. Weldable reinforcing steel. General.

For all NDPs (Nationally Determined Parameter) in the Eurocodes the recommended values are used.

NDP's are as follows:

Parameter	γ_c	γ_s	α_{cc}	α_{ct}
Recommended value	1.5	1.15	1.0	1.0

Table 1: NDP-s in EC-2.

Parameter	γ_{M0}	γ_{M1}	γ_{M2}
Recommended value	1.0	1.0	1.25

Table 2: NDP-s in EC-3.

QUALITIES

Concrete grade C35/45:

$f_{ck} = 35,0$ MPa — EC2, Table 3.1

$f_{cd} = \alpha_{cc} \cdot f_{ck} / \gamma_c = 1 \cdot 35/1,5 = 23,3$ MPa — EC2, Pt.3.15

$f_{ctd} = \alpha_{ct} \cdot f_{ctk,0,05} / \gamma_c = 1 \cdot 2,20/1,5 = 1,46$ MPa — EC2, Pt.3.16

$f_{bd} = 2,25 \cdot \eta_1 \cdot \eta_2 \cdot f_{ctd} = 2,25 \cdot 0,7 \cdot 1,0 \cdot 1,46 = 2,3$ MPa — EC2, Pt.8.4.2

Reinforcement 500C (EN 1992-1-1, Annex C):

$f_{yd} = f_{yk} / \gamma_s = 500/1,15 = 435$ MPa — EC2, Clause 3.2.7

Note: *Reinforcement steel of different ductility grade may be chosen provided that the bendability is sufficient for fitting the vertical suspension reinforcement to the half round steels in front of the unit.*

Structural steel S355:

Tension: $f_{yd} = f_y / \gamma_{M0} = 355/1,0 = 355$ MPa

Compression: $f_{yd} = f_y / \gamma_{M0} = 355/1,0 = 355$ MPa

Shear: $f_{sd} = f_y / (\gamma_{M0} \cdot \sqrt{3}) = 355/(1,0 \cdot \sqrt{3}) = 205$ MPa

DIMENSIONS

Inner tube: HUP 100x50x6, Cold formed, S355

Outer tube: HUP 120x60x4, Cold formed, S355

LOADS

Vertical ultimate limit state load = F_V = 100kN.

PART 2 - REINFORCEMENT

EQUILIBRIUM

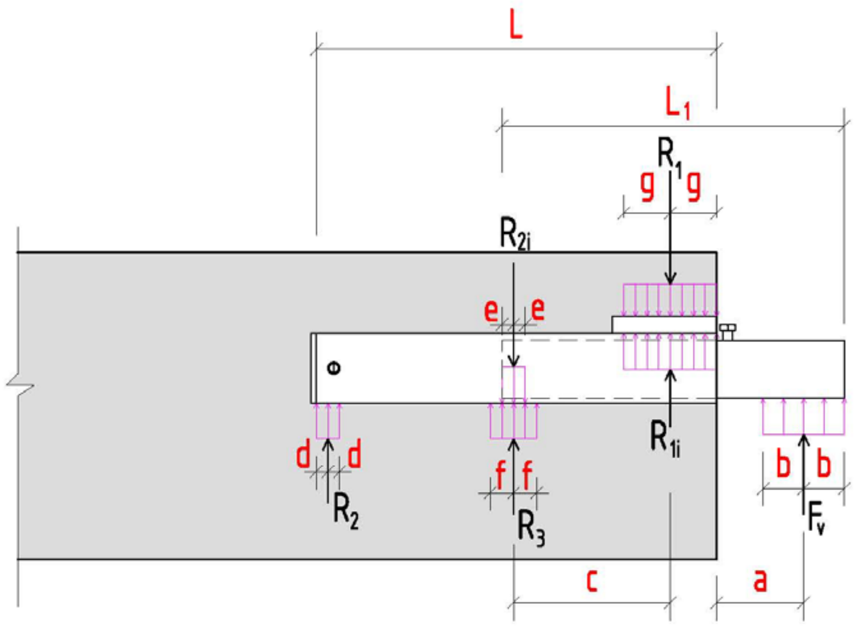

Figure 1: Forces acting on the unit.

F_V = External force on the inner tube

R_{1i}, R_{2i} = Internal forces between the inner and outer tubes.
R_1, R_2, R_3 = Support reaction forces the outer tube.

g= distance to the middle plane of the anchoring stirrups in front of the unit.

I) Equilibrium inner tube:

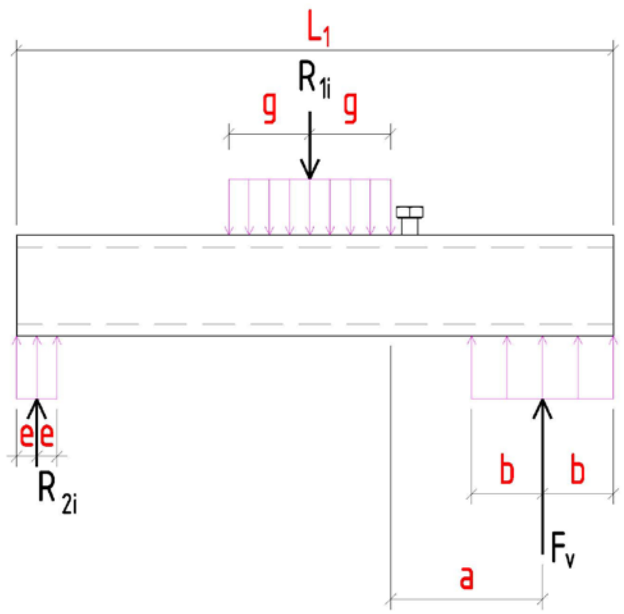

Figure 2: Forces acting on the inner tube.

Equilibrium equations of the inner tube:

1): ∑M=0: $F_v \cdot (L_1\text{-}b\text{-}e) - R_{1i} \cdot (L_1\text{-}b\text{-}a\text{-}g\text{-}e)=0$ (1)

2): ∑F_y=0: $F_v - R_{1i} + R_{2i} = 0$ (2)

Assuming nominal values:
L_1=295mm, a=75mm, b=35mm, g=40mm, e=10mm

Solving R_{1i} from eq. 1:

$$R_{1i} = \frac{F_v \cdot (L_1 - b - e)}{(L_1 - b - a - g - e)} \quad (3)$$

Solving R_{2i} from eq. 2:

$R_{2i} = R_{1i} - F_v$ (4)

Results:

$$R_{1i} = \frac{100kN \cdot (295 - 35 - 10)mm}{(295 - 35 - 75 - 40 - 10)mm} = 185.2kN$$

$$R_{2i} = 185.2kN - 100kN = 85.2kN$$

II) Equilibrium outer tube:

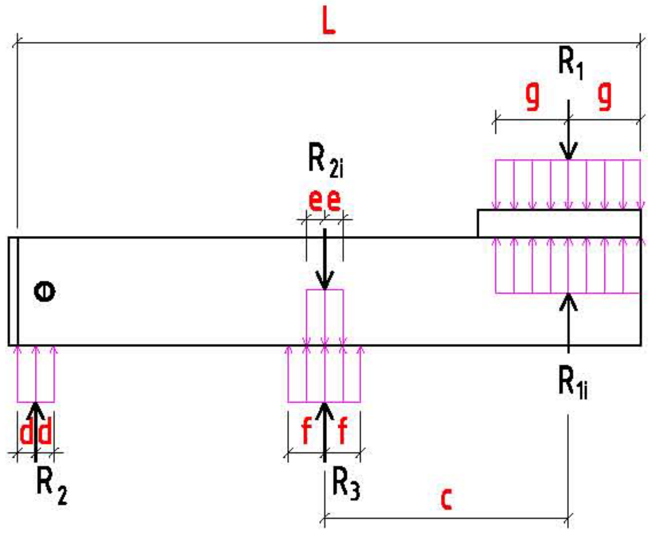

Figure 3: Forces acting on the outer tube.

Exact distribution of forces depends highly on the behavior of the outer tube. Both longitudinal bending stiffness and local transverse bending stiffness in the contact points between the inner and the outer tubes affects the equilibrium. Two situations are considered:

1) Rigid outer tube.

Outer tube rotates as a stiff body. This assumption gives minimum reaction force at R_1, and maximum reaction force at R_2. R_3 becomes zero. (The force R_3 will actually be negative, but since no reinforcement to take the negative forces is included at this position, it is assumed to be zero.)

Equilibrium equations of the outer tube:

1): $\sum M=0$: $(R_{1i}-R_1)\cdot(L-g-d) - (R_{2i}-R_3)\cdot(L-g-c-d)=0$ (5)

2): $\sum F_y=0$: $R_2+R_3+R_{1i}-R_{2i}-R_1=0$ (6)

Assuming nominal values:
L=345mm, c=135mm, g=40mm, e=10mm, d=10mm ; ($c=L_1$-b-a-g-e=295-35-75-40-10=135mm, see Figure 1)

Solving $R_1$from eq. 5:

$$(R_{1i} - R_1) \cdot (L - g - d) - (R_{2i} - R_3) \cdot (L - g - c - d) = 0$$
$$(185.2 - R_1) \cdot (345 - 40 - 10) - (85.2 - 0) \cdot (345 - 40 - 135 - 10) = 0$$
$$54634 - 295 R_1 - 13632 = 0$$
$$R_1 = \frac{41002}{295} = 139 kN$$

Solving R_2 from eq. 6:

$$R_2 = R_1 + R_{2i} - R_{1i} - R_3 = 139 + 85.2 - 185.2 = 39 kN$$

2) Outer tube without bending stiffness. No forces transferred to outer tube at the back of inner tube.

This assumption gives maximum reaction forces R_1 and R_3. R_2 becomes zero. The forces follow directly from the assumption: $R_1 = R_{1i}$ $R_3 = R_{2i}$ and $R_2 = 0$

$$R_1 = 185.2 kN$$
$$R_2 = 0 kN$$
$$R_3 = 85.2 kN$$

The magnitude of the forces will be somewhere in between the two limits, and the prescribed reinforcement ensures integrity for both situations. Reinforcement is to be located at the assumed attack point for support reactions.

Reinforcement for R_1, R_2 and R_3:

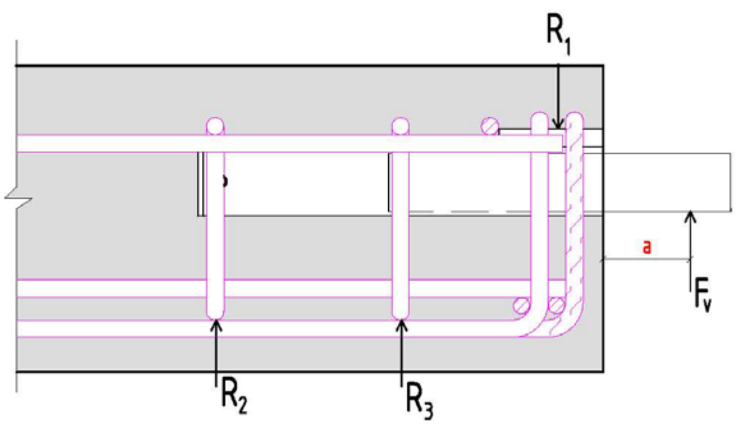

Figure 4: Forces.

Reinforcement necessary to anchor the unit to the concrete:

Reinforcement R_1: $A_{s1} = R_1/f_{sd}$ = 185.2kN/435Mpa =426 mm²
Select 2-Ø12 = 2×2×113 =452 mm²
Capacity selected reinforcement: R=452 mm² ·435MPa=196.6kN

Reinforcement R_3: $A_{s3} = R_3/f_{sd}$ = 85.2kN/435MPa =196 mm²
Select 1-Ø12 = 1×2×113 = 226 mm²
Capacity selected reinforcement: R=226 mm² ·435MPa=98.3kN

Reinforcement R_2: $A_{s2} = R_2/f_{sd}$ = 39kN/435MPa =89 mm²
Select 1-Ø12 = 1×2×113 = 226mm²
Capacity selected reinforcement: R=226 mm² ·435MPa=98.3kN

Tolerances on the positioning of the reinforcement:

Due to the small internal distances, the magnitude of the forces will change when changing the position of the reinforcement. Thus, strict tolerances are required.

Alt 1) Assume:
L_1=295mm, a=75mm, b=35mm, g=40+5=45mm, e=10mm
Gives:

$$R_1 = \frac{100kN \cdot (295-35-10)mm}{(295-35-75-45-10)mm} = 192.3kN$$

$$R_2 = 192.3kN - 100kN = 92.3kN$$

Alt 2) Assume:
L_1=295mm, a=75mm, b=35mm, g=40-5=35mm, e=10mm

Gives:

$$R_1 = \frac{100kN \cdot (295-35-10)mm}{(295-35-75-35-10)mm} = 178.6kN$$

$$R_2 = 178.6kN - 100kN = 78.6kN$$

Alt 3) Assume:
L_1=295mm, a=75mm, b=35mm, g=40mm, e=10-5=5mm

Gives:

$$R_1 = \frac{100kN \cdot (295-35-5)mm}{(295-35-75-40-5)mm} = 182.1kN$$

$$R_2 = 182.1kN - 100kN = 82.1kN$$

Alt 4) Assume:
L_1=295mm, a=75mm, b=35mm, g=40mm, e=10+5=15mm

Gives:

$$R_1 = \frac{100kN \cdot (295-35-15)mm}{(295-35-75-40-15)mm} = 188.5kN$$

$$R_2 = 188.5kN - 100kN = 88.5kN$$

Alt 5) Assume:
L_1=295mm, a=75mm, b=35mm, g=40+5=45mm, e=10+5=15mm

Gives:

$$R_1 = \frac{100kN \cdot (295-35-15)mm}{(295-35-75-45-15)mm} = 196kN$$

$$R_2 = 196kN - 100kN = 96kN$$

Conclusion tolerances: Alt 5 represents the most unfavorable position of reinforcement allowed without exceeding the reinforcement capacity. Thus, the assembling tolerances for P1, P2 and P4 should be ±5mm. For recommended reinforcement pattern, see Memo 55d.

Transverse reinforcement:

- One transverse bar with the same diameter as the anchorage bar to be placed in the bend of every anchoring bar.

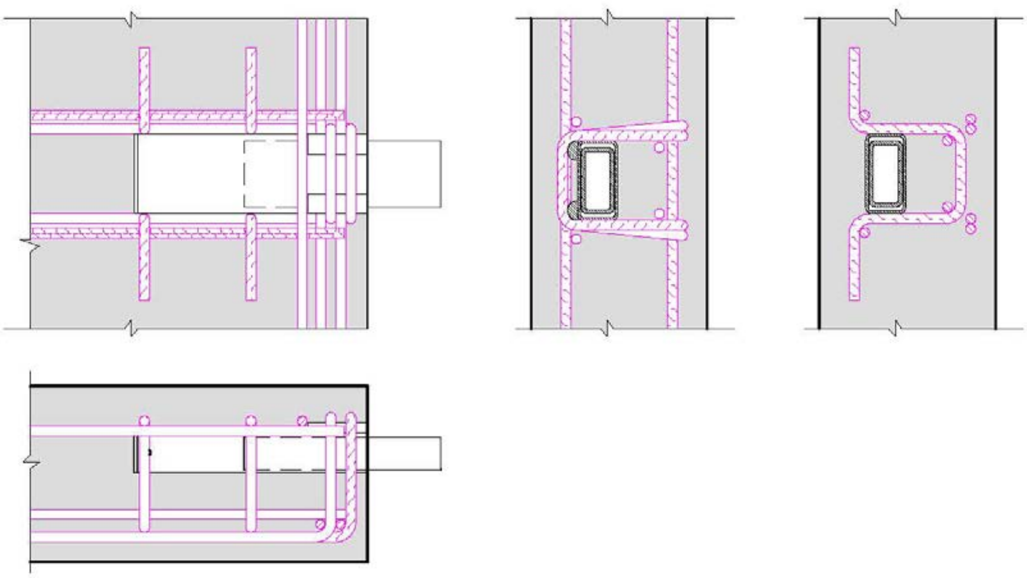

Figure 5: Anchoring reinforcement.

REVISION HISTORY	
Date:	**Description:**
26.04.2011	First Edition.
19.10.2011	Updated.
24.11.2015	Updated.
07.01.2016	Included revision history table. Included note on reinforcement ductility grade. Reduced number of values in Table 2.
25.06.2016	New template.