Design
MEMO 60
Reinforcement design for TSS 102

CONTENTS

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}	$C_{Rd,c}$	v_{min}	k_1
Recommended value	1.5	1.15	1.0	1.0	0.12	$0.035k^{1/3}\cdot f_{ck}^{1/2}$	0.15

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.

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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 B500C:

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

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 120x80x5, Cold formed, S355

LOADS

Vertical ultimate limit state load = F_V = 100kN.

PART 2 - REINFORCEMENT

EQUILIBRIUM

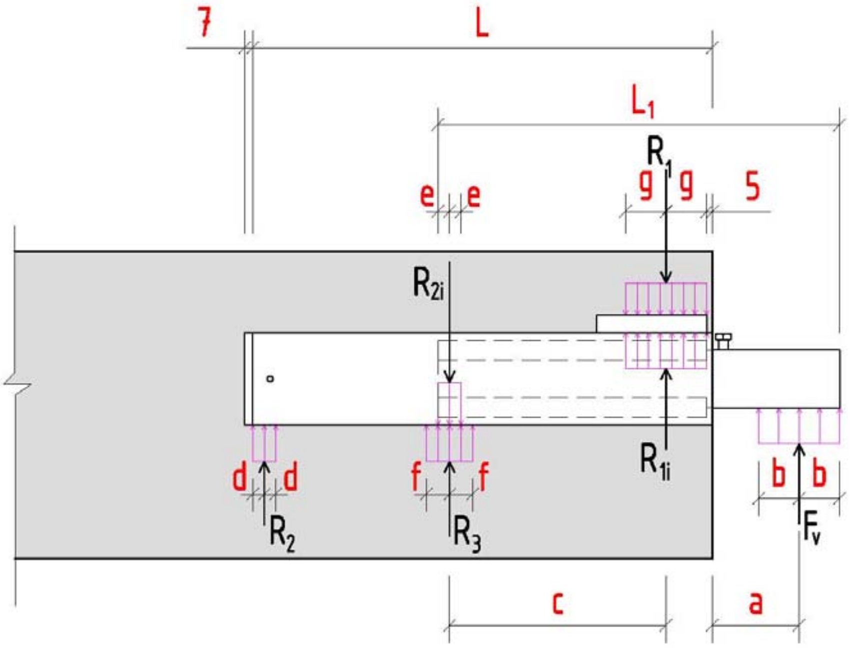

Figure 1: Forces acting on the unit.

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.

I) Equilibrium inner tube:

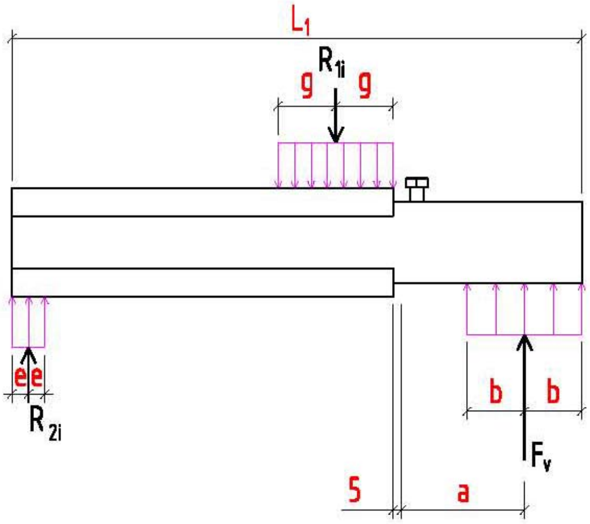

Figure 2: Forces acting on the inner tube.

Equilibrium equations of the inner tube:

1): ∑M=0: $F_v \cdot (L_1 - b - e) - R_{1i} \cdot (L_1 - b - a - 5 - g - e) = 0$ (1)

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

Assuming nominal values:
L_1=347mm, a=75mm, b=35mm, g=35mm, e=10mm

Solving R_{1i} from eq. 1:

$$R_{1i} = \frac{F_v \cdot (L_1 - b - e)}{(L_1 - b - a - 5 - g - e)} \quad (3)$$

Solving R_{2i} from eq. 2:

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

Results:

$$R_{1i} = \frac{100kN \cdot (347 - 35 - 10)mm}{(347 - 35 - 75 - 5 - 35 - 10)mm} = 161.5kN$$

$$R_{2i} = 161.5kN - 100kN = 61.5kN$$

II) Equilibrium outer tube:

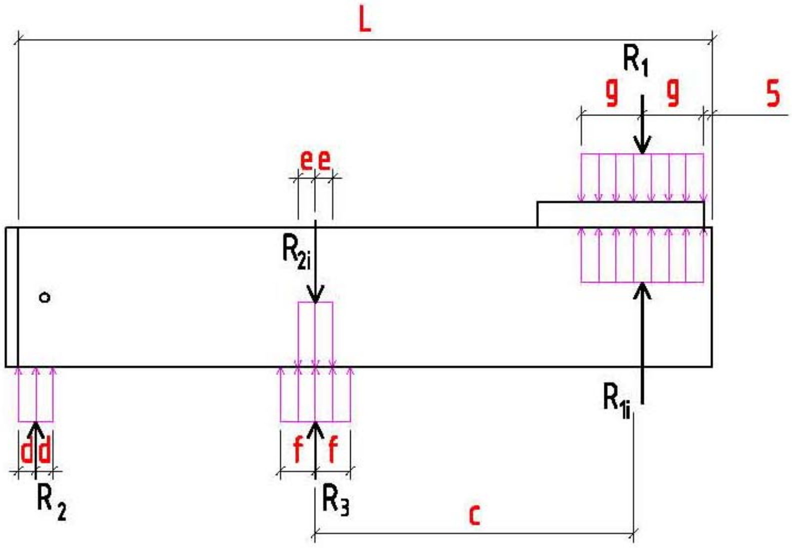

Figure 3: Forces acting on the outer tube.

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

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

Assuming nominal values:

L=397mm, c=187mm, g=35mm, e=10mm, d=10mm ; ($c=L_1$-b-a-5-g-e=347-35-75-5-35-10=187mm, see Figure 1)

Solving R_1 from eq. 5:

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

$$(161.5-R_1)\cdot(397-5-35-10)-(61.5-0)\cdot(397-5-35-187-10)=0$$

$$56040-347R_1-9840=0$$

$$R_1=\frac{46200}{347}=133.1kN$$

Solving R_2 from eq. 6:

$$R_2 = R_1 + R_{2i} - R_{1i} - R_3 = 133.1 + 61.5 - 161.5 = 33.1kN$$

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 $R_2 = 0$

$$R_1 = 161.5kN$$
$$R_2 = 0kN$$
$$R_3 = 61.5kN$$

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:

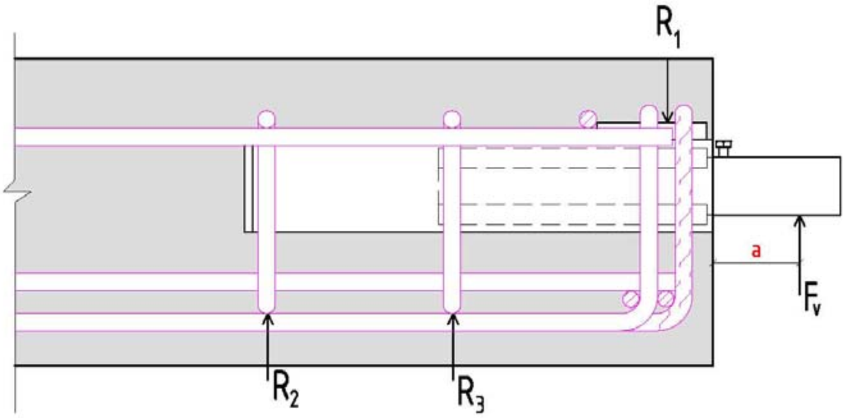

Figure 4: Forces.

Reinforcement necessary to anchor the unit to the concrete:

Reinforcement R_1: $A_{s1} = R_1/f_{sd}$ = 161.5kN/435Mpa =371 mm^2
Select 2-Ø12 = 2×2×113 =452 mm^2
Capacity selected reinforcement: R=452 mm^2 ·435MPa=196.6kN

Reinforcement R_3: $A_{s3} = R_3/f_{sd}$ = 61.5kN/435MPa =141 mm^2
Select 1-Ø12 = 1×2×113 = 226 mm^2
Capacity selected reinforcement: R=226 mm^2 ·435MPa=98.3kN

Reinforcement R_2: $A_{s2} = R_2/f_{sd}$ = 33.1kN/435MPa =76 mm^2
Select 1-Ø12 = 1×2×113 = 226mm^2
Capacity selected reinforcement: R=226 mm^2 ·435MPa=98.3kN

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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=347mm, a=75mm, b=35mm, g=35+5=40mm, e=10mm

Gives:

$$R_{1i} = \frac{100kN \cdot (347-35-10)mm}{(347-35-75-5-40-10)mm} = 166kN$$

$$R_{2i} = 166kN - 100kN = 66kN$$

Alt 2) Assume:
L_1=347mm, a=75mm, b=35mm, g=35-5=30mm, e=10mm

Gives:

$$R_{1i} = \frac{100kN \cdot (347-35-10)mm}{(347-35-75-5-30-10)mm} = 157.3kN$$

$$R_{2i} = 157.3kN - 100kN = 157.3kN$$

Alt 3) Assume:
L_1=347mm, a=75mm, b=35mm, g=35mm, e=10-5=5mm

Gives:

$$R_{1i} = \frac{100kN \cdot (347-35-5)mm}{(347-35-75-5-35-5)mm} = 159.9kN$$

$$R_{2i} = 159.9kN - 100kN = 59.9kN$$

Alt 4) Assume:
L_1=347mm, a=75mm, b=35mm, g=35mm, e=10+5=15mm

Gives:

$$R_{1i} = \frac{100kN \cdot (347-35-15)mm}{(347-35-75-5-35-15)mm} = 163.2kN$$

$$R_{2i} = 163.2kN - 100kN = 63.2kN$$

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Alt 5) Assume:
L_1=347mm, a=75mm, b=35mm, g=35+5=40mm, e=10+5=15mm

Gives:

$$R_{1i} = \frac{100kN \cdot (347-35-15)mm}{(347-35-75-5-40-15)mm} = 167.8kN$$

$$R_{2i} = 167.8kN - 100kN = 67.8kN$$

Conclusion tolerances: The assembling tolerances for P1, P2 and P4 should be ±5mm. For recommended reinforcement pattern, see Memo 57.

Transverse reinforcement:

- One transverse bar to be placed in the bend of every anchoring bar, see Figure 5.
- One transverse bar with the same diameter as the anchorage bar to be placed in the bend of every anchoring bar.

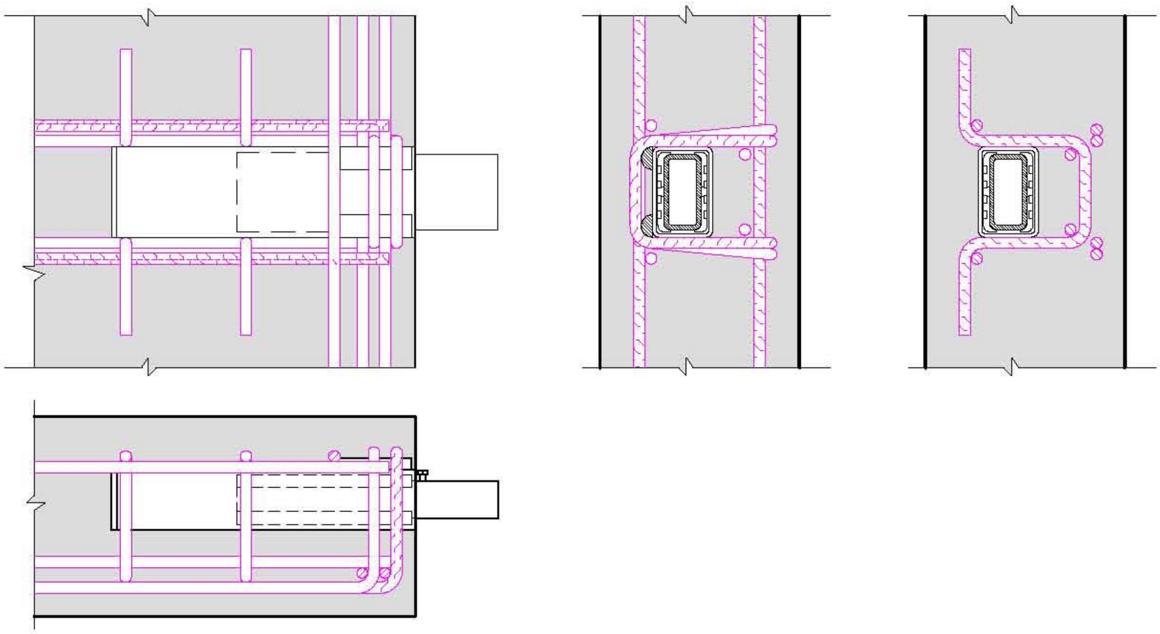

Figure 5: Anchoring reinforcement.