

MEMO  
RVK 101  
REINFORCEMENT DESIGN  
DESIGN

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## **REINFORCEMENT DESIGN**

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# PART 1 – BASIC ASSUMPTIONS

## 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	$\gamma_c$	$\gamma_s$	$\alpha_{cc}$	$\alpha_{ct}$
Recommended value	1.5	1.15	1.0	1.0

**Table 1: NDP-s in EC-2.**

Parameter	$\gamma_{M0}$	$\gamma_{M1}$	$\gamma_{M2}$
Recommended value	1.0	1.0	1.25

**Table 2: NDP-s in EC-3.**

## QUALITIES

Concrete grade C35/45:

$f_{ck} = 35,0 \text{ MPa}$	EC2, Table 3.1
$f_{cd} = \alpha_{cc} \cdot f_{ck} / \gamma_c = 1 \cdot 35 / 1,5 = 23,3 \text{ MPa}$	EC2, Pt.3.15
$f_{ctd} = \alpha_{ct} \cdot f_{ctk,0,05} / \gamma_c = 1 \cdot 2,20 / 1,5 = 1,46 \text{ MPa}$	EC2, Pt.3.16
$f_{bd} = 2,25 \cdot \eta_1 \cdot \eta_2 \cdot f_{ctd} = 2,25 \cdot 0,7 \cdot 1,0 \cdot 1,46 = 2,3 \text{ MPa}$	EC2, Pt.8.4.2

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

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

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:

$$\begin{aligned} \text{Tension: } f_{yd} &= f_y / \gamma_{M0} = 355 / 1,0 = 355 \text{ MPa} \\ \text{Compression: } f_{yd} &= f_y / \gamma_{M0} = 355 / 1,0 = 355 \text{ MPa} \\ \text{Shear: } f_{sd} &= f_y / (\gamma_{M0} \cdot \sqrt{3}) = 355 / (1,0 \cdot \sqrt{3}) = 205 \text{ MPa} \end{aligned}$$

## DIMENSIONS

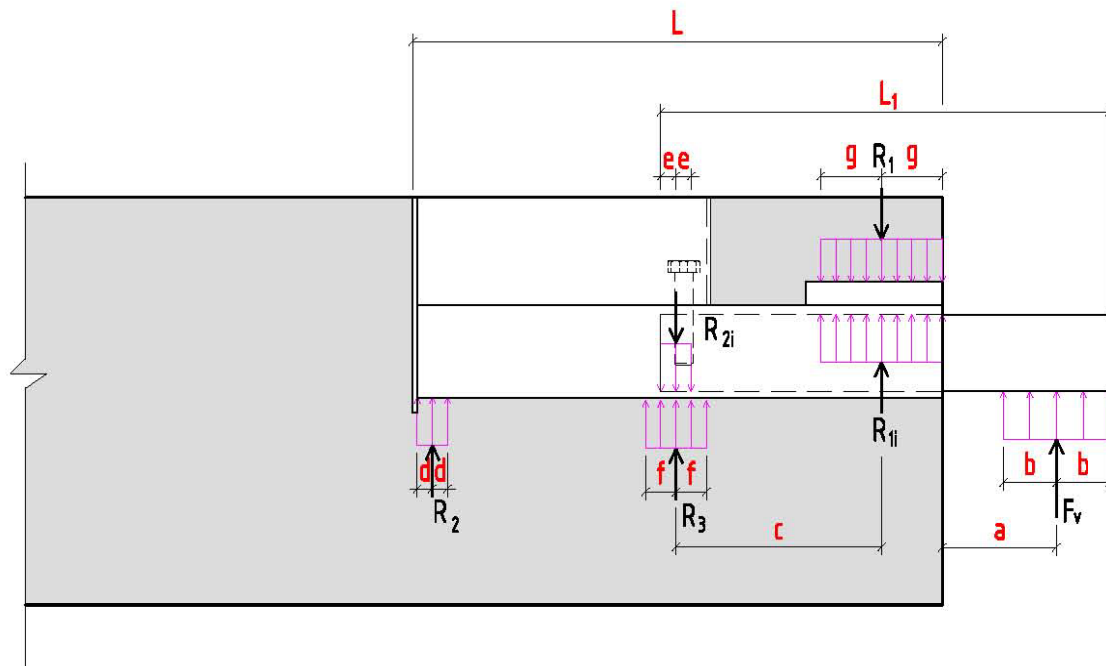
Inner tube: HUP 100x50x6, Cold formed, S355  
Outer tube: HUP 120x60x4, Cold formed, S355

## LOADS

Vertical ultimate limit state load =  $F_v = 100 \text{ kN}$ .

## PART 2 - REINFORCEMENT

### EQUILIBRIUM



**Figure 1: Forces acting on the unit.**

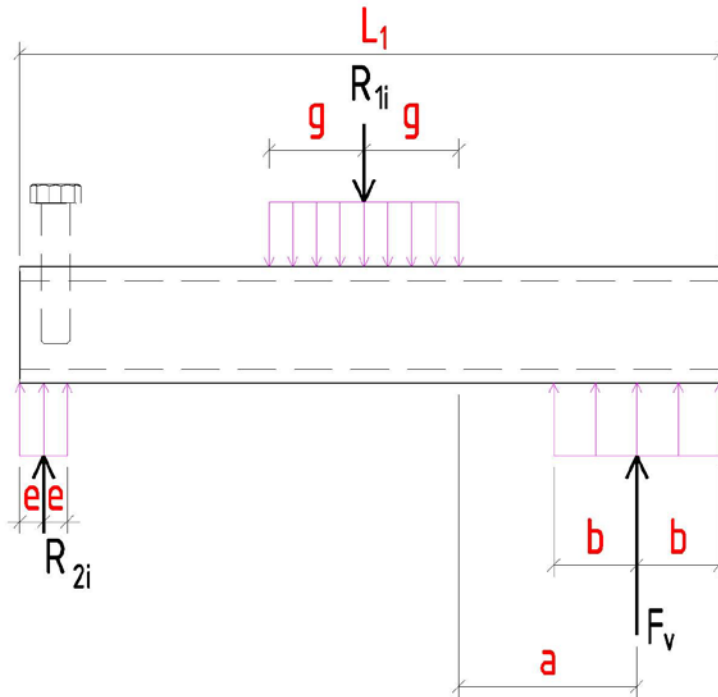
$F_v$  = External force on the inner tube

$R_{1i}$ ,  $R_{2i}$  = 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:

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

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

Assuming nominal values:

$L_1=295\text{mm}$ ,  $a=75\text{mm}$ ,  $b=35\text{mm}$ ,  $g=40\text{mm}$ ,  $e=10\text{mm}$

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:

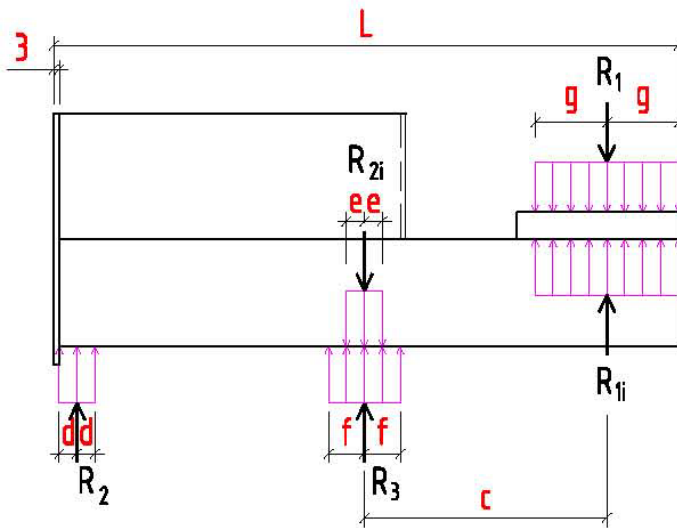
$$R_{2i} = R_{1i} - F_v \quad (4)$$

Results:

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

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

**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:

$$1): \sum M=0: \quad (R_{1i}-R_1) \cdot (L-3-g-d) - (R_{2i}-R_3) \cdot (L-3-g-c-d)=0$$

(5)

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

Assuming nominal values:

$L=348\text{mm}$ ,  $c=135\text{mm}$ ,  $g=40\text{mm}$ ,  $e=10\text{mm}$ ,  $d=10\text{mm}$  ;  $(c=L_1-b-a-g-e=295-35-75-40-10=135\text{mm}$ , see Figure 1)

Solving  $R_1$  from eq. 5:

$$(R_{1i} - R_1) \cdot (L - 3 - g - d) - (R_{2i} - R_3) \cdot (L - 3 - g - c - d) = 0$$
$$(185.2 - R_1) \cdot (348 - 3 - 40 - 10) - (85.2 - 0) \cdot (348 - 3 - 40 - 135 - 10) = 0$$
$$54634 - 295R_1 - 13632 = 0$$
$$R_1 = \frac{41002}{295} = 139kN$$

Solving  $R_2$  from eq. 6:

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

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  $R_2 = 0$

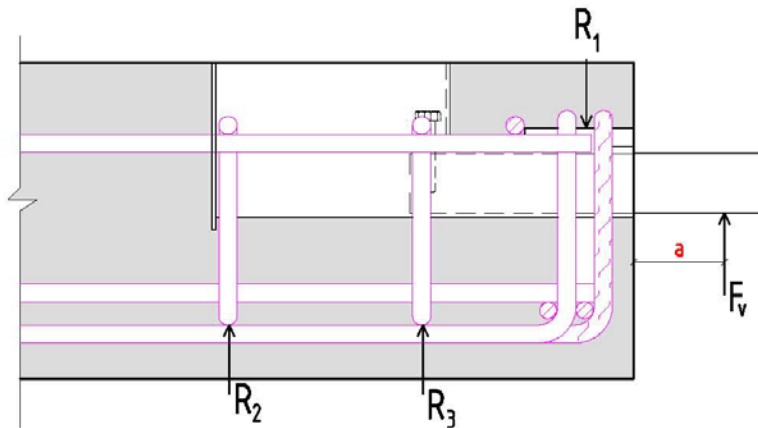
$$R_1 = 185.2kN$$

$$R_2 = 0kN$$

$$R_3 = 85.2kN$$

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<sub>1</sub>, R<sub>2</sub> and R<sub>3</sub>:**



**Figure 4: Forces.**

**Reinforcement necessary to anchor the unit to the concrete:**

Reinforcement R<sub>1</sub>:  $A_{s1} = R_1/f_{sd} = 185.2\text{kN}/435\text{MPa} = 426 \text{ mm}^2$   
 Select 2-Ø12 =  $2 \times 2 \times 113 = 452 \text{ mm}^2$   
 Capacity selected reinforcement:  $R = 452 \text{ mm}^2 \cdot 435\text{MPa} = 196.6\text{kN}$

Reinforcement R<sub>3</sub>:  $A_{s3} = R_3/f_{sd} = 85.2\text{kN}/435\text{MPa} = 196 \text{ mm}^2$   
 Select 1-Ø12 =  $1 \times 2 \times 113 = 226 \text{ mm}^2$   
 Capacity selected reinforcement:  $R = 226 \text{ mm}^2 \cdot 435\text{MPa} = 98.3\text{kN}$

Reinforcement R<sub>2</sub>:  $A_{s2} = R_2/f_{sd} = 39\text{kN}/435\text{MPa} = 89 \text{ mm}^2$   
 Select 1-Ø12 =  $1 \times 2 \times 113 = 226\text{mm}^2$   
 Capacity selected reinforcement:  $R = 226 \text{ mm}^2 \cdot 435\text{MPa} = 98.3\text{kN}$



## 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:

$$L_1=295\text{mm}, a=75\text{mm}, b=35\text{mm}, g=40+5=45\text{mm}, e=10\text{mm}$$

Gives:

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

$$R_2 = 192.3\text{kN} - 100\text{kN} = 92.3\text{kN}$$

Alt 2) Assume:

$$L_1=295\text{mm}, a=75\text{mm}, b=35\text{mm}, g=40-5=35\text{mm}, e=10\text{mm}$$

Gives:

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

$$R_2 = 178.6\text{kN} - 100\text{kN} = 78.6\text{kN}$$

Alt 3) Assume:

$$L_1=295\text{mm}, a=75\text{mm}, b=35\text{mm}, g=40\text{mm}, e=10-5=5\text{mm}$$

Gives:

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

$$R_2 = 182.1\text{kN} - 100\text{kN} = 82.1\text{kN}$$

Alt 4) Assume:

$$L_1=295\text{mm}, a=75\text{mm}, b=35\text{mm}, g=40\text{mm}, e=10+5=15\text{mm}$$

Gives:

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

$$R_2 = 188.5\text{kN} - 100\text{kN} = 88.5\text{kN}$$

Alt 5) Assume:

$$L_1=295\text{mm}, a=75\text{mm}, b=35\text{mm}, g=40+5=45\text{mm}, e=10+5=15\text{mm}$$

Gives:

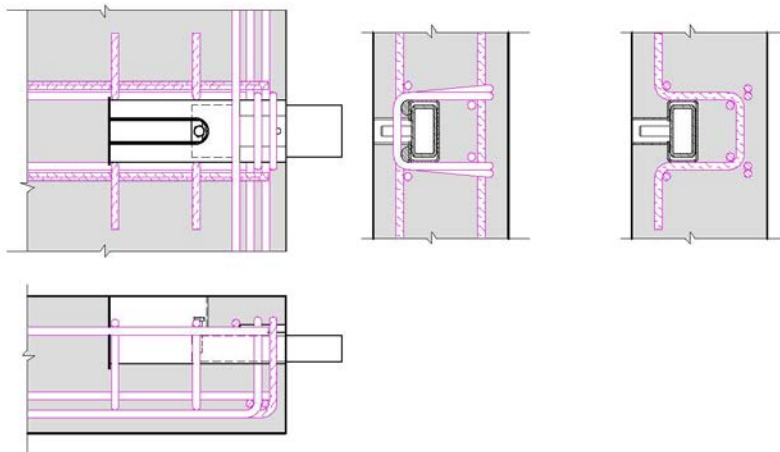
$$R_1 = \frac{100kN \cdot (295 - 35 - 15)mm}{(295 - 35 - 75 - 45 - 15)mm} = 196kN$$

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

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  $\pm 5mm$ . For recommended reinforcement pattern, see Memo 55b.

**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.**

<b>REVISION HISTORY</b>	
<b>Date:</b>	<b>Description:</b>
26.04.2011	First Edition.
19.10.2011	Updated.
07.01.2016	Included revision history table. Included note on reinforcement ductility grade. Reduced number of values in Table 2.
25.05.2016	New template