

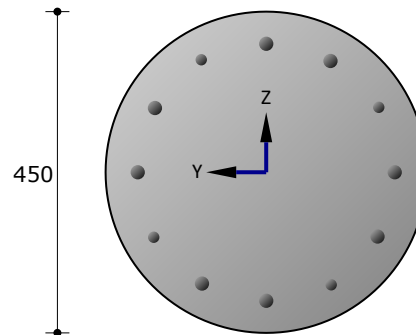
GENERAL

File :Struct4U\website\voorbeeld uitdraai\XConstruct\ Voorbeelden\Dutch.xcst

Consequence class : CC2

COLUMN: Concrete Column**INPUT DATA**

Column dimensions : D = 450 mm
 L=3500 mm
 Concrete grade C45/55 Creep coefficient 3,20
 Granule diameter 31,5 mm
 Environmental class XC1
 Prefab yes
 Reworked no
 Cast in place pile no
 Cover c 25 mm
 Steel grade B500B
 Basic reinforcement 8x20
 Add. reinforcement 4x16
 Stirrup diameter 10 mm
 Buckling length Y 5.7 a → $l_{0,y} = 3500$ mm
 Buckling length Z 5.7 a → $l_{0,z} = 3500$ mm
 Beam group Y 5.7 a → $l_{0,y} = 3500$ mm
 Beam group Z 5.7 a → $l_{0,z} = 3500$ mm



Connection
 Thickness bedding 30 mm
 Concrete grade mortar C20/25
 Mortar type b; aangieten of injecteren
 Concrete grade support C20/25
 Steel grade B500B
 Reinforcement connection 2x16 Edge distance 75 mm

Load cases

No.	Description	Type	Nx [kN]	My;t [kNm]	My;c [kNm]	My;b [kNm]	Mz;t [kNm]	Mz;c [kNm]	Mz;b [kNm]
1	Permanent	Dead load incl. sel	1620,0	40,0	20,0	0,0	0,0	0,0	0,0
2	Veranderlijk	B:office	450,0	32,0	16,0	0,0	0,0	0,0	0,0

Load Combinations

No.	Description	Type	Load cases ($\psi \times \gamma$)	
			1:Permanent	2:Veranderlijk
1	(6.10a)	ULS	1,00 x 1,35	0,50 x 1,50
2	(6.10b)	ULS	1,00 x 1,20	1,00 x 1,50
3	(6.11a)	ULS fire	1,00 x 1,00	1,00 x 1,00
4		Quasi permanent	1,00 x 1,00	0,60 x 1,00

CALCULATION

Applied standards: : NEN-EN 1992-1-1+C1:2011/NB:2016+A1:2020 nl

$$h_{oh} = 99 \text{ mm} < h_{oh \text{ max}} = 150 \text{ mm}$$

$$s = 81 \text{ mm} > s_{\text{min}} = 37 \text{ mm}$$

$$s_{cl, \text{max}} = \text{Min}[20\emptyset; \text{Min}[h, b]; 400] = \text{Min}[20 \times 16; \text{Min}[350; 350]; 400] = 320 \text{ mm} \quad \dots 9.5.3(3)$$

Minimum stirrup reinforcement is: $\emptyset 6-320$

1: ULS fire R60 bending about Y-axis

Decisive combination 3: (6.11a)

$$N_{Edx} = 2070 \text{ kN}; M_{Edy, \text{top}} = 72 \text{ kNm}; M_{Edy, \text{centre}} = 36 \text{ kNm}; M_{Edy, \text{bottom}} = 0 \text{ kNm};$$

5.8.3.2 Slenderness and effective length of isolated members

$$i = \sqrt{\frac{I}{A}} = \sqrt{\frac{1228166675}{124232}} = 99,4 \text{ mm}$$

$$l_0 = l = 3500 \text{ mm} \quad \dots (\text{fig.5.7 a})$$

$$\lambda = l_0 / i = 3500 / 99,4 = 35,2 \quad \dots (5.14)$$

5.2 Geometric imperfections

$$\alpha_h = \min [\max [2 / \sqrt{l}; 2/3]; 1.00] = \min [\max [2 / \sqrt{3,5}; 2/3]; 1.00] = 1$$

$$\alpha_m = \sqrt{0,5 (1+1/m)} = \sqrt{0,5 (1+1/1)} = 1$$

$$\theta_i = \theta_i \alpha_h \alpha_m = 1/300 \times 1 \times 1 = 0,00333 \quad \dots (5.1)$$

$$e_i = \theta_i l_0 / 2 = 0,0033 \times 3500 / 2 = 5,8 \text{ mm} \quad \dots (5.2)$$

5.8.4 Creep

$$\varphi_{ef} = \varphi_{(\text{infinite}, t_0)} M_{0Eqp} / M_{0Ed} = 3,2 \times 46,55/55,28 = 2,69 \quad \dots (5.19)$$

5.8.3.1 Slenderness criterion for isolated members

$$A = 1 / (1 + 0,2 \varphi_{ef}) = 1 / (1 + 0,2 \times 2,69) = 0,65$$

$$\omega = A s f_{yd} / (A_c f_{cd}) = 3318 \times 434,8 / (124232 \times 30) = 0,387$$

$$B = \sqrt{1 + 2 \omega} = \sqrt{1 + 2 \times 0,387} = 1,332$$

$$r_m = M_{01} / M_{02} = 0 / 72 = 0 \quad C = 1,7 - r_m = 1,7 - 0 = 1,7$$

$$n = N_{Ed} / (A_c f_{cd}) = 2070000 / (124232 \times 30) = 0,5554$$

$$\lambda_{lim} = 20.A.B.C / \sqrt{n} = 20 \times 0,65 \times 1,332 \times 1,7 / \sqrt{0,5554} = 39,49 \quad \dots (5.13N)$$

$\lambda < \lambda_{lim} \rightarrow$ 2nd order calculation is not required

5.8.8.2 Bending moments

$$M_{0e} = \max [0,6 M_{02} + 0,4 M_{01}; 0,4 M_{02}] = \quad \dots (5.32)$$

$$= \max [0,6 \times 72 + 0,4 \times 0; 0,4 \times 72] = 43,2 \text{ kNm}$$

$$M_{0Ed} = M_{0e} + N_{Ed} e_i = 43,2 + 2070 \times 5,8 \times 10^{-3} = 55,275 \text{ kNm}$$

$$M_2 = N_{Ed} e_2 = 2070 \times 0 \times 10^{-3} = 0 \text{ kNm} \quad \dots(5.33)$$

$$\begin{aligned} M_{Ed} &= \max [M_{0Ed} + M_2 ; M_{02} + N_{Ed} e_i ; M_{01} + 0,5 M_2 + N_{Ed} e_i] = \dots(5.31) \\ &= \max [55,275 + 0 ; 72 + 2070 \times 5,8 \times 10^{-3} ; 0 + 0,5 \times 0 + 2070 \times 5,8 \times 10^{-3}] = \\ &= 84,075 \text{ kNm} \end{aligned}$$

$$e_t = M_{Ed} / N_{Ed} = 84,075 / 2070 \times 10^{-3} = 40,6 \text{ mm}$$

$$e_{\min} = \max [h/30, 20] = \max [350/30, 20] = 20,0 \text{ mm} \quad \dots 6.1(4)$$

$$A_{s,\min} = \max \left[\frac{0,10 N_{Ed}}{f_{yd}} ; 0,002 A_c \right] = \max \left[\frac{0,10 \times 2070000}{434,8} ; 0,002 \times 158992,667 \right] = 476,1 \text{ mm}^2 \quad \dots(9.12N)$$

$$A_{s,\max} = 0,04 A_c = 0,04 \times 158993 = 6359,7 \text{ mm}^2$$

$$N_{Edx} = 2070 \text{ kN}; M_{Ed} = 84,075 \text{ kNm}; A_{ben} = 0 \text{ mm}^2$$

EN 1992-1-2 Annex A Fig. A.17: Temperature profiles for a circular column, D = 300 - R60

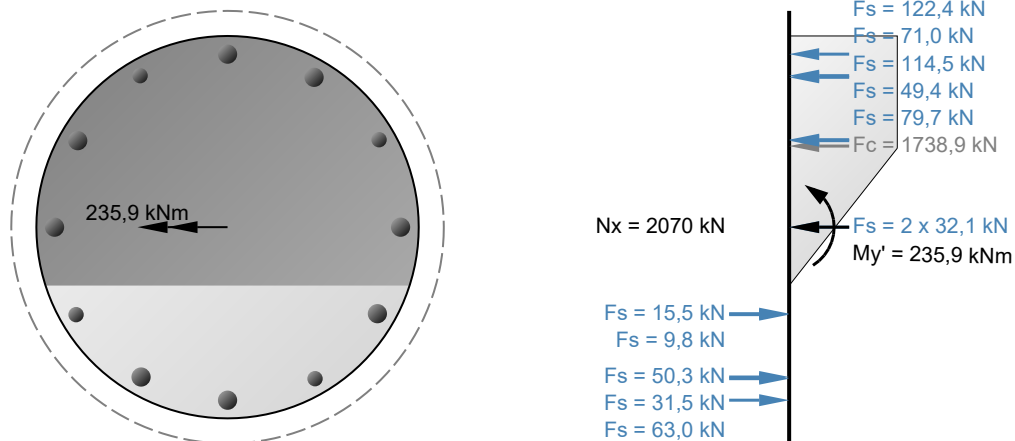
→ 500 °C isotherm a = 26 mm

...EN 1992-1-2 B1.2(1)

$$\frac{M_{Ed}}{M_{Rd}} = \frac{84,075}{235,869} = 0,36 < 1,0$$

$$A_{s,\min} = 476 \text{ mm}^2 < A_s = 3318 \text{ mm}^2 < A_{s,\max} = 6360 \text{ mm}^2$$

Sectional calculation



Angle bending axis and neutral line $\alpha = 0,000^\circ$; $x_u = 285,8 \text{ mm}$; $d = 380,4 \text{ mm}$
 Centroid section $y' = 0,0$ $z' = -225,0$ ($y = 0,0$ $z = 0,0$)

y' [mm]	z' [mm]	Wap.	Temp.*) [°C]	fsy,θ [N/mm ²]	As [mm ²]	Δε [o/oo]	σc [N/mm ²]	Δσs [N/mm ²]
0,0	0,0					-3,500	-30,0	
0,0	-45,0	1Ø20	321	-390	314	-2,949		-389,6
-91,0	-67,4	1Ø16	337	-381	201	-2,675		-353,4
90,0	-69,1	1Ø20	321	-390	314	-2,653		-364,5
157,6	-134,0	1Ø16	337	-381	201	-1,859		-245,6
-155,9	-135,0	1Ø20	321	-390	314	-1,846		-253,6
-180,0	-225,0	1Ø20	321	-390	314	-0,744		-102,2
180,0	-225,0	1Ø20	321	-390	314	-0,744		-102,2
155,9	-315,0	1Ø20	321	494	314	0,358		49,2
-157,6	-316,0	1Ø16	337	489	201	0,370		48,9
-90,0	-380,9	1Ø20	321	494	314	1,165		160,0
91,0	-382,6	1Ø16	337	489	201	1,186		156,7
0,0	-405,0	1Ø20	321	494	314	1,461		200,6

y' [mm]	z' [mm]	Fc [kN]	Fs [kN]	dy' [mm]	dz' [mm]	F [kN]	F.dy' [kNm]	F.dz' [kNm]
0,0	-140,6	-1738,9		0,0	84,4	-1738,9	0,0	-146,7
0,0	-45,0		-122,4	0,0	180,0	-122,4	0,0	-22,0
-91,0	-67,4		-71,0	-91,0	157,6	-71,0	6,5	-11,2
90,0	-69,1		-114,5	90,0	155,9	-114,5	-10,3	-17,8
157,6	-134,0		-49,4	157,6	91,0	-49,4	-7,8	-4,5
-155,9	-135,0		-79,7	-155,9	90,0	-79,7	12,4	-7,2
-180,0	-225,0		-32,1	-180,0	0,0	-32,1	5,8	0,0
180,0	-225,0		-32,1	180,0	0,0	-32,1	-5,8	0,0
155,9	-315,0		15,5	155,9	-90,0	15,5	2,4	-1,4
-157,6	-316,0		9,8	-157,6	-91,0	9,8	-1,6	-0,9
-90,0	-380,9		50,3	-90,0	-155,9	50,3	-4,5	-7,8
91,0	-382,6		31,5	91,0	-157,6	31,5	2,9	-5,0
0,0	-405,0		63,0	0,0	-180,0	63,0	0,0	-11,3
totaal:						-2070,0	0,0	-235,9

*) EN 1992-1-2 Annex A

Fig. A.17: Temperature profiles for a circular column, D = 300 - R60

2: ULS fire R60 bending about Z-axis

Decisive combination 3: (6.11a)

N_{Edx} = 2070 kN; M_{Edz;top} = 0 kNm; M_{Edz;centre} = 0 kNm; M_{Edz;bottom} = 0 kNm;

5.8.3.2 Slenderness and effective length of isolated members

$$i = \sqrt{\frac{I}{A}} = \sqrt{\frac{1228166675}{124232}} = 99,4 \text{ mm}$$

$$l_0 = l = 3500 \text{ mm}$$

...(fig.5.7 a)

$$\lambda = l_0 / i = 3500 / 99,4 = 35,2$$

...(5.14)

5.2 Geometric imperfections

$$\alpha_h = \min [\max [2 / \sqrt{l} ; 2/3]; 1.00] = \min [\max [2 / \sqrt{3,5} ; 2/3]; 1.00] = 1$$

$$\alpha_m = \sqrt{0,5 (1+1/m)} = \sqrt{0,5 (1+1/1)} = 1$$

$$\theta_i = \theta_i \alpha_h \alpha_m = 1/300 \times 1 \times 1 = 0,00333$$

...(5.1)

$$e_i = \theta_i l_0 / 2 = 0,0033 \times 3500 / 2 = 5,8 \text{ mm}$$

...(5.2)

5.8.4 Creep

$$\varphi_{ef} = \varphi_{(infinite,t0)} M_{0Eqp} / M_{0Ed} = 3,2 \times 11,03/12,08 = 2,92 \quad \dots(5.19)$$

5.8.3.1 Slenderness criterion for isolated members

$$A = 1 / (1 + 0,2 \varphi_{ef}) = 1 / (1 + 0,2 \times 2,92) = 0,631$$

$$\omega = A_s f_{yd} / (A_c f_{cd}) = 3318 \times 434,8 / (124232 \times 30) = 0,387$$

$$B = \sqrt{1 + 2 \omega} = \sqrt{1 + 2 \times 0,387} = 1,332$$

$$r_m = 1 \quad C = 1,7 - r_m = 1,7 - 1 = 0,7$$

$$n = N_{Ed} / (A_c f_{cd}) = 2070000 / (124232 \times 30) = 0,5554$$

$$\lambda_{lim} = 20.A.B.C / \sqrt{n} = 20 \times 0,631 \times 1,332 \times 0,7 / \sqrt{0,5554} = 15,79 \quad \dots(5.13N)$$

$\lambda > \lambda_{lim} \rightarrow$ 2nd order calculation is required

5.8.8.3 Curvature

$$n_u = 1 + \omega = 1 + 0,3870 = 1,3870$$

$$K_r = (n_u - n) / (n_u - n_{bal}) = (1,387 - 0,555) / (1,387 - 0,4) = 0,8425 \quad \dots(5.36)$$

$$\beta = 0,35 + f_{ck}/200 - \lambda/150 = 0,35 + 45/200 - 35,2/150 = 0,3403$$

$$K_\varphi = 1 + \beta \varphi_{ef} = 1 + 0,3403 \times 2,922 = 1,9943 \quad \dots(5.37)$$

$$i_s = \sqrt{\frac{I}{A}} = \sqrt{\frac{54110691}{3318}} = 127,7 \text{ mm} \quad d = (h/2) + i_s = (450/2) + 127,7 = 352,7 \text{ mm} \quad \dots(5.35)$$

$$1/r_0 = \varepsilon_{yd} / (0,45 d) = 0,0022 / (0,45 \times 353) = 1,3696E-05$$

$$1/r = K_r \cdot K_\varphi \cdot 1/r_0 = 0,8425 \times 1,9943 \times 1,3696E-05 = 2,3014E-05 \quad \dots(5.34)$$

5.8.8.2 Bending moments

$$M_{0e} = \max [0,6 M_{02} + 0,4 M_{01} ; 0,4 M_{02}] = \quad \dots(5.32)$$

$$= \max [0,6 \times 0 + 0,4 \times 0 ; 0,4 \times 0] = 0 \text{ kNm}$$

$$M_{0Ed} = M_{0e} + N_{Ed} e_i = 0 + 2070 \times 5,8 \times 10^{-3} = 12,075 \text{ kNm}$$

$$e_2 = (1/r) l_0^2 / c = 2,3014E-05 \times 3500^2 / 10 = 28,2 \text{ mm}$$

$$M_2 = N_{Ed} e_2 = 2070 \times 28,2 \times 10^{-3} = 58,359 \text{ kNm} \quad \dots(5.33)$$

$$M_{Ed} = \max [M_{0Ed} + M_2 ; M_{02} + N_{Ed} e_i ; M_{01} + 0,5 M_2 + N_{Ed} e_i] = \quad \dots(5.31)$$

$$= \max [12,075 + 58,359; 0 + 2070 \times 5,8 \times 10^{-3}; 0 + 0,5 \times 58,359 + 2070 \times 5,8 \times 10^{-3}] =$$

$$= 70,434 \text{ kNm}$$

$$e_t = M_{Ed} / N_{Ed} = 70,434 / 2070 \times 10^{-3} = 34 \text{ mm}$$

$$e_{min} = \max [h/30, 20] = \max [350/30, 20] = 20,0 \text{ mm} \quad \dots(6.1(4))$$

$$A_{s,min} = \max \left[\frac{0,10 N_{Ed}}{f_{yd}} ; 0,002 A_c \right] = \max \left[\frac{0,10 \times 2070000}{434,8} ; 0,002 \times 158992,667 \right] = 476,1 \text{ mm}^2 \quad \dots(9.12N)$$

$$A_{s,max} = 0,04 A_c = 0,04 \times 158993 = 6359,7 \text{ mm}^2$$

$$N_{Edx} = 2070 \text{ kN}; M_{Ed} = 70,434 \text{ kNm}; A_{ben} = 0 \text{ mm}^2$$

EN 1992-1-2 Annex A Fig. A.17: Temperature profiles for a circular column, D = 300 - R60

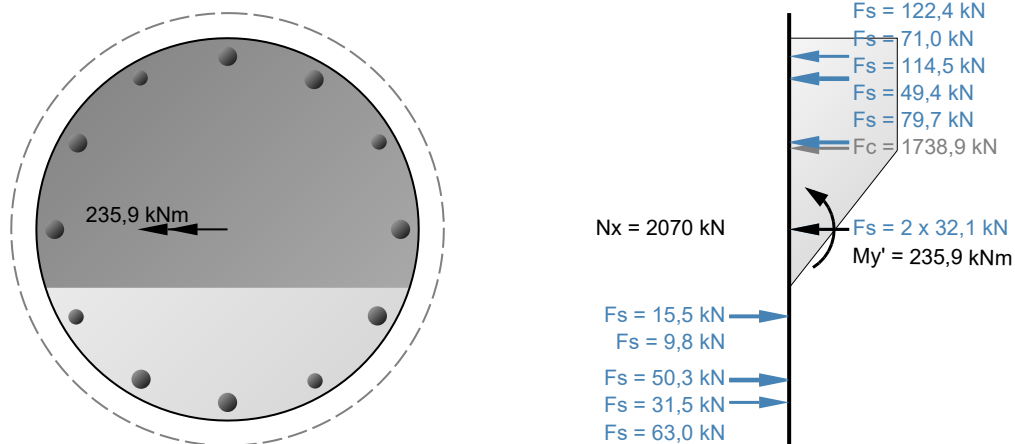
→ 500 °C isotherm a = 26 mm

...EN 1992-1-2 B1.2(1)

$$\frac{M_{Ed}}{M_{Rd}} = \frac{70,434}{235,869} = 0,30 < 1,0$$

$$A_{s,min} = 476 \text{ mm}^2 < A_s = 3318 \text{ mm}^2 < A_{s,max} = 6360 \text{ mm}^2$$

Sectional calculation

Angle bending axis and neutral line $\alpha = 0,000^\circ$; $x_u = 285,8 \text{ mm}$; $d = 380,4 \text{ mm}$ Centroid section $y' = 225,0$ $z' = 0,0$ ($y = 225,0$ $z = 225,0$)

y' [mm]	z' [mm]	Wap.	Temp.*) [°C]	$f_{sy,\theta}$ [N/mm ²]	A_s [mm ²]	$\Delta\epsilon$ [o/oo]	σ_c [N/mm ²]	$\Delta\sigma_s$ [N/mm ²]
225,0	225,0					-3,500	-30,0	
225,0	180,0	1Ø20	321	-390	314	-2,949		-389,6
134,0	157,6	1Ø16	337	-381	201	-2,675		-353,4
315,0	155,9	1Ø20	321	-390	314	-2,653		-364,5
382,6	91,0	1Ø16	337	-381	201	-1,859		-245,6
69,1	90,0	1Ø20	321	-390	314	-1,846		-253,6
45,0	0,0	1Ø20	321	-390	314	-0,744		-102,2
405,0	0,0	1Ø20	321	-390	314	-0,744		-102,2
380,9	-90,0	1Ø20	321	494	314	0,358		49,2
67,4	-91,0	1Ø16	337	489	201	0,370		48,9
135,0	-155,9	1Ø20	321	494	314	1,165		160,0
316,0	-157,6	1Ø16	337	489	201	1,186		156,7
225,0	-180,0	1Ø20	321	494	314	1,461		200,6

y'	z'	F _c	F _s	dy'	dz'	F	F.dy'	F.dz'
[mm]	[mm]	[kN]	[kN]	[mm]	[mm]	[kN]	[kNm]	[kNm]
225,0	84,4	-1738,9		0,0	84,4	-1738,9	0,0	-146,7
225,0	180,0		-122,4	0,0	180,0	-122,4	0,0	-22,0
134,0	157,6		-71,0	-91,0	157,6	-71,0	6,5	-11,2
315,0	155,9		-114,5	90,0	155,9	-114,5	-10,3	-17,8
382,6	91,0		-49,4	157,6	91,0	-49,4	-7,8	-4,5
69,1	90,0		-79,7	-155,9	90,0	-79,7	12,4	-7,2
45,0	0,0		-32,1	-180,0	0,0	-32,1	5,8	0,0
405,0	0,0		-32,1	180,0	0,0	-32,1	-5,8	0,0
380,9	-90,0		15,5	155,9	-90,0	15,5	2,4	-1,4
67,4	-91,0		9,8	-157,6	-91,0	9,8	-1,6	-0,9
135,0	-155,9		50,3	-90,0	-155,9	50,3	-4,5	-7,8
316,0	-157,6		31,5	91,0	-157,6	31,5	2,9	-5,0
225,0	-180,0		63,0	0,0	-180,0	63,0	0,0	-11,3
totaal:						-2070,0	0,0	-235,9

*) EN 1992-1-2 Annex A

Fig. A.17: Temperature profiles for a circular column, D = 300 - R60

3: ULS fire R60 bending about Y-and Z-axis

Decisive combination 3: (6.11a)

5.8.9 Biaxial bending

$$\lambda_y / \lambda_z = 35,2 / 35,2 = 1,00 < 2$$

$$\lambda_z / \lambda_y = 35,2 / 35,2 = 1,00 < 2 \quad \dots(5.38a)$$

$$b_{eq} = i_y \sqrt{12} = 99,4 \times \sqrt{12} = 344,4 \text{ mm}$$

$$h_{eq} = i_z \sqrt{12} = 99,4 \times \sqrt{12} = 344,4 \text{ mm}$$

$$\frac{e_y / h_{eq}}{e_z / b_{eq}} = \frac{29,5 / 344,4}{40,6 / 344,4} = 0,73 > 0,2$$

$$\frac{e_z / b_{eq}}{e_y / h_{eq}} = \frac{40,6 / 344,4}{29,5 / 344,4} = 1,38 > 0,2 \quad \dots(5.38b)$$

Biaxial check is required!

$$\left(\frac{M_{Edz}}{M_{Rdz}} \right)^a + \left(\frac{M_{Edy}}{M_{Rdy}} \right)^a = \left(\frac{61,13}{235,87} \right)^{2,00} + \left(\frac{84,08}{235,87} \right)^{2,00} = 0,19 < 1,00 \quad \dots(5.39)$$

4: Controle voeg

Decisive combination 3: (6.11a)

N_{Edx} = 2070 kN; Granule diameter = 0 kNm;

10.9.4.3 Verbindingen die drukkraften overdragen

...NEN-EN 1992-1-1+C2:2011/NB:2011

Mortelvoeg: aangieten of injecteren k₁ = 0,9

$$k_4 = \min \left[\frac{b}{v}; \frac{x_u}{v} \right] = \min \left[\frac{397,8}{30}; \frac{369,9}{30} \right] = 12,329$$

$$A_{c0} = b_1 d_1 = 398 \times 370 = 147132 \text{ mm}^2$$

$$A_{c1} = b_2 d_2 = 1193 \times 1110 = 1324184 \text{ mm}^2$$

$$f_{cd} = \min \left(\sqrt{\frac{A_{c1}}{A_{c0}}}; 3 \right) f_{cd} = 40,0 \text{ N/mm}^2 \quad \dots(6.63)$$

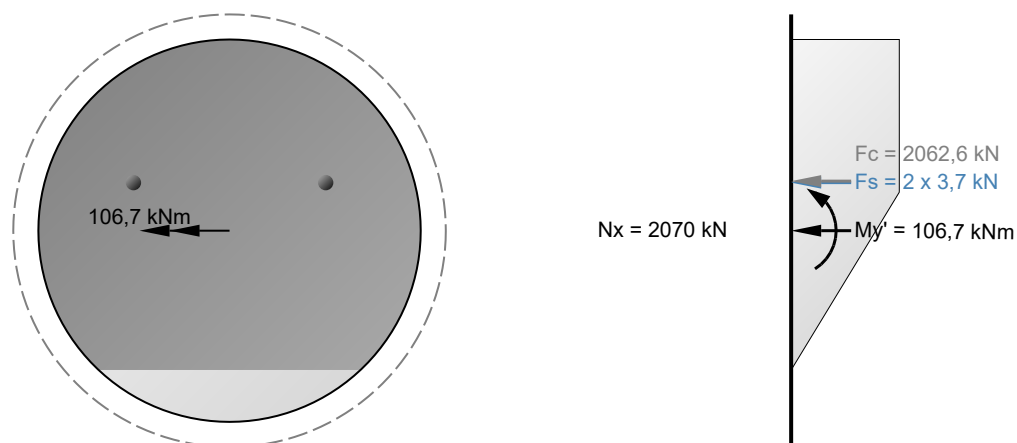
$$k_3 = \min \left[k_5 \frac{f_{md}}{f_{cd}}; 1,00 \right] = \min \left[0,5 \times \frac{15}{30}; 1,00 \right] = 0,25$$

$$k_2 = k_3 \frac{5(1 - k_3) + k_4^2}{5(1 - k_3) + k_3 k_4^2} = 0,25 \times \frac{5 \times (1 - 0,25) + 12,329^2}{5 \times (1 - 0,25) + 0,25 \times 12,329^2} = 0,933$$

$$f_{vd} = k_1 k_2 f_{cd} = 0,9 \times 0,933 \times 30 = 25,181 \text{ N/mm}^2$$

$$\frac{M_{Ed}}{M_{Rd}} = \frac{41,400}{106,728} = 0,39 < 1,0$$

Sectional calculation



Angle bending axis and neutral line $\alpha = 0,000^\circ$; $x_u = 369,9 \text{ mm}$; $d = 175,0 \text{ mm}$

Centroid section $y' = 0,0$ $z' = -225,0$ ($y = 0,0$ $z = 0,0$)

y' [mm]	z' [mm]	Wap.	Temp.*) [°C]	$f_{sy,\theta}$ [N/mm ²]	A_s [mm ²]	$\Delta\varepsilon$ [o/oo]	σ_c [N/mm ²]	$\Delta\sigma_s$ [N/mm ²]
0,0	0,0					-3,500	-25,2	
100,0	-175,0	1Ø16	900	-30	201	-1,844		-18,4
-100,0	-175,0	1Ø16	900	-30	201	-1,844		-18,4

y' [mm]	z' [mm]	F_c [kN]	F_s [kN]	dy' [mm]	dz' [mm]	F [kN]	$F \cdot dy'$ [kNm]	$F \cdot dz'$ [kNm]
0,0	-173,4	-2062,6		0,0	51,6	-2062,6	0,0	-106,3
100,0	-175,0		-3,7	100,0	50,0	-3,7	-0,4	-0,2
-100,0	-175,0		-3,7	-100,0	50,0	-3,7	0,4	-0,2
totaal:						-2070,0	0,0	-106,7

*) EN 1992-1-2 Annex A

Fig. A.17: Temperature profiles for a circular column, $D = 300 - R60$

Conclusion: Column complies.