Project name: TryIt
Project number: P-205/1
Description: Simple check
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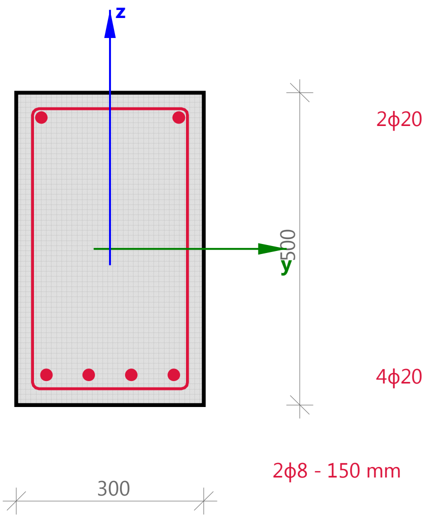
Date: 17.9.2014

NEMETSCHEK Scia



Calculation settings

EN 1992-1-1:2004/AC:2010-11	EC EN 1992-1-1
Member type	Beam Check
Lenght of member	5 m
Environment classes	X0

Materials

Concrete	C 20/25
Longitudinal reinforcement	B 500 B
Shear reinforcement	B 600 B

Cover

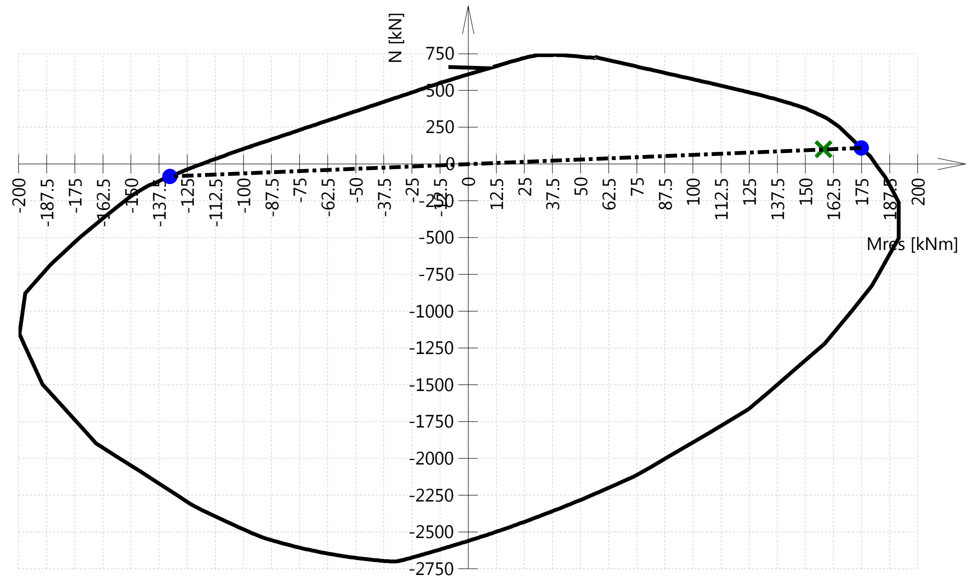
Nominal cover	22 mm
Maximal cover of reinforcement	38 mm
Minimal cover of reinforcement	30 mm

Calculation Summary

Check	Combination	N_{Ed} [kN]	V_{Edy} [kN]	V_{Edz} [kN]	T_{Ed} [kNm]	$M_{Edy,rec}$ [kNm]	$M_{Edz,rec}$ [kNm]	Unity check	Status
N+My+Mz - Diagram	ULS	100	10	25	15	150	50	0.90	OK
N+My+Mz - Response	ULS	100	10	25	15	150	50	1.00	OK
Capacity V_y-V_z - Shear	ULS	100	10	25	15	150	50	0.10	OK,*
Capacity T - Torsion	ULS	100	10	25	15	150	50	0.36	OK,*
Interaction V+T+M	ULS	100	10	25	15	150	50	0.93	OK,*
Stress limitation	SLS - Ch SLS - QP	0 0	0 0	0 0	0 0	42 45	0 0	0.56	OK,*
Crack width	SLS - Ch SLS - QP	0 0	0 0	0 0	0 0	42 45	0 0	0.13	OK
Deflections	SLS - Ch SLS - QP	0 0	0 0	0 0	0 0	42 45	0 0	0.99	OK

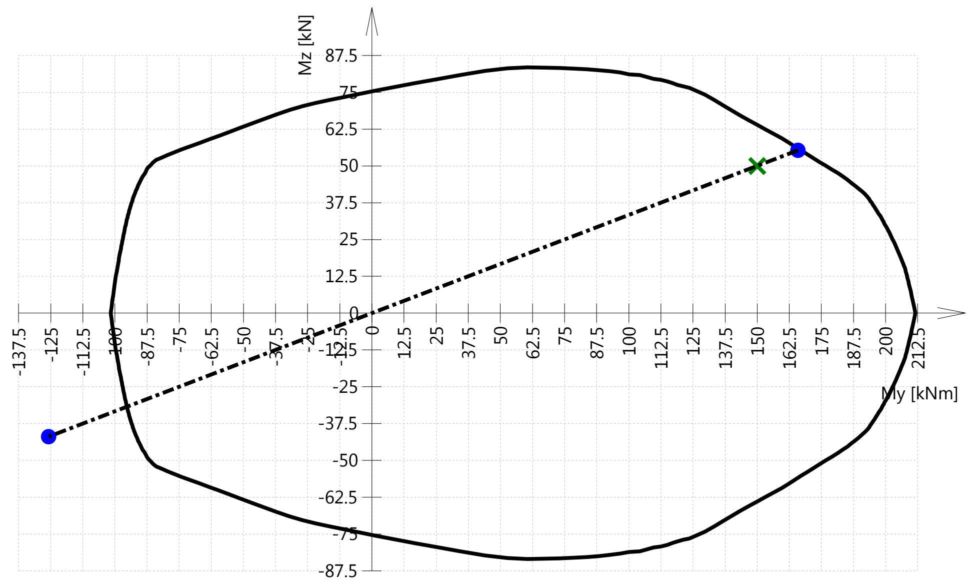
Capacity N+My+Mz - Diagram

3D interaction diagram - Vertical section N-M_{res}



Extreme	N [kN]	M_{res} [kNm]
Min	-2700	-200
Max	742	192

3D interaction diagram - Horizontal section M_y-M_z



Extreme	M_y [kN]	M_z [kNm]
Min	-102	-83.5
Max	212	83.5

Resistances in intersections

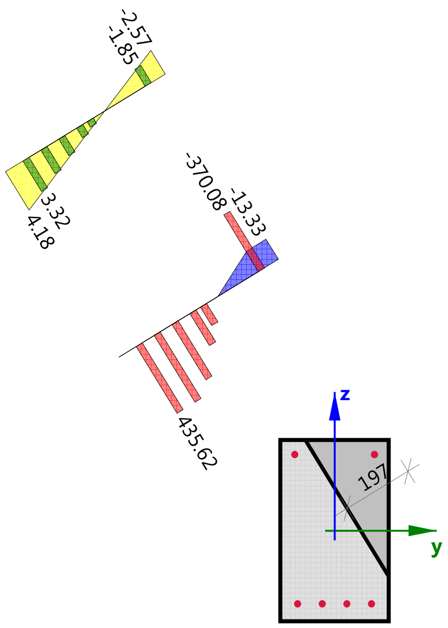
Intersection	Method of check	N_{Rd} [kN]	M_{Rdy} [kNm]	M_{Rdz} [kNm]
1	N_uM_u	111	166	55.3
2	N_uM_u	-83.9	-126	-42

Summary of check

N_{Ed} [kN]	M_{Edy} [kNm]	M_{Edz} [kNm]	Method of check	N_{Rd} [kN]	M_{Rdy} [kNm]	M_{Rdz} [kNm]	U.C. [-]	Limit [-]	Status
100	150	50	N_uM_u	111	166	55.3	0.90	1	

Capacity N+My+Mz - Response

Stress and strain distribution



Extreme values of stress/strain in component

Type of component	Fibre / Bar	ε [‰]	$ε_{lim}$ [‰]	σ [MPa]	$σ_{lim}$ [MPa]	U.C. [-]	Status
Concrete in compression	3	-2.57	-3.5	-13.3	-13.3	1.00	OK
Concrete in tension	1	4.18	0	0	0	0.00	OK
Reinforcement in compression	6	-1.85	-45	-370	-466	0.79	OK
Reinforcement in tension	1	3.32	45	436	466	0.93	OK

Parameters of the plane of equilibrium

Translation in (x) axis	ε_x = 0.8063 ‰
Curvature around (y) axis	ε_y = -11.15 ‰
Curvature around (z) axis	ε_z = -6.813 ‰
Height of compression zone	x = 197 mm
Balanced height of compression zone	x_{bal} = 221 mm
Limit height of compression zone	x_{lim} = 26.6 mm
Angle of neutral axis	α_{NA} = -58.6 °
Height of cross-section perpendicular to neutral axis	h = 517 mm
Effective height of cross-section	d = 455 mm
Inner lever arm	z = 344 mm
Effective depth of the cross-section perpendicular to the neutral axis (distance of the projection to a straight line perpendicular to the neutral axis of the furthemost compressed fibre of the cross-section and the centre of tensile forces	d_{rec}= 368 mm
Lever arm of the cross-section perpendicular to the neutral axis (distance of the projection to a straight line perpendicular to the neutral axis of the compressive force and the centre of tensile force)	z_{rec}=268 mm
Part of inner lever arm (distance from centre of tensile force to centre of CSS)	z+ = 0.169 m
Part of inner lever arm (distance from centre of compressive force to centre of CSS)	z- = 0.175 m

Cross-section characteristics on CSS components

Type of component	t_y [m]	t_z [m]	A [m^2]	I_y [m^4]	I_z [m^4]
Compressive concrete	0.073	0.124	0.0435	$1.01\cdot10^{-3}$	$361\cdot10^{-6}$
Tensile concrete	-0.03	-0.051	0.107	$2.11\cdot10^{-3}$	$764\cdot10^{-6}$
Compressive reinf.	0.11	0.21	$314\cdot10^{-6}$	$13.9\cdot10^{-6}$	$3.8\cdot10^{-6}$
Tensile reinf.	-0.022	-0.12	$1.57\cdot10^{-3}$	$65.1\cdot10^{-6}$	$11.1\cdot10^{-6}$
Whole concrete	0	0	0.15	$3.13\cdot10^{-3}$	$1.13\cdot10^{-3}$
All reinf. bars	0	-0.065	$1.89\cdot10^{-3}$	$79\cdot10^{-6}$	$14.9\cdot10^{-6}$

Forces in all cross-section components

Type of component	N_{res} [kN]	$M_{res,y}$ [kNm]	$M_{res,z}$ [kNm]	e_y [m]	e_z [m]
Concrete in compression	-274	42.1	25	-91.1	-154
Concrete in tension	0	0	0	0	0
Reinf. in compression	-116	24.4	12.8	-110	-210
Reinf. in tension	490	83.5	12.2	24.9	170
All in compression	-391	66.5	37.8	-96.7	-170
All in tension	490	83.5	12.2	24.9	170
Summary	99.8	150	50		

Detailed results of stresses and strains in concrete fibres

Fibre	Material	y_i [m]	z_i [m]	ε [‰]	ε_{lim} [‰]	σ [MPa]	σ_{lim} [MPa]	$\varepsilon / \varepsilon_{lim}$ [-]	σ / σ_{lim} [-]	Check
1	C 20/25	-0.15	-0.25	4.18	0	0	0	0	0	OK
2	C 20/25	0.15	-0.25	0.838	0	0	0	0	0	OK
3	C 20/25	0.15	0.25	-2.57	-3.5	-13.3	-13.3	0.734	1	OK
4	C 20/25	-0.15	0.25	0.775	0	0	0	0	0	OK

Detailed results of stresses and strains in reinforcement bars

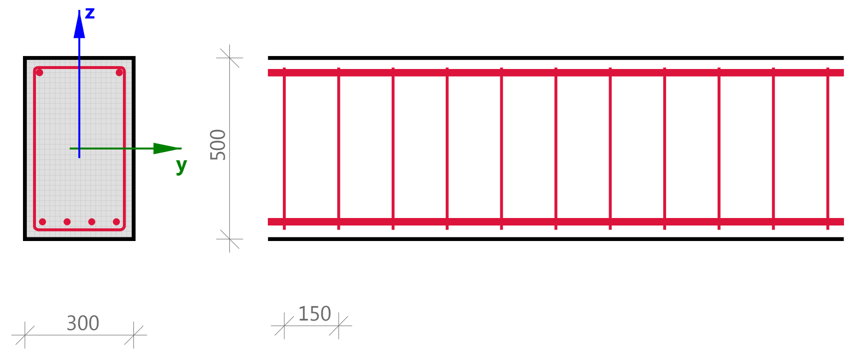
Bar	Material	d_s [mm]	y_i [m]	z_i [m]	ε [‰]	ε_{lim} [‰]	σ [MPa]	σ_{lim} [MPa]	$\varepsilon / \varepsilon_{lim}$ [-]	σ / σ_{lim} [-]	Check
1	B 500 B	20	-0.102	-0.202	3.32	45	436	466	0.0738	0.935	OK
2	B 500 B	20	-0.034	-0.202	2.56	45	435	466	0.0569	0.933	OK
3	B 500 B	20	0.034	-0.202	1.8	45	361	466	0.0401	0.774	OK
4	B 500 B	20	0.102	-0.202	1.05	45	209	466	0.0232	0.449	OK
5	B 500 B	20	-0.11	0.21	0.602	45	120	466	0.0134	0.258	OK
6	B 500 B	20	0.11	0.21	-1.85	-45	-370	-466	0.0411	0.794	OK

Summary of check

Type of component	Fibre / Bar	ε_{extr} [‰]	σ_{extr} [MPa]	Check strain [-]	Check stress [-]	U.C. [-]	Limit [-]	Status
Concrete	3	-2.57	-13.3	0.73	1.00	1.00	1	OK
Reinf.	1	3.32	436	0.07	0.93			

Capacity V_y+V_z - Shear

Cross section parameters



Minimum width of the cross-section in tensile area

y_{bw} = 65.5 mm

z_{bw} = 164 mm

b_w = 99.1 mm

Note: Value b_w is calculated as the smallest width of cross-section in tensile area perpendicular to resultant of shear force

Minimum width of cross-section between tension and compression chord

y_{bw1} = 72.1 mm

z_{bw1} = 180 mm

b_{w1} = 272 mm

Note: Value b_{w1} is calculated as the smallest width of cross-section between tension and compression chord perpendicular to resultant of shear force

Height of cross-section recalculated to direction of shear force resultant

h = 576 mm

Note: Value h is calculated as width of cross-section in center of gravity in direction shear force resultant

Concrete cross-section area

A_c = 0.15 m^2

Effective depth recalculated to direction of shear force resultant

d = 455 mm

Lever arm of internal forces recalculated to direction of shear force resultant

z = 361 mm

Parameters of reinforcement

Shear reinforcement

Number of stirrup links n_s = 2

Diameter of shear reinforcement ϕ_s = 8 mm

Centre - to - centre distance of stirrup in longitudinal direction s_{inp} = 0.15 m

Angle of stirrups from axis of member α_s = 90 °

Characteristic yield strength of shear reinforcement f_{ywk} = 600 MPa

Cross - sectional area of shear reinforcement

$$A_{sw} = n_s \cdot \pi \cdot \frac{\phi_s}{2}^2 = 2 \cdot 3.14 \cdot \frac{8}{2}^2 = 101\ mm^2$$

$s_l = s_{inp} = 150$ mm

Cross - sectional area of shear reinforcement per meter

$$A_{swm} = \frac{A_{sw}}{s_l} = \frac{101 \cdot 10^{-6}}{0.15} = 670\ mm^2/m$$

Parameters of longitudinal reinforcement

The area of tensile longitudinal reinforcement

$A_{sl} = 1571\ mm^2$

Calculation of shear resistances

Design shear resistance of the member without shear reinforcement

$\sigma_{ct.max} = 19.3$ MPa $\geq f_{ctd} = 1$ MPa => section cracked in flexure

Calculation design shear resistance of the member without shear reinf. according to chapter 6.2.2(1)

Coefficient for cross - section height

$$k = \min\left(1 + \left(\frac{200}{d}\right)^{\frac{1}{2}};2\right) = \min\left(1 + \left(\frac{200}{455}\right)^{\frac{1}{2}};2\right) = 1.7$$

$C_{Rdc} = 0.12$

$v_{min} = 0.336$

$k_1 = 0.15$

Geometrical reinforcement ratio

$$\rho_1 = \min\left(\frac{A_{sl}}{b_w \cdot d};0.02\right) = \min\left(\frac{1571}{99.1 \cdot 455};0.02\right) = 0.02$$

Cross-section axial stress

$$\sigma_{cp} = \min\left(\frac{-N_{Ed}}{A_c};0.2 \cdot f_{cd}\right) = \min\left(\frac{-100000}{0.15};0.2 \cdot 13.3 \cdot 10^6\right) = -0.667\ MPa$$

Calculation design shear resistance of the member without shear reinforcement

$$V_{Rdc} = 10^6 \cdot \left(C_{Rdc} \cdot k \cdot \left(100 \cdot \rho_1 \cdot f_{ck}\right)^{\frac{1}{3}} + k_1 \cdot \sigma_{cp}\right) \cdot b_w \cdot d$$
$$= 10^6 \cdot \left(0.12 \cdot 1.7 \cdot \left(100 \cdot 0.02 \cdot 20\right)^{\frac{1}{3}} + 0.15 \cdot -0.667\right) \cdot 99.1 \cdot 455 = 26.3\ kN$$

$$V_{Rdcmin} = 10^6 \cdot \left(v_{min} + k_1 \cdot \sigma_{cp}\right) \cdot b_w \cdot d = 10^6 \cdot \left(0.336 + 0.15 \cdot -0.667\right) \cdot 99.1 \cdot 455 = 10.6\ kN$$

$$V_{Rdc} = \max\left(V_{Rdc};V_{Rdcmin}\right) = \max\left(26.3;10.6\right) = 26.3\ kN$$

Note: Design shear resistance of the member without shear reinforcement is calculated according to clause 6.2.2(1) because section is cracked in flexure in ULS or section is not loaded by normal force and bending moments

Calculation of angle between concrete compression strut and member axis

Limit value of angle between concrete compression strut and member axis :

- minimum value:

$\theta_{min} = 21.8°$ => $\cot(\theta_{min}) = 2.5$

- maximum value:

$\theta_{max} = 45°$ => $\cot(\theta_{max}) = 1$

Note: Automatic calculation of angle is switched on, the calculated value from interaction V+T is taken into account.

Design shear resistance of the member with shear reinforcement

Design stress of shear reinforcement

$$\sigma_{swd} = \frac{\frac{V_{Ed}}{z}\cdot s_l}{A_{sw}\cdot \text{cotg}(\theta) + \text{cotg}(\alpha_s)\cdot \sin(\alpha_s)} = \frac{\frac{26.9}{361}\cdot 150}{101\cdot \text{cotg}(21.8) + \text{cotg}(90)\cdot \sin(90)} = 44.5\ \text{MPa}$$

Design yield strength of shear reinforcement

$f_{ywd} = 0.8 \cdot f_{ywk} = 0.8 \cdot 600 = 480$ MPa , (because $\sigma_{swd} < 0.8*f_{ywk}$)

Note: Design yield strength of shear reinforcement was reduced to 0.8x fywk (EN 1992-1-1, clause 6.2.3(3)) because design stress of the shear reinforcement is below 80% of the characteristic yield stress fyk

Design shear resistance of the member with shear reinforcement

$$V_{Rds} = \frac{A_{sw}}{s_l}\cdot z\cdot f_{ywd}\cdot \text{cotg}(\theta) + \text{cotg}(\alpha_s)\cdot \sin(\alpha_s) = \frac{101}{150}\cdot 361\cdot 480\cdot \text{cotg}(21.8) + \text{cotg}(90)\cdot \sin(90) = 291\ \text{kN}$$

Design value of the max.shear force which can be sustained by the member

Strength reduction factor for concrete cracked in shear - value ν

$$\nu = 0.6\cdot\left(1 - \frac{f_{ck}}{250}\right) = 0.6\cdot\left(1 - \frac{20}{250}\right) = 0.552$$

Strength reduction factor for concrete cracked in shear - value ν_1

$\nu_1 = 0.6$

Coeffcient taking into account state of the stress in the compresion chord

$\alpha_{cw} = 1$ (for non-prestressed member)

Design value of the max.shear force which can be sustained by the member

$$V_{Rdmax} = \frac{\alpha_{cw}\cdot b_{w1}\cdot z\cdot \nu_1\cdot f_{cd}}{\text{cotg}(\theta) + \text{tg}(\theta)} = \frac{1\cdot 272\cdot 361\cdot 0.6\cdot 13.3}{\text{cotg}(21.8) + \text{tg}(21.8)} = 271\ \text{kN}$$

Maximum shear force near the support (without using factor β)

$$V_{Edmax} = 0.5\cdot b_{w1}\cdot d\cdot \nu\cdot f_{cd} = 0.5\cdot 0.272\cdot 0.455\cdot 0.552\cdot 13.3\cdot 10^6 = 455\ \text{kN}$$

Shear resistance of the member

$$V_{Rd} = \min(V_{Rds} + V_{ccd} + V_{td}; V_{Rdmax}; V_{Edmax}) = \min(291 + 0 + 0; 271; 455) = 271\ \text{kN}$$

Shear check

Check of V_{Rdmax}

$V_{Ed} = 26.9\ \text{kN} \le V_{Rdmax} + V_{ccd} + V_{td} = 271\ \text{kN}$

Note: The check satisfies for crushing of the compression strut (VEd<=VRd,max+ Vtd+Vccd).

Check of V_{Edmax}

$V_{Ed} = 26.9\ \text{kN} \le V_{Edmax} + V_{ccd} + V_{td} = 455\ \text{kN}$

Note: The check satisfies for shear force near the support (VEd<=VEd,max+ Vtd+Vccd).

Check of V_{Rdc} and V_{Rds}

$V_{Ed} = 26.9\ \text{kN} < V_{Rds} + V_{ccd} + V_{td} = 291\ \text{kN}$

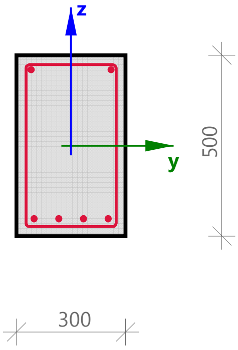
Note: The check satisfies for shear reinforcement (VEd < VRds + Vccd + Vtd)

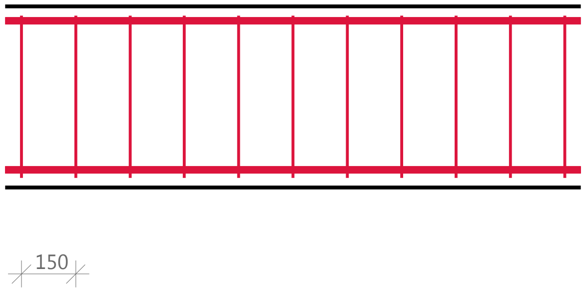
Unity check

$$UC = \frac{\text{abs}(V_{Ed})}{V_{Rd}} = \frac{\text{abs}(26.9\ \text{kN})}{271\ \text{kN}} = 0.0994$$

Capacity T - Torsion

Cross section parameters





Total area of cross-section

$A_c = 150000\ mm^2$

Total circumference of cross-section

$u_c = 1600\ mm$

The area of longitudinal reinforcement for torsion

$A_{sl} = 1885\ mm^2$

The minimum distance between reinf. bars inside stirrup for torsion and edge of Css

$a_{sl} = 40\ mm$

Effective wall thickness

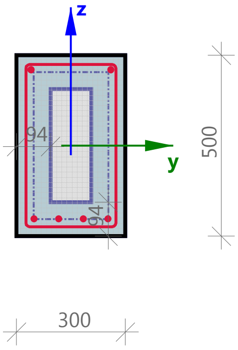
$$t_{ef} = \max\left(\frac{A_c}{u_c};2\cdot a_{sl}\right) = \max\left(\frac{0.15}{1.6};2\cdot 0.04\right) = 93.8\ mm$$

Perimeter of area and area enclosed by the centre line of effective cross-section

$u_k = 1225\ mm$

$A_k = 83789\ mm^2$

Note: Parameters for torsion (value A_k and u_k) are calculated for equivalent thin walled section which is created from input cross-section



Parameters of shear/torsion reinforcement

Diameter of shear reinforcement $\phi_s = 8$ mm

Centre - to - centre distance of stirrup in longitudinal direction $s_{inp} = 0.15$ m

Angle of stirrups from axis of member $\alpha_s = 90$ °

Characteristic yield strength of shear reinforcement $f_{ywk} = 500$ MPa

Cross - sectional area of shear reinforcement

$$A_{swt} = \pi \cdot \frac{\phi_s}{2}^2 = 3.14 \cdot \frac{8}{2}^2 = 50.3 \text{ mm}^2$$

Minimum shear reinforcement ratio

$$\rho_{w,min} = \frac{0.08 \cdot \sqrt{f_{ck}}}{f_{yk}} = \frac{0.08 \cdot \sqrt{20}}{500} = 716 \cdot 10^{-6}$$

Minimum area of shear reinforcement per meter

$$A_{swtm.min} = \rho_{w,min} \cdot b_w = 716 \cdot 10^{-6} \cdot 150 = 107 \text{ mm}^2$$

Maximum longitudinal spacing of shear links

$$s_l = s_{inp} = 150 \text{ mm}$$

Cross - sectional area of shear reinforcement per meter

$$A_{swtm} = \frac{A_{swt}}{s_l} = \frac{50.3 \cdot 10^{-6}}{0.15} = 335 \text{ mm}^2$$

Design yield strength of shear reinforcement

$$f_{ywd} = \frac{f_{ywk}}{\gamma_s} = \frac{500}{1.15} = 435 \text{ MPa}$$

Calculation of angle between concrete compression strut and member axis

Note: Automatic calculation of angle is switched on, the calculated value from interaction V+T is taken into account.

$$\theta = \theta_{int} = 21.8 \text{ °}$$

Calculation of torsional resistances

Design torsional cracking moment

$$T_{Rdc} = 2 \cdot f_{ctd} \cdot t_{ef} \cdot A_k = 2 \cdot 1 \cdot 10^6 \cdot 0.0938 \cdot 0.0838 = 15.7 \text{ kNm}$$

Design torsional resistance moment of torsional reinforcement

$$T_{Rdst} = 2 \cdot A_k \cdot \frac{A_{swt}}{s_l} \cdot f_{ywd} \cdot \text{cotg}(\theta) = 2 \cdot 0.0838 \cdot \frac{50.3 \cdot 10^{-6}}{0.15} \cdot 435 \cdot 10^6 \cdot \text{cotg}(21.8) = 61 \text{ kNm}$$

Maximal design torsional resistance moment

Strength reduction factor for concrete cracked in shear - value ν

$$\nu = 0.6 \cdot \left(1 - \frac{f_{ck}}{250}\right) = 0.6 \cdot \left(1 - \frac{20}{250}\right) = 0.552$$

Coeffcient taking into account state of the stress in the compression chord

$$\alpha_{cw} = 1$$

Maximal design torsional resistance moment

$$T_{Rdmax} = 2 \cdot \nu \cdot \alpha_{cw} \cdot f_{cd} \cdot A_k \cdot t_{ef} \cdot \cos(\theta) \cdot \sin(\theta)$$
$$= 2 \cdot 0.571 \cdot 1 \cdot 13.3 \cdot 10^6 \cdot 0.0838 \cdot 0.0938 \cdot \cos(21.8) \cdot \sin(21.8) = 41.3 \text{ kNm}$$

Torsional resistance moment of the member

$$T_{Rd} = \min\left(T_{Rdst};T_{Rdmax}\right) = \min\left(61;41.3\right) = 41.3\text{ kNm}$$

Torsional check

Check T_{Rdmax}

$$T_{Ed} = 15\text{ kNm} \leq T_{Rdmax} = 41.3\text{ kNm}$$

The check satisfies.

Check T_{Rdc} and T_{Rdst}

$$T_{Ed} = 15\text{ kNm} < T_{Rdc} = 15.7\text{ kNm and } T_{Ed} = 15\text{ kNm} < T_{Rdst} = 61\text{ kNm}$$

The check satisfies, torsional moment can be carried by concrete

Note: Only minimum shear reinforcement according to detailing provisions has to be inputted

Unity check

$$UC = \frac{abs\left(T_{Ed}\right)}{T_{Rd}} = \frac{abs\left(15\text{ kNm}\right)}{41.3\text{ kNm}} = 0.364$$

Summary of check

T_{Ed} [kNm]	T_{Rdc} [kNm]	T_{Rdst} [kNm]	T_{Rdmax} [kNm]	T_{Rd} [kNm]	U.C. [-]	Limit [-]	Status
15	15.7	61	41.3	41.3	0.36	1	

Explanation of errors, warnings and notes

Index	Type	Description	Solution
N4/1	Note	Parameters for torsion (value A_k and u_k) are calculated for equivalent thin walled section which is created from input cross-section	-
N4/2	Note	Automatic calculation of angle is switched on, the calculated value from interaction V+T is taken into account.	-
W4/1	Warning	The check satisfies, torsional moment can be carried by concrete, no shear reinforcement is required	Only minimum shear reinforcement according to detailing provision has to be inputted

Interaction V+T+M

Interaction Vy+Vz+T (concrete)

Check equation $(T_{Ed}/T_{Rdmax})+(V_{Ed}/V_{Rdmax})$

$$\left(\frac{abs\left(T_{Ed}\right)}{T_{Rdmax}}\right)+\left(\frac{abs\left(V_{Ed}\right)}{V_{Rdmax}}\right) = \left(\frac{abs\left(15\right)}{58.9}\right)+\left(\frac{abs\left(26.9\right)}{387}\right) = 0.324 \leq 1$$

Interaction check Vy+Vz+T for concrete satisfies.

Check equation $(T_{Ed}/T_{Rdc})+(V_{Ed}/V_{Rdc})$

$$\left(\frac{abs(T_{Ed})}{T_{Rdc}}\right)+\left(\frac{abs(V_{Ed})}{V_{Rdc}}\right)=\left(\frac{abs(15)}{15.7}\right)+\left(\frac{abs(26.9)}{26.3}\right)=1.98 > 1$$

Shear forces and torsional moment cannot be carried by concrete, shear reinforcement is required

Interaction Vy+Vz+T (shear reinforcement)

Check of shear reinforcement

Design stress of shear reinforcement

$$\sigma_{swd}=\left(\frac{T_{Ed}}{2\cdot A_k}+\frac{V_{Ed}}{n_s\cdot z}\right)\cdot\left(\frac{s_l}{A_{swt}\cdot cotg(\theta)}\right)=\left(\frac{15000}{2\cdot 0.0837}+\frac{26926}{2\cdot 0.361}\right)\cdot\left(\frac{0.15}{50.3\cdot 10^{-6}\cdot cotg(21.8)}\right)=151\ MPa$$

Design yield strength of shear reinforcement

$f_{ywd}=0.8\cdot f_{ywk}=0.8\cdot 500=400\ MPa$,(because $\sigma_{swd} < 0.8*f_{ywk}$)

Design force in shear reinforcement

$$F_{swd}=\sigma_{swd}\cdot A_{swt}=151\cdot 50.3=7.61\ kN$$

Maximum design force in shear reinforcement

$$F_{swdmax}=f_{ywd}\cdot A_{swt}=400\cdot 50.3=20.1\ kN$$

$$UC_{shear}=\frac{F_{swd}}{F_{swdmax}}=\frac{7.61}{20.1}=0.378 \quad < 1$$

Interaction check Vy+Vz+T for shear reinforcement satisfies

Interaction Vy+Vz+T (longitudinal reinforcement)

Check of longitudinal reinforcement to additional force

Design additional stress in longitudinal reinforcement

$$\sigma_{sd}=\left(\frac{T_{Ed}}{2\cdot A_k}\cdot u_k+V_{Ed}\right)\cdot\left(\frac{cotg(\theta)}{A_{sl.tor}}\right)=\left(\frac{15000}{2\cdot 0.0837}\cdot 1.34+26926\right)\cdot\left(\frac{cotg(21.8)}{1.88\cdot 10^{-3}}\right)=195\ MPa$$

Design yield strength of longitudinal reinforcement

$$f_{yd}=\frac{f_{yk}}{\gamma_s}=\frac{500}{1.15}=435\ MPa$$

Design additional tensile force in longitudinal reinforcement

$$F_{sd}=\sigma_{sd}\cdot A_{sl.tor}=195\cdot 1885=367\ kN$$

Maximum design force in longitudinal reinforcement

$$F_{sdmax}=f_{yd}\cdot A_{sl.tor}=435\cdot 1885=820\ kN$$

$$UC_{long}=\frac{F_{sd}}{F_{sdmax}}=\frac{367}{820}=0.448 \quad < 1$$

Interaction check Vy+Vz+T for longitudinal reinforcement satisfies

Interaction Vy+Vz+T+M

Calculation additional tensile force in long. reinforcement due to shear

$$\Delta F_{tds}=V_{Ed}\cdot cotg(\theta)=26.9\cdot cotg(21.8)=67.3\ kN$$

Calculation additional tensile force in long. reinforcement due to torsion

$$\Delta F_{tdt}=\left(\frac{T_{Ed}}{2\cdot A_k}\cdot u_k\right)\cdot cotg(\theta)=\left(\frac{15000}{2\cdot 0.0837}\cdot 1.34\right)\cdot cotg(21.8)=300\ kN$$

Calculation additional tensile force in long. reinforcement due to shear and torsion

$$\Delta F_{td}=\Delta F_{tds}+\Delta F_{tdt}=67.3+300=367\ kN$$

Detailed results of stress and strain

Bar [-]	ε [‰]	$\Delta\varepsilon$ [‰]	ε_{tot} [‰]	ε_{lim} [‰]	$\varepsilon_{tot}/\varepsilon_{lim}$ [-]	σ [MPa]	$\Delta\sigma$ [MPa]	σ_{tot} [MPa]	σ_{lim} [MPa]	$\sigma_{tot}/\sigma_{lim}$ [-]	Check [-]
1	3.32	$58.2\cdot10^{-6}$	3.32	45	0.0738	436	$42.5\cdot10^{-6}$	436	466	0.935	OK
2	2.56	$58.2\cdot10^{-6}$	2.56	45	0.0569	435	$42.5\cdot10^{-6}$	435	466	0.933	OK
3	1.8	$58.2\cdot10^{-6}$	1.8	45	0.0401	361	0.0116	361	466	0.774	OK
4	1.05	$58.2\cdot10^{-6}$	1.05	45	0.0232	209	0.0116	209	466	0.449	OK
5	0.602	$75\cdot10^{-6}$	0.602	45	0.0134	120	0.015	120	466	0.258	OK
6	-1.85	$75\cdot10^{-6}$	-1.85	45	-0.0411	-370	0.015	-370	-466	0.794	OK

Calculation strain and stress for long. reinforcement with maximum unity check

- strain in long. reinforcement due to normal force and bending moment: $\varepsilon_{max} = 3.32$ ‰
- additional tensile strain in long. reinforcement due to shear and torsion: $\Delta\varepsilon_{max} = 58.2\cdot10^{-6}$ ‰
- total strain in long. reinforcement: $\varepsilon_{tot.max} = \varepsilon_{max}+\Delta\varepsilon_{max} = 3.32 + 58.2\cdot10^{-6} = 3.32$ ‰
- ultimate value of strain in long. reinforcement: $\varepsilon_{lim.max} = 45$ ‰
- stress in long. reinforcement due to normal force and bending moment: $\sigma_{max} = 436$ MPa
- additional tensile stress in long. reinforcement due to shear and torsion: $\Delta\sigma_{max} = 42.5\cdot10^{-6}$ MPa
- total stress in long. reinforcement: $\sigma_{tot.max} = \sigma_{max}+\Delta\sigma_{max} = 436 + 42.5\cdot10^{-6} = 436$ MPa
- maximal value of stress in long. reinforcement: $\sigma_{lim.max} = 466$ MPa

Check of interaction Vy+Vz+T+M

$$\max\left(\frac{\varepsilon_{tot.max}}{\varepsilon_{lim.max}};\frac{\sigma_{tot.max}}{\sigma_{lim.max}}\right) = \max\left(\frac{3.32}{45};\frac{436}{466}\right) = 0.935 < 1$$

Interaction check Vy+Vz+T+M satisfies.

Unity check

$$UC = \max\left(UC_{con};UC_{shear};UC_{long};UC_{int}\right) = \max\left(0.324;0.378;0.448;0.935\right) = 0.935$$

All checks of interaction Vy+Vz+T+M satisfy

Summary of check

Type of check	UC [-]	Status
Interaction check Vy+Vz+T(concrete)	0.32	OK*
Interaction check Vy+Vz+T(shear)	0.38	OK*
Interaction check Vy+Vz+T(long. reinf.)	0.45	OK*
Interaction check Vy+Vz+T+M	0.93	OK*
Summary of check	0.93	OK*

List of errors/warnings/notes: W4/1, N4/1, N4/2

Explanation of errors, warnings and notes

Index	Type	Description	Solution
W4/1	Warning	The angle between gradient of the strain plane and the resultant of shear forces is greater, than 15 degrees	The more sophisticated method (biaxial shear calculation) should be used, because for greater angle than 15 degree, the value d and z recalculated to direction of shear force decrease rapidly
N4/1	Note	The value θ is calculated automatically by iterative calculation until condition $[(V_{Ed}/V_{Rd.max})+(T_{Ed}/T_{Rd.max})]$ <1 is fullfilled.	
N4/2	Note	Design yield strength of shear reinforcement was reduced to 0.8x fywk (EN 1992-1-1, clause 6.2.3(3)) because design stress of the shear reinforcement is below 80% of the characteristic yield stress fyk	-

Stress limitation

Short term load

Appearence of cracks

Calculation of $f_{ct,eff}$

f_{ctm} = 2.2 MPa

$\alpha_{M,char}$ = 90 deg

h_{char} = 500 mm

$f_{ctm,fl,char} = \max\left(1.6 - h_{char} \cdot f_{ctm}; f_{ctm}\right) = \max\left(1.6 - 500 \cdot 2.2; 2.2\right) = 2.42$ MPa

Concrete strength used for calculation $f_{ctm,fl}$

$f_{ct,eff,char} = f_{ctm,fl,char} = 2.42$ MPa

Strength in concrete , when crack is appeared:

$f_{ct,eff,char} = f_{ct,eff,char} = 2.42$ MPa

Characteristic combination - Short-term load

$\sigma_{ct} > f_{ct,eff}$ i.e. 2.82 MPa > 2.42 MPa => Cracks appear.

Summary of check

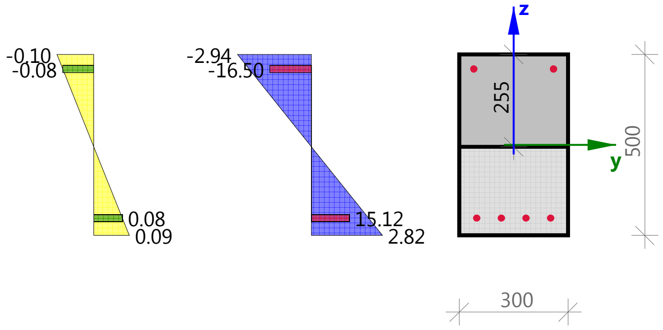
Load	E type	E_c [MPa]	U.C. §7.2(2) [-]	Status §7.2(2) Char.	U.C. §7.2(3) [-]	Status §7.2(3) Q.-P.	U.C. §7.2(5) [-]	Status §7.2(5) Char.	U.C. [-]	Limit [-]	Status
Short	E_c	30000	0.00	OK*	0.56	OK	0.20	OK	0.56	1	OK*

List of errors/warnings/notes: W5/1, N5/1.

Check if section is cracked or not

Load	Type of module	E_c [MPa]	Combi.	N_{Ed} [kN]	M_{Edy} [kNm]	M_{Edz} [kNm]	σ_{ct} [MPa]	h [mm]	$f_{ct,eff}$ [MPa]	Cracks appear
Short	E_c	30000	Char.	0	42	0	2.82	500	2.42	YES

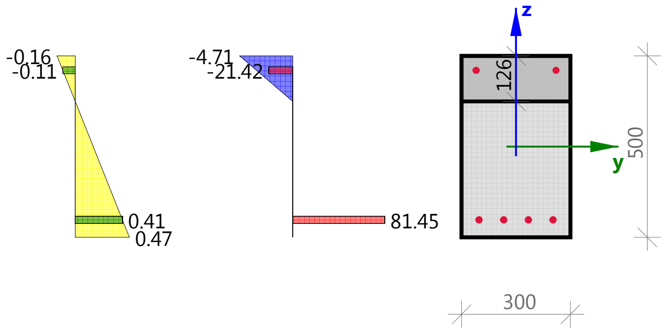
Stress-strain distribution in case of cracking - short-term load



Cross-section characteristics

Load	Combi.	t_{iy} [m]	t_{iz} [m]	A_i [m^2]	I_{iy} [m^4]	I_{iz} [m^4]	x_i [m]	$\varepsilon_{c,max}$ [‰]	$\varepsilon_{c,min}$ [‰]	$\sigma_{c,max}$ [MPa]	$\sigma_{c,min}$ [MPa]
Short	Char.	0	$-5 \cdot 10^{-3}$	0.163	$3.65 \cdot 10^{-3}$	$1.22 \cdot 10^{-3}$	0.126	4.67	-1.57	0	-4.71
Short	Q.-P.	0	$-5 \cdot 10^{-3}$	0.163	$3.65 \cdot 10^{-3}$	$1.22 \cdot 10^{-3}$	0.126	5.01	-1.68	0	-5.05

Stress-strain distribution without concrete tensile strength under characteristic combination - short-term load



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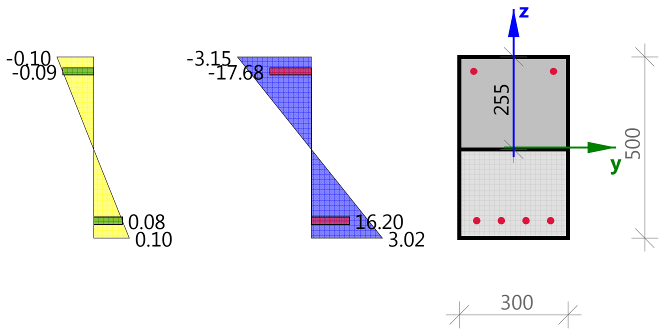
Stress-strain distribution with concrete tensile strength under quasi-permanent combination - short-term load



Stress limitation in concrete

Check type	Load	N_{Ed} [kN]	M_{Edy} [kNm]	M_{Edz} [kNm]	Fibre	y_i [mm]	z_i [mm]	σ_c [MPa]	$\sigma_{c,lim}$ [MPa]	$\sigma_c/\sigma_{c,lim}$ [-]	Status
§7.2(2) Char.	Short	0	42	0							OK*
§7.2(3) Q.-P.	Short	0	45	0	2	0.15	0.25	-5.05	-9	0.561	OK

Stress limitation in non-prestressed reinforcement

Check type	Load	N_{Ed} [kN]	M_{Edy} [kNm]	M_{Edz} [kNm]	Reinf	y_i [mm]	z_i [mm]	σ_s [MPa]	$\sigma_{s,lim}$ [MPa]	$\sigma_s/\sigma_{s,lim}$ [-]	Status
§7.2(5) Char.	Short	0	42	0	0	-0.102	-0.202	81.5	400	0.204	OK

Explanation of errors, warnings and notes

Index	Type	Description	Solution
W5/1	Warning	The maximal effective concrete strength is exceeded; cracks appear under the characteristic combination of Short-term loads. Furthermore, the concrete stress-strain diagram without tension branch is used.	Change amount of reinforcement, dimensions of the cross-section and/or quality of the used materials.
N5/1	Note	Check of stress limitaton is not required for the selected exposure class.	Change the exposure class to XD, XS or XF.

Long term load

Appearence of cracks

Calculation of $f_{ct,eff}$

f_{ctm} = 2.2 MPa

$\alpha_{M,char}$ = 90 deg

h_{char} = 500 mm

$$f_{ctm,fl,char} = \max\left(1.6 - h_{char} \cdot f_{ctm}; f_{ctm}\right) = \max\left(1.6 - 500 \cdot 2.2; 2.2\right) = 2.42 \text{ MPa}$$

Concrete strength used for calculation $f_{ctm,fl}$

$f_{ct,eff,char} = f_{ctm,fl,char}$ = 2.42 MPa

Strength in concrete , when crack is appeared:

$f_{ct,eff,char} = f_{ct,eff,char}$ = 2.42 MPa

Characteristic combination - Long-term load

$\sigma_{ct} < f_{ct,eff}$ i.e. 2.41 MPa < 2.42 MPa => No cracks appear.

Summary of check

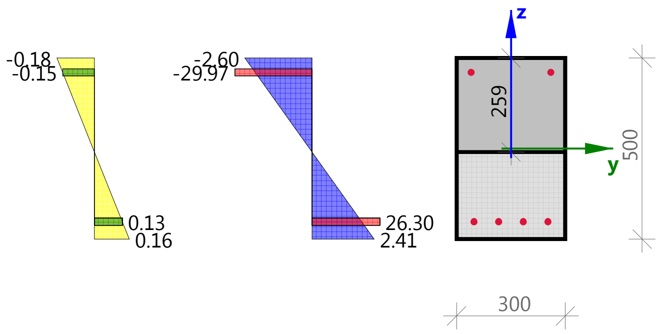
Load	E type	E_c [MPa]	U.C. §7.2(2) [-]	Status §7.2(2) Char.	U.C. §7.2(3) [-]	Status §7.2(3) Q.-P.	U.C. §7.2(5) [-]	Status §7.2(5) Char.	U.C. [-]	Limit [-]	Status
Long	$E_{c,eff}$	14699	0.00	OK*	0.31	OK	0.07	OK	0.31	1	OK

List of errors/warnings/notes: N5/1.

Check if section is cracked or not

Load	Type of module	E_c [MPa]	Combi.	N_{Ed} [kN]	M_{Edy} [kNm]	M_{Edz} [kNm]	σ_{ct} [MPa]	h [mm]	$f_{ct,eff}$ [MPa]	Cracks appear
Long	$E_{c,eff}$	14699	Char.	0	42	0	2.41	500	2.42	NO

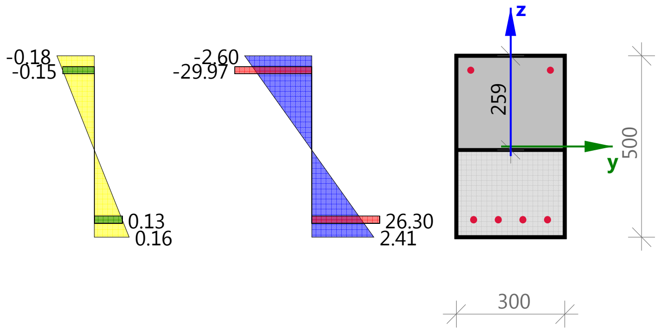
Stress-strain distribution in case of cracking - long-term load



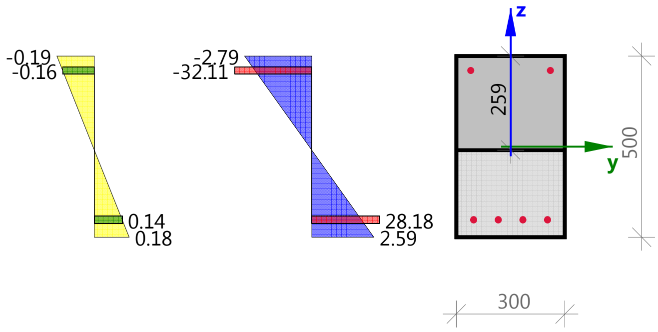
Cross-section characteristics

Load	Combi.	t_{iy} [m]	t_{iz} [m]	A_i [m^2]	I_{iy} [m^4]	I_{iz} [m^4]	x_i [m]	$\varepsilon_{c,max}$ [‰]	$\varepsilon_{c,min}$ [‰]	$\sigma_{c,max}$ [MPa]	$\sigma_{c,min}$ [MPa]
Long	Char.	0	$-9.4 \cdot 10^{-3}$	0.176	$4.2 \cdot 10^{-3}$	$1.33 \cdot 10^{-3}$	0.259	1.64	-1.77	2.41	-2.6
Long	Q.-P.	0	$-9.4 \cdot 10^{-3}$	0.176	$4.2 \cdot 10^{-3}$	$1.33 \cdot 10^{-3}$	0.259	1.76	-1.9	2.59	-2.79

Stress-strain distribution with concrete tensile strength under characteristic combination - long-term load



Stress-strain distribution with concrete tensile strength under quasi-permanent combination - long-term load



Stress limitation in concrete

Check type	Load	N_{Ed} [kN]	M_{Edy} [kNm]	M_{Edz} [kNm]	Fibre	y_i [mm]	z_i [mm]	σ_c [MPa]	$\sigma_{c,lim}$ [MPa]	$\sigma_c/\sigma_{c,lim}$ [-]	Status
§7.2(2) Char.	Long	0	42	0							OK*
§7.2(3) Q.-P.	Long	0	45	0	2	0.15	0.25	-2.79	-9	0.31	OK

Stress limitation in non-prestressed reinforcement

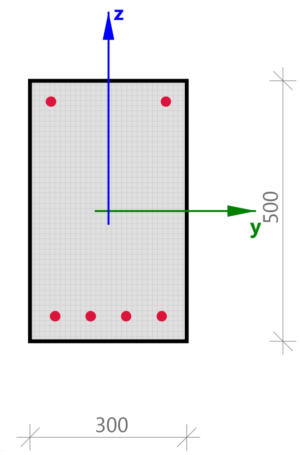
Check type	Load	N_{Ed} [kN]	M_{Edy} [kNm]	M_{Edz} [kNm]	Reinf	y_i [mm]	z_i [mm]	σ_s [MPa]	$\sigma_{s,lim}$ [MPa]	$\sigma_s/\sigma_{s,lim}$ [-]	Status
§7.2(5) Char.	Long	0	42	0	0	-0.102	-0.202	26.3	400	0.0658	OK

Explanation of errors, warnings and notes

Index	Type	Description	Solution
N5/1	Note	Check of stress limitaton is not required for the selected exposure class.	Change the exposure class to XD, XS or XF.

Crack width

Cross-section characteristics



Type	Css cracked	Css uncracked
t_{iy} [m]	0	0
t_{iz} [m]	$-9 \cdot 10^{-3}$	0.088
A_i [m^2]	0.176	0.0742
I_{iy} [m^4]	$4.2 \cdot 10^{-3}$	$2.57 \cdot 10^{-3}$
I_{iz} [m^4]	$1.33 \cdot 10^{-3}$	$566 \cdot 10^{-6}$

Calculation of cracking forces (uncracked section)

Maximal stress in concrete $\sigma_{ct} = 2.41$ MPa

Cracking forces $N_{cr} = 0$ kN $M_{cry} = 45.4$ kNm $M_{crz} = 0$ kNm

$\sigma_{ct} = 2.41 \text{ MPa} > \sigma_{cr} = 0 \text{ MPa}$ => Cracks appear

Note: The crack is appeared, because maximal tensile stress is greater than effective strength of concrete

Calculation of crack width (cracked section)

Height of cross-section in direction of bending resultant

$h = 500$ mm

Calculation effective height of cross-section

$d = 452$ mm

Calculation height of compression zone

$x_r = 162$ mm

Depth of effective area of the concrete in the tension

$$h_{c.ef} = \mathrm{Min}\begin{Bmatrix} 2.5 \cdot h - d \\ \dfrac{h - x_r}{3} \\ \dfrac{h}{2} \end{Bmatrix} = \mathrm{Min}\begin{Bmatrix} 2.5 \cdot 500 - 452 \\ \dfrac{500 - 162}{3} \\ \dfrac{500}{2} \end{Bmatrix} = 113 \text{ mm}$$

Calculation fibre of concrete cross-section with max/min tensile strength of the concrete

y_{fib} = -150 mm

z_{fib} = -250 mm

Effective area of the concrete in the tension

$A_{c.eff} = 33828\ mm^2$

Minimum and maximum value of the strain in concrete

ε_{max} = 0.52 ‰

ε_{min} = -0.249 ‰

Greater value of tensile strain in concrete

$\varepsilon_1 = max(\varepsilon_{min};\varepsilon_{max}) = max(-0.249;0.52) = 0.52$ ‰

Lesser value of tensile strain in concrete

ε_2 = 0 ‰

Coefficient, which takes into account distribution of the strain

$$k_2 = \frac{(\varepsilon_1 + \varepsilon_2)}{2 \cdot \varepsilon_1} = \frac{(0.52 + 0)}{2 \cdot 0.52} = 0.5$$

$k_{t.long} = 0.4$

$k_{t.short} = 0.6$

Factor dependent on duration of the load

$$k_t = k_{t.long} + (k_{t.short} - k_{t.long}) \cdot (1 - Coeff_{long}) = 0.4 + (0.6 - 0.4) \cdot (1 - 0.6) = 0.48$$

Equivalent diamater of the longitudinal reinforcement inside area $A_{c,eff}$

ϕ_{eq} = 20 mm

Maximal value of tensile stress of the reinforcement inside area $A_{c,eff}$

σ_s = 89.3 MPa

Area of reinforcement inside area $A_{c,eff}$

$A_s = 1257\ mm^2$

Ratio of modulus of concrete and reinforcement

$$\alpha_E = \frac{E_s}{E_c} = \frac{200000}{8857} = 22.6$$

Ratio of reinforcement inside area $A_{c,eff}$

$$\rho_{p.eff} = \frac{A_s}{A_{c.eff}} = \frac{1257}{33828} = 0.0371$$

Cover of the reinf., which is nearest to the edge of Css in direction of bending moment resultant

c = 30 mm

Calculation maximal centre to centre distance between bars inside area $A_{c,eff}$

s_{max} = 68 mm

Coefficient, which takes bond properties of the reinforcement

k_1 =0.8

Coefficient for calculation maximum crack spacing

k_3 = 3.4

k_4 = 0.425

Maximum crack spacing

s_{max} = 68 mm <= 5*(c+0.5*ϕ_{eq}) = 200 mm or $\rho_{p.eff}$ == 0,

therefore:

$$s_{r.max} = k_3 \cdot c + \frac{k_1 \cdot k_2 \cdot k_4 \cdot \phi_{eq}}{\rho_{p.eff}} = 3.4 \cdot 0.03 + \frac{0.8 \cdot 0.5 \cdot 0.425 \cdot 0.02}{0.0371} = 194 \text{ mm}$$

Mean strain in the reinforcement

$$\varepsilon_{sm\_cm} = \max\left(\frac{\sigma_s - k_t \cdot \left(\frac{f_{ct.eff}}{\rho_{p.eff}}\right) \cdot \left(1 + \alpha_E \cdot \rho_{p.eff}\right)}{E_s}; \frac{0.6 \cdot \sigma_s}{E_s}\right)$$

$$= \max\left(\frac{89.3 - 0.48 \cdot \left(\frac{2.6}{0.0371}\right) \cdot \left(1 + 22.6 \cdot 0.0371\right)}{200000}; \frac{0.6 \cdot 89.3}{200000}\right) = 0.268\ ‰$$

Calculated crack width

$$w = \varepsilon_{sm\_cm} \cdot s_{r.max} = 268 \cdot 10^{-6} \cdot 0.194 = 0.0518 \text{ mm}$$

Limit value of crack width

w_{max} = 0.4 mm

Unity check

Calculation unity check

$$UC = \frac{w}{w_{max}} = \frac{0.0518 \text{ mm}}{0.4 \text{ mm}} = 0.13$$

Check crack width

w = 0.0518 mm = < w_{max} = 0.4 mm

Note: Check crack width satisfies, because the crack width is lesser than limit value

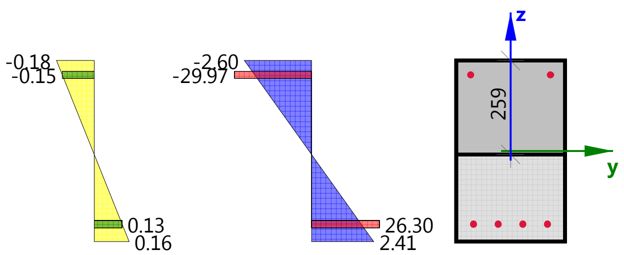
Summary of check

σ_{ct} [MPa]	σ_{cr} [MPa]	Cracked	w [mm]	w_{lim} [mm]	Unity check [-]	Limit check [-]	Status
2.41	0	YES	0.0518	0.4	0.13	1	OK

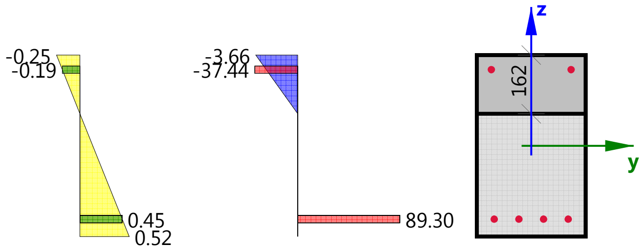
Explanation of errors, warnings and notes

Index	Type	Description	Solution
N5/1	Note	The crack is appeared, because maximal tensile stress is greater than effective strength of concrete	
N5/2	Note	Check crack width satisfies, because the crack width is lesser than limit value	

Stress and strain of uncracked section loading by SLS char loads



Stress and strain of cracked section loading by SLS quasi permanent loads



Deflections

Short-term stiffnesses and curvatures

Calculation settings

Long-term part of applied load = 0%

Creep coefficient $\varphi = 0$

Calculation of $f_{ct,eff}$

$f_{ctm} = 2.2$ MPa

$\alpha_M = 90$ °

$h = 0.5$ m

$f_{ctm,fl} = \max\left(1.6 - h \cdot f_{ctm}; f_{ctm}\right) = \max\left(1.6 - 0.5 \cdot 2.2; 2.2\right) = 2.42$ MPa

$f_{ct,eff} = f_{ctm,fl} = 2.42$ MPa

Strength in concrete , when crack is appeared

$f_{ct,eff} = f_{ct,eff} = 2.42$ MPa

Cracks - Short -term

$\sigma_{ct} = 2.82$ MPa

$\sigma_{ct} > f_{ct,eff}$ = 2.82 MPa > 2.42 MPa => Cracks appear.

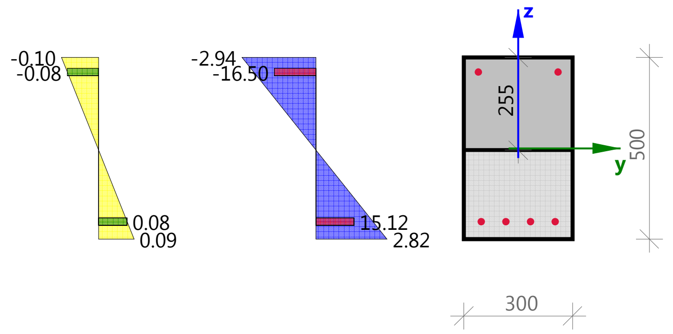
Cross-section characteristics

Type of component	t_y [m]	t_z [m]	A [m^2]	I_y [m^4]	I_z [m^4]	x_i [m]	A_{st} [m^2]	A_{sc} [m^2]	A_s [m^2]
Linear	0	0	0.15	$3.13 \cdot 10^{-3}$	$1.13 \cdot 10^{-3}$	0.25	-	-	-
Uncracked	0	$-5 \cdot 10^{-3}$	0.163	$3.65 \cdot 10^{-3}$	$1.22 \cdot 10^{-3}$	0.255	$1.26 \cdot 10^{-3}$	$628 \cdot 10^{-6}$	$1.89 \cdot 10^{-3}$
Cracked	0	0.124	0.0503	$1.9 \cdot 10^{-3}$	$382 \cdot 10^{-6}$	0.126	$1.26 \cdot 10^{-3}$	$628 \cdot 10^{-6}$	$1.89 \cdot 10^{-3}$

Check of concrete stresses and calculation of cracking forces

$N_{cr,}$ [kN]	$M_{y,cr}$ [kNm]	$M_{z,cr}$ [kNm]	σ_{ct} [MPa]	$f_{ct,eff}$ [MPa]	Cracked section	σ_{sr} [MPa]	σ_s [MPa]	β [-]	ζ [-]	E_c [GPa]
0	-34.7	0	2.82	2.42	YES	129	87.3	1	0	30

Stress and strain distribution for Short-term load



Stiffnesses

Type of component	EI [MNm^2]	EI_y [MNm^2]	EI_z [MNm^2]	EA [MN]
Linear	93.8	93.8	33.8	4500
Uncracked	110	110	36.7	4877
Cracked	56.9	56.9	11.5	1509
Resultant	110	110	36.7	4877

Curvatures

Type of component	1/r [m^{-1}]	$1/r_y$ [m^{-1}]	$1/r_z$ [m^{-1}]	ε_0 [‰]
Linear	$480\cdot10^{-6}$	$-480\cdot10^{-6}$	0	0
Uncracked	$410\cdot10^{-6}$	$-410\cdot10^{-6}$	0	$-2\cdot10^{-6}$
Cracked	$1.34\cdot10^{-3}$	$-1.34\cdot10^{-3}$	0	$166\cdot10^{-6}$
Resultant	$410\cdot10^{-6}$	$-410\cdot10^{-6}$	0	$-2\cdot10^{-6}$

List of errors/warnings/notes: W8/1.

Explanation of errors, warnings and notes

Index	Type	Description	Solution
W8/1	Warning	The maximal effective concrete strength is exceeded; cracks appear under the Short-term characteristic load combination. Furthermore, the concrete stress-strain diagram without tensile branch is used.	Change (a) the dimensions of the cross-section, (b) the amount of reinforcement or (c) the quality of the used materials.

Long-term stiffnesses and curvatures

Calculation settings

Long-term part of applied load = 60%

Creep coefficient φ = 1.04

Calculation of $f_{ct,eff}$

f_{ctm} = 2.2 MPa

$\alpha_M = 90\,°$

h = 0.5 m

$f_{ctm,fl} = \max(1.6 - h \cdot f_{ctm}; f_{ctm}) = \max(1.6 - 0.5 \cdot 2.2; 2.2) = 2.42$ MPa

$f_{ct,eff} = f_{ctm,fl} = 2.42$ MPa

Strength in concrete , when crack is appeared

$f_{ct,eff} = f_{ct,eff} = 2.42$ MPa

Cracks - Long -term

$\sigma_{ct} = 2.41$ MPa

$\sigma_{ct} < f_{ct,eff}$ = 2.41 MPa < 2.42 MPa => No cracks appear

Project name: TryIt
Project number: P-205/1
Description: Simple check
Author: Broz, Nemetschek Scia s.r.o.
Date: 17.9.2014

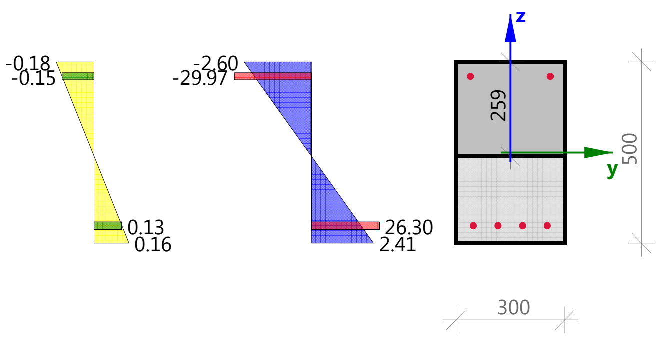
Cross-section characteristics

Type of component	t_y [m]	t_z [m]	A [m^2]	I_y [m^4]	I_z [m^4]	x_i [m]	A_{st} [m^2]	A_{sc} [m^2]	A_s [m^2]
Linear	0	0	0.15	$3.13 \cdot 10^{-3}$	$1.13 \cdot 10^{-3}$	0.25	-	-	-
Uncracked	0	$-9 \cdot 10^{-3}$	0.176	$4.2 \cdot 10^{-3}$	$1.33 \cdot 10^{-3}$	0.259	$1.26 \cdot 10^{-3}$	$628 \cdot 10^{-6}$	$1.89 \cdot 10^{-3}$
Cracked	0	0.088	0.0742	$2.57 \cdot 10^{-3}$	$566 \cdot 10^{-6}$	0.162	$1.26 \cdot 10^{-3}$	$628 \cdot 10^{-6}$	$1.89 \cdot 10^{-3}$

Check of concrete stresses and calculation of cracking forces

$N_{cr,}$ [kN]	$M_{y,cr}$ [kNm]	$M_{z,cr}$ [kNm]	σ_{ct} [MPa]	$f_{ct,eff}$ [MPa]	Cracked section	σ_{sr} [MPa]	σ_s [MPa]	β [-]	ζ [-]	E_c [GPa]
0	-39.2	0	2.41	2.42	NO	149	35.7	0.5	0	14.7

Stress and strain distribution for Long-term load



Stiffnesses

Type of component	EI [MNm^2]	EI_y [MNm^2]	EI_z [MNm^2]	EA [MN]
Linear	45.9	45.9	16.5	2205
Uncracked	61.7	61.7	19.5	2582
Cracked	37.8	37.8	8.32	1090
Resultant	61.7	61.7	19.5	2582

Curvatures

Type of component	1/r [m^{-1}]	$1/r_y$ [m^{-1}]	$1/r_z$ [m^{-1}]	ε_0 [‰]
Linear	$390 \cdot 10^{-6}$	$-390 \cdot 10^{-6}$	0	0
Uncracked	$290 \cdot 10^{-6}$	$-290 \cdot 10^{-6}$	0	$-3 \cdot 10^{-6}$
Cracked	$620 \cdot 10^{-6}$	$-620 \cdot 10^{-6}$	0	$54 \cdot 10^{-6}$
Resultant	$290 \cdot 10^{-6}$	$-290 \cdot 10^{-6}$	0	$-3 \cdot 10^{-6}$

Deflections

Basic values of deflections

Type of deflection	Ratio short [-]	Ratio long [-]	δ_{lin} [mm]	δ_{imm} [mm]	δ_{add} [mm]	δ_{short} [mm]	δ_{long} [mm]	$\delta_{long+creep}$ [mm]	δ_{creep} [mm]
u_x	0.923	0.854	0	0	0	0	0	0	0
u_y	0.919	0.848	0	0	0	0	0	0	0
u_z	0.856	0.744	25	12.8	6.88	8.56	12.8	11.2	-1.68

Check of additional and total deflections

Type of deflection	L [m]	δ_{add} [mm]	$\delta_{add,lim}$ [mm]	$U.C._{add}$ [-]	δ_{tot} [mm]	$\delta_{tot,lim}$ [mm]	$U.C._{tot}$ [-]	U.C. [-]	Limit [-]	Status
u_x	5	0	10	0.00	0	20	0.00	0.00	1	OK
u_y	5	0	10	0.00	0	20	0.00	0.00	1	OK
u_z	5	6.88	10	0.69	19.7	20	0.99	0.99	1	OK