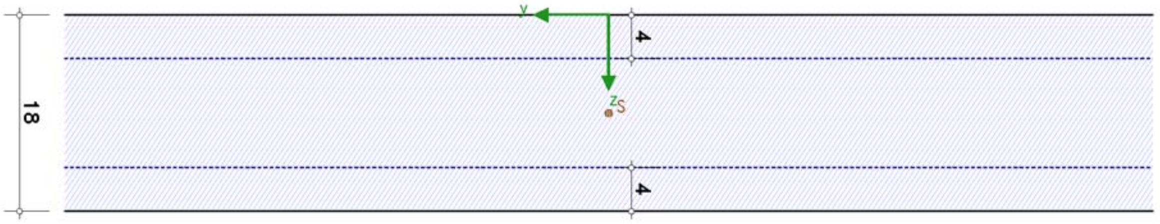
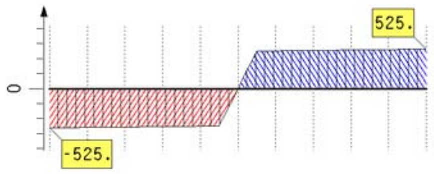
reinforced concrete design EC 2 (1.11), NA: Deutschland 4H-EC2QB Version: 10/2023-1b

1. input protocol

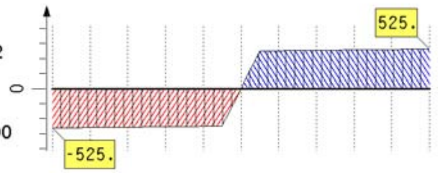


1.1. building material

reinforcing steel bottom B500A, above B500A, concrete C30/37
characteristic values for the consideration of creep and shrinkage in concrete (for verifications in SLS):
creep coefficient φ_{eff} = 2.367, shrinkage $\varepsilon_{cs,\infty}$ = 0.000‰
characteristic values for the calculation of effective concrete strengths (crack verification): cement CEM 32.5 R (class N), effective section thickness h_0 = 18.0 cm
stress-strain line of reinforcing steel: EC 2-1-1, 3.2.7 (bilinear)

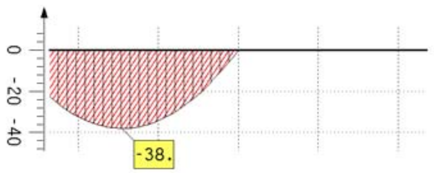


bottom:
σ in N/mm²
ε in ‰
max ε = 25.00
max σ = 525.00



above:
σ in N/mm²
ε in ‰
max ε = 25.00
max σ = 525.00

stress-strain line of concrete: EC 2-1-1, 3.1.5 (realistic)



σ in N/mm²
ε in ‰
min ε = -11.79
min σ = -38.00

1.2. material safety factors

serviceability: concrete γ_c = 1.00, reinforcement γ_s = 1.00

1.3. cross section

plate: h = 18.0 cm
axis distances: d_o = 4.0 cm, d_u = 4.0 cm
max. reinforcement ratio ρ_s = 8.00%

1.4. design parameters

1.4.1. crack verification

perm. crack width: $w_{o,lim}$ = 0.30 mm, $w_{u,lim}$ = 0.30 mm
bar diameter of the crack-distributing reinforcement: $Ø_{ro}$ = 10 mm, $Ø_{ru}$ = 10 mm

1.4.1.1. minimum reinforcement (EC 2, 7.3.2)

calculation acc. to Lohmeyer/Ebeling
time of crack initiation $t_{crit} = 1.3 \cdot t_{max,T} + 24$ = 55 h,
$t_{max,T}$ = 24 h for normal hardening concrete (CEM 32.5 R) and h_0 = 18.0 cm
concrete tensile strength during initial cracking $f_{ct,eff} = k_{ct} \cdot f_{ctm}$ = 2.16 N/mm²,
coefficient $k_{ct} = k_j \cdot k_{ct(t)}$ = 0.75 for normal hardening concrete (CEM 32.5 R) and t_{crit} = 55 h, $k_{ct(t)}$ = 0.68,
k_j = 1.1 (summer)

calculation of the constraint force for in-situ concrete walls

dimensions of the wall H_w = 3.20 m, L_w = 6.00 m, t_w = 18.0 cm
constraint force $N_{ct} = \sigma_{ct,d} \cdot A_{c,eff}$ = 481.29 kN/m, $A_{c,eff}$ = 1800.0 cm²/m
design value of constraint stress $\sigma_{ct,d} = k_{ct,d} \cdot \sigma_{ct(t)}$ = 2.67 N/mm², $k_{ct,d}$ = 0.48 for L_w/H_w = 1.88
constraint stress $\sigma_{ct(t)} = \alpha_{T(t)} \cdot \Delta T_{c,B} \cdot E_{c(t)} + \varepsilon_{cst} \cdot E_{c(t)}$ = 5.56 N/mm²
shrinkage at time t = 55 h: $\varepsilon_{cst} = -(\varepsilon_{cas}+\varepsilon_{cds})$ = -0.024‰ where
autogenous shrinkage: $\varepsilon_{cas} = \varepsilon_{cas,0} \cdot \beta_{as}$ = 0.013‰ with $\varepsilon_{cas,0} = 2.5 \cdot (f_{ck}-10)$ = 0.050‰, $\beta_{as} = 1-e^{-0.2 \cdot t^{1/2}}$ = 0.261
drying shrinkage: $\varepsilon_{cds} = \varepsilon_{cds,0} \cdot \beta_{ds} \cdot k_h$ = 0.011‰ with $\varepsilon_{cds,0} = 0.85 \cdot ((220+110 \cdot \alpha_{ds1}) \cdot e^{-\alpha_{ds2} \cdot f_{cm}/10}) \cdot \beta_{RH}$ = 0.541‰,
k_h = 0.88 for h_0 = 18.0 cm, α_{ds1} = 4.0 and α_{ds2} = 0.12 for cement group N,
$\beta_{RH} = 1.55 \cdot (1-(RH/100)^3)$ = 1.356 for RH = 50%, $\beta_{ds} = \Delta t/(\Delta t+0.04 \cdot (h_0^3)^{1/2})$ = 0.023, $\Delta t = t-t_s$ = 2.29 d

coefficient of thermal expansion of young concrete $\alpha_{T(t)} = 12.7 \cdot 10^{-6}$ 1/K at time t = 2.29 d (55 h)
average cooling of concrete $\Delta T_{c,B} = 15.2$ K for normal hard. concrete (CEM 32.5 R) and $h_0 = 18.0$ cm (summer)
E-modulus of young concrete $E_{c(t)} = k_{Et} \cdot E_c = 25587.3$ N/mm², tangent modulus $E_c = 1.05 \cdot E_{cm} = 34478.4$ N/mm²
coefficient $k_{Et} = \alpha_{E,g} \cdot 0.82 = 0.74$ for normal hardening concrete (CEM 32.5 R) and $t_{crit} = 55$ h, $\alpha_{E,g} = 0.9$
constraint force $N_{ct} = 481.29$ kN/m
constraint force (EC 2): $N_{ct,EC2} = f_{ct,eff} \cdot A_{c,eff} = 389.50$ kN/m, $f_{ct,eff} = 2.16$ N/mm², $A_{c,eff} = 1800.0$ cm²/m
constraint force $N_{ct} > N_{ct,EC2}$ $\Rightarrow$ crack resistance not existent ($N_{ct}/N_{ct,EC2} = 1.236 > 1$) $\Rightarrow$ $N_{ct} = N_{ct,EC2}$
calculation of minimum reinforcement with $N_{ct,clc} = N_{ct} \cdot A_c / A_{c,eff} = 389.50$ kN/m, $A_c = 1800.0$ cm²/m, $A_{c,eff} = 1800.0$ cm²/m
coefficient for stress distribution k_c from centric constraint
coefficient for consideration of nonlinearly distributed residual stresses k from self-induced constraint

2. notes

crack verification: perm. crack width (load+constraint) is not verified.
cross section type plate: results refer to 1 m plate width.

3. crack verification

material properties
σ-ε line acc. to EC 2, 3.1.5(1): C30/37, $\varepsilon_{c1} = -2.16‰$, $\varepsilon_{cu1} = -3.50‰$, $f_{cm} = 38.00$ N/mm², $E_{cm} = 32836.6$ N/mm²
σ-ε line acc. to EC 2, 3.2.7(2a): B500A, $\varepsilon_u = 25.00‰$, $f_{yk} = 500.0$ N/mm², $f_{tk} = 525.0$ N/mm², $E_s = 200000.0$ N/mm²
σ-ε line acc. to EC 2, 3.2.7(2a): B500A, $\varepsilon_u = 25.00‰$, $f_{yk} = 500.0$ N/mm², $f_{tk} = 525.0$ N/mm², $E_s = 200000.0$ N/mm²

3.1. calculation of minimum reinforcement (EC 2, 7.3.2)

crack stress $\sigma_{cr} = 2.16$ N/mm², coefficient for non-linear residual stresses k = 0.80
reinforcement above
perm. crack width $w_{o,lim} = 0.30$ mm
coefficient for stress distribution $k_{co} = 1.00$, tension zone $A_{cto} = 9.00$ dm², crack zone $A_{c,eff,o} = 9.00$ dm²
stress in reinforcement $\sigma_{sro} = 279.1$ N/mm²
reinforcement (minimum reinforcement) $A_{so,min} = 5.58$ cm²
reinforcement bottom
perm. crack width $w_{u,lim} = 0.30$ mm
coefficient for stress distribution $k_{cu} = 1.00$, tension zone $A_{ctu} = 9.00$ dm², crack zone $A_{c,eff,u} = 9.00$ dm²
stress in reinforcement $\sigma_{sru} = 279.1$ N/mm²
reinforcement (minimum reinforcement) $A_{su,min} = 5.58$ cm²

4. final result

maximum reinforcement: $A_{so} = 5.58$ cm², $A_{su} = 5.58$ cm²

design resistance ensured

5. regulations

EN 1990, Eurocode 0: Grundlagen der Tragwerksplanung;
Deutsche Fassung EN 1990:2002 + A1:2005 + A1:2005/AC:2010, Ausgabe Dezember 2010
EN 1990/NA, Nationaler Anhang zur EN 1990, Ausgabe Dezember 2010

EN 1992-1-1, Eurocode 2: Bemessung und Konstruktion von Stahlbeton- und Spannbetonbauteilen -
Teil 1-1: Allgemeine Bemessungsregeln und Regeln for den Hochbau;
Deutsche Fassung EN 1992-1-1:2004 + AC:2010, Ausgabe Januar 2011
EN 1992-1-1/NA, Nationaler Anhang zur EN 1992-1-1, Ausgabe April 2013

G. Lohmeyer, K. Ebeling: Weiße Wannen - einfach und sicher, Planung und Konstruktion
wasserundurchlässiger Bauwerke aus Beton, Verlag Bau+Technik GmbH, Düsseldorf