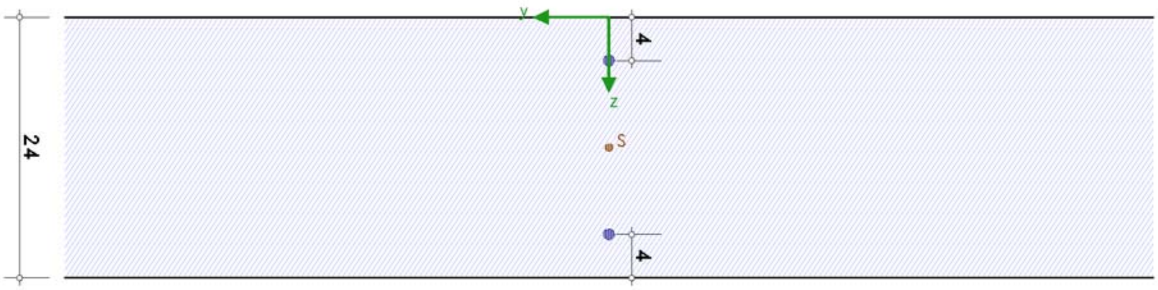
POS. 61: BSP. 8.3 W (LOHMEYER)

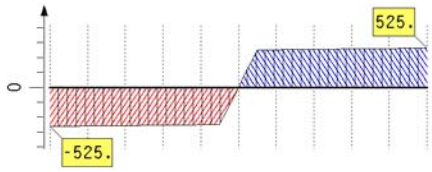
reinforced concrete design EC 2 (1.11), NA: Deutschland 4H-EC2QB Version: 10/2023-1b

1. input protocol

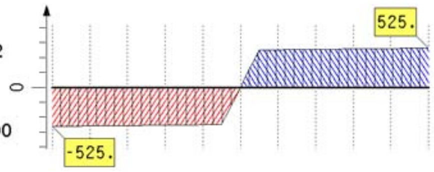


1.1. building material

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 = 24.0 cm
stress-strain line of reinforcing steel: EC 2-1-1, 3.2.7 (bilinear)

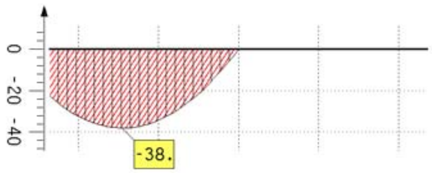


bottom:
σ in N/mm²
ε in ‰
max ε = 25.00
max σ = 525.00



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 = 24.0 cm
axis distances: d_o = 4.0 cm, d_u = 4.0 cm
base reinforcement: A_{so0} = Ø 10 / 90.0 = 0.87 cm²/m, A_{su0} = Ø 10 / 90.0 = 0.87 cm²/m
max. reinforcement ratio ρ_s = 8.00%

1.4. durability and concrete cover

above: minimum strength class, concrete cover for $Ø_s$ = 10 mm
due to reinforcement corrosion XC1 ⇒ C16/20, c_{min} = $Ø_s$ = 10 mm, Δc = 10 mm, c_{nom} = c_{min}+Δc = 20 mm
minimum concrete quality C16/20 with f_{ck} = 16.0 N/mm² < 30.0 N/mm² ok
minimum axial spacing min d = c_{nom}+$Ø_s$/2 = 25 mm < clc d = 40 mm ok
bottom: minimum strength class, concrete cover for $Ø_s$ = 10 mm
due to reinforcement corrosion XC2 ⇒ C16/20, c_{min} = 20 mm, Δc = 15 mm, c_{nom} = c_{min}+Δc = 35 mm
due to concrete attack XA1 ⇒ C25/30
minimum concrete quality C25/30 with f_{ck} = 25.0 N/mm² < 30.0 N/mm² ok
minimum axial spacing min d = c_{nom}+$Ø_s$/2 = 40 mm ≤ clc d = 40 mm ok

1.5. design parameters

1.5.1. 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

1.5.1.1. minimum reinforcement (EC 2, 7.3.2)
calculation acc. to Lohmeyer/Ebeling
time of crack initiation $t_{crit} = 1.3 \cdot t_{max,T}+24$ = 56 h,
$t_{max,T}$ = 25 h for normal hardening concrete (CEM 32.5 R) and h_0 = 24.0 cm
concrete tensile strength during initial cracking $f_{ct,eff} = k_{ct} \cdot f_{ctm}$ = 1.98 N/mm²,
coefficient $k_{ct} = k_j \cdot k_{ct(t)}$ = 0.68 for normal hardening concrete (CEM 32.5 R) and t_{crit} = 56 h, $k_{ct(t)}$ = 0.68,
k_j = 1.0 (spring/autumn)
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 = 24.0 cm
constraint force $N_{ct} = \sigma_{ct,d} \cdot A_{c,eff}$ = 449.55 kN/m, $A_{c,eff}$ = 2080.0 cm²/m
design value of constraint stress $\sigma_{ct,d} = k_{ct,d} \cdot \sigma_{ct(t)}$ = 2.16 N/mm², $k_{ct,d}$ = 0.48 for L_W/H_W = 1.88
constraint stress $\sigma_{ct(t)} = \alpha_{T(t)} \cdot \Delta T_{c,B} \cdot E_{c(t)} + \varepsilon_{cst} \cdot E_{c(t)}$ = 4.49 N/mm²
shrinkage at time t = 56 h: $\varepsilon_{cst} = -(\varepsilon_{cas}+\varepsilon_{cds})$ = -0.020‰ 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‰, $\beta_{as} = 1-e^{-0.2.t1/2}$ = 0.263
drying shrinkage: $\varepsilon_{cds} = \varepsilon_{cds,0} \cdot \beta_{ds} \cdot k_h$ = 0.007‰ with $\varepsilon_{cds,0} = 0.85 \cdot ((220+110 \cdot \alpha_{ds1}) \cdot e^{-\alpha ds2.fcm/10}) \cdot \beta_{RH}$ = 0.557‰,
k_h = 0.81 for h_0 = 24.0 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%, $\beta_{ds} = \Delta t/(\Delta t+0.04 \cdot (h_0^3)^{1/2})$ = 0.015, $\Delta t = t-t_s$ = 2.33 d
coefficient of thermal expansion of young concrete $\alpha_{T(t)} = 12.7 \cdot 10^{-6}$ 1/K at time t = 2.33 d (56 h)
average cooling of concrete $\Delta T_{c,B}$ = 12.2 K for normal hard. concrete (CEM 32.5 R) and h_0 = 24.0 cm (spring/autumn)
E-modulus of young concrete $E_{c(t)} = k_{Et} \cdot E_c$ = 25651.9 N/mm², tangent modulus $E_c = 1.05 \cdot E_{cm}$ = 34478.4 N/mm²
coefficient $k_{Et} = \alpha_{E,g} \cdot 0.83$ = 0.74 for normal hardening concrete (CEM 32.5 R) and t_{crit} = 56 h, $\alpha_{E,g}$ = 0.9
constraint force N_{ct} = 449.55 kN/m
constraint force (EC 2): $N_{ct,EC2} = f_{ct,eff} \cdot A_{c,eff}$ = 411.68 kN/m, $f_{ct,eff}$ = 1.98 N/mm², $A_{c,eff}$ = 2080.0 cm²/m
constraint force $N_{ct} > N_{ct,EC2}$ ⇒ crack resistance not existent ($N_{ct}/N_{ct,EC2}$ = 1.092 > 1) ⇒ $N_{ct} = N_{ct,EC2}$
calculation of minimum reinforcement with $N_{ct,clc} = N_{ct} \cdot A_c/A_{c,eff}$ = 475.02 kN/m, A_c = 2400.0 cm²/m, $A_{c,eff}$ = 2080.0 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, ε_{c1} = -2.16‰, ε_{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, ε_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, ε_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 σ_{cr} = 1.98 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} = 12.00 dm², crack zone $A_{c,eff,o}$ = 10.40 dm²
stress in reinforcement σ_{sro} = 266.9 N/mm²
reinforcement (minimum reinforcement) $A_{so,min}$ = 7.12 cm²
reinforcement bottom
perm. crack width $w_{u,lim}$ = 0.30 mm
coefficient for stress distribution k_{cu} = 1.00, tension zone A_{ctu} = 12.00 dm², crack zone $A_{c,eff,u}$ = 10.40 dm²
stress in reinforcement σ_{sru} = 266.9 N/mm²
reinforcement (minimum reinforcement) $A_{su,min}$ = 7.12 cm²

4. final result

maximum reinforcement: A_{so} = 7.12 cm², A_{su} = 7.12 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