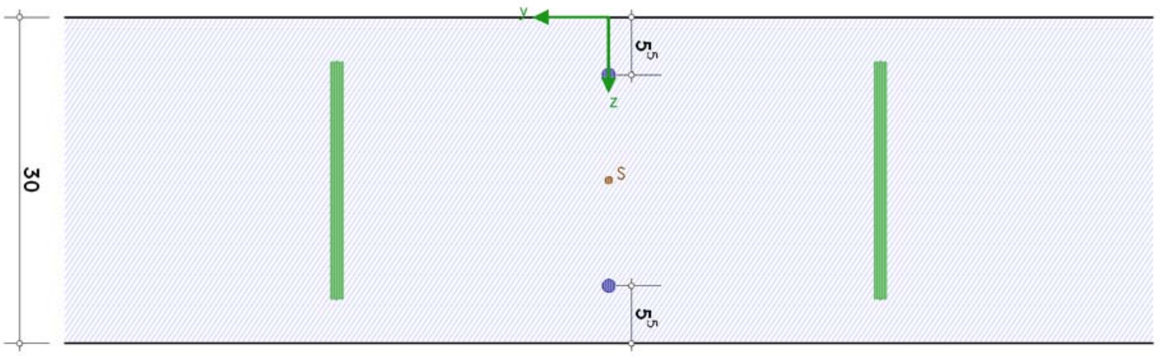
POS. 41: BSP. 8.6 P (LOHMEYER)

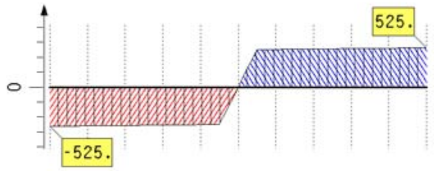
reinforced concrete design EC 2 (1.11), NA: Deutschland 4H-EC2QB Version: 10/2023-1b

1. input protocol

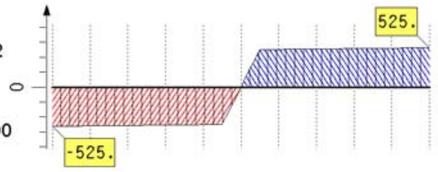


1.1. building material

reinforcing steel bottom B500A, above B500A, concrete C25/30
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 42.5 N (class N), effective section thickness h_0 = 30.0 cm
stress-strain line of reinforcing steel: EC 2-1-1, 3.2.7 (bilinear)

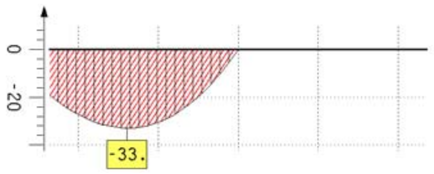


bottom:
σ in N/mm²
ε in ‰
max ε = 25.00
max σ = 525.00



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 = -33.00

1.2. material safety factors

serviceability: concrete γ_c = 1.00, reinforcement γ_s = 1.00

1.3. cross section

plate: h = 30.0 cm
axis distances: d_o = 5.3 cm, d_u = 5.3 cm
base reinforcement: A_{so0} = Ø 12 / 90.0 = 1.26 cm²/m, A_{su0} = Ø 12 / 90.0 = 1.26 cm²/m, a_{sbv0} = Ø 12 / 100.0 = 2.26 cm²/m (2-cut)
max. reinforcement ratio ρ_s = 8.00%

1.4. durability and concrete cover

above: minimum strength class, concrete cover for $Ø_s$ = 12 mm, $Ø_{sb}$ = 12 mm
due to reinforcement corrosion XC1 ⇒ C16/20, c_{min} = $Ø_s$ = 12 mm, Δc = 10 mm, c_{nom} = c_{min}+Δc = 22 mm
minimum concrete quality C16/20 with f_{ck} = 16.0 N/mm² < 25.0 N/mm² ok
minimum axial spacing min d = c_{nom}+$Ø_{sb}$+$Ø_s$/2 = 40 mm < clc d = 53 mm ok
bottom: minimum strength class, concrete cover for $Ø_s$ = 12 mm, $Ø_{sb}$ = 12 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 ≤ 25.0 N/mm² ok
minimum axial spacing min d = c_{nom}+$Ø_{sb}$+$Ø_s$/2 = 53 mm ≤ clc d = 53 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: $Ø_{ro}$ = 12 mm, $Ø_{ru}$ = 12 mm

1.5.1.1. minimum reinforcement (EC 2, 7.3.2)

calculation acc. to Lohmeyer/Ebeling
time of crack initiation t_{crit} = 672 h (input value)
concrete tensile strength during initial cracking $f_{ct,eff} = k_{ct} \cdot f_{ctm}$ = 3.00 N/mm² $\leq$ min $f_{ct,eff}$ = 3.0 N/mm²,
coefficient $k_{ct} = k_j \cdot k_{ct(t)}$ = 1.00 for normal hardening concrete (CEM 42.5 N) and t_{crit} = 672 h, $k_{ct(t)}$ = 1.00,
k_j = 1.0 (spring/autumn)

calculation of the constraint force for base plates

dimensions of the base plate L_p = 24.00 m, B_p = 16.00 m, t_p = 30.0 cm
separation cracking in base plates (friction model)
constraint force $N_{ct,1} = \gamma_{ct} \cdot \mu_d \cdot \sigma_0 \cdot L_p/2$ = 566.40 kN/m, γ_{ct} = 1.00
design value of friction $\mu_d = \gamma_R \cdot \mu_0$ = 1.000, γ_R = 1.25, μ_0 = 0.80
design value of ground compression $\sigma_{0d} = t_p \cdot \rho_p + q_p$ = 47.20 kN/m², ρ_p = 0.0 kN/m³, q_p = 47.20 kN/m²
constraint force N_{ct} = 566.40 kN/m
creep and relaxation $N_{ct,red} = k_{(\varphi+\psi)spät} \cdot N_{ct}$ = 453.12 kN, $k_{(\varphi+\psi)spät}$ = 0.80
constraint force (EC 2): $N_{ct,EC2} = f_{ct,eff} \cdot A_{c,eff}$ = 697.67 kN/m, $f_{ct,eff}$ = 2.56 N/mm², $A_{c,eff}$ = 2720.0 cm²/m
constraint force $N_{ct} \leq N_{ct,EC2}$ $\Rightarrow$ crack resistance available ($N_{ct}/N_{ct,EC2}$ = 0.649 < 1)
calculation of minimum reinforcement with $N_{ct,clc} = N_{ct} \cdot A_c/A_{c,eff}$ = 499.76 kN/m, A_c = 3000.0 cm²/m, $A_{c,eff}$ = 2720.0 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): C25/30, ε_{c1} = -2.07‰, ε_{cu1} = -3.50‰, f_{cm} = 33.00 N/mm², E_{cm} = 31475.8 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} = 1.67 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} = 15.00 dm², crack zone $A_{c,eff,o}$ = 13.60 dm²
stress in reinforcement σ_{sro} = 223.6 N/mm²
reinforcement (minimum reinforcement) $A_{so,min}$ = 8.94 cm²
reinforcement bottom
perm. crack width $w_{u,lim}$ = 0.30 mm
coefficient for stress distribution k_{cu} = 1.00, tension zone A_{ctu} = 15.00 dm², crack zone $A_{c,eff,u}$ = 13.60 dm²
stress in reinforcement σ_{sru} = 223.6 N/mm²
reinforcement (minimum reinforcement) $A_{su,min}$ = 8.94 cm²

4. final result

maximum reinforcement: A_{so} = 8.94 cm², A_{su} = 8.94 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