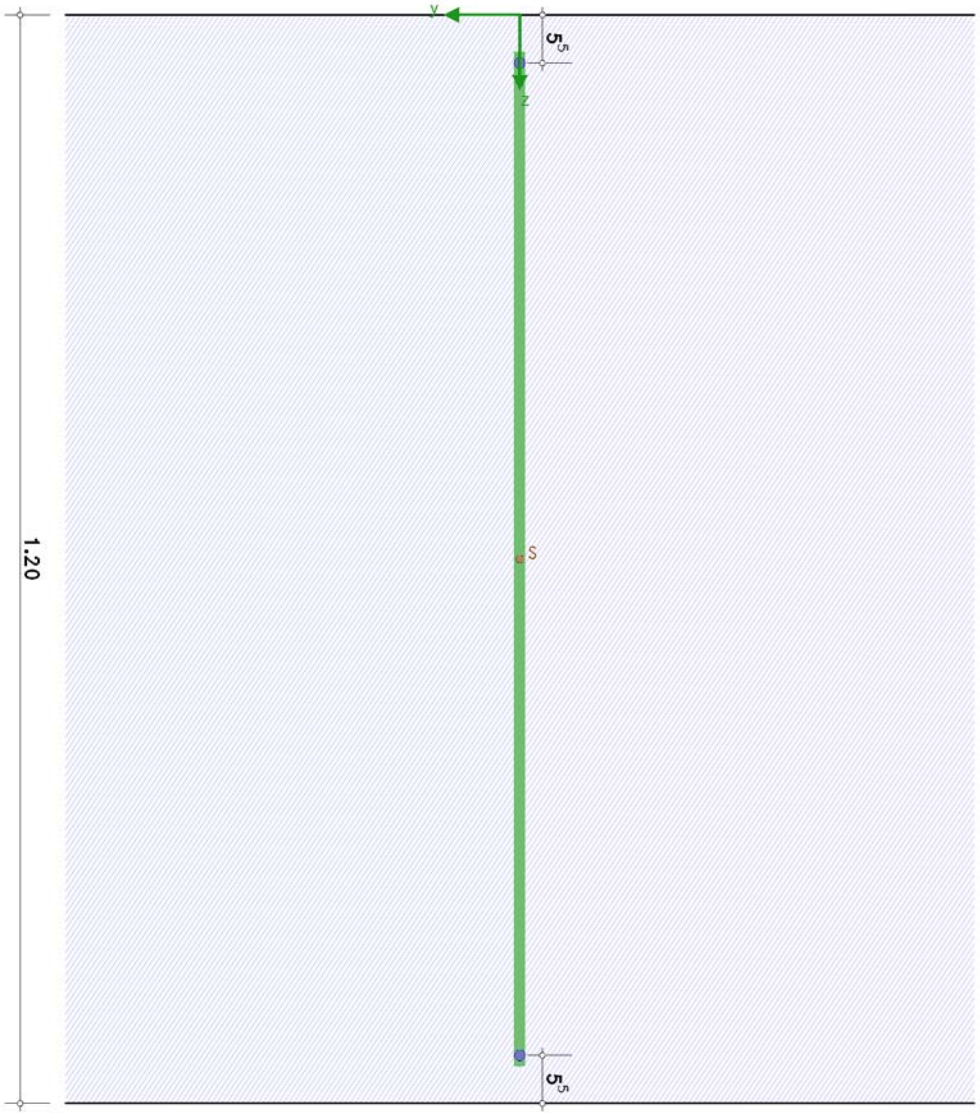
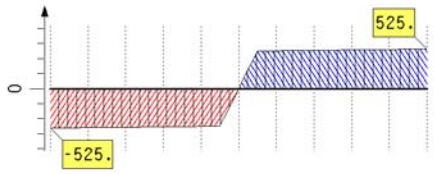
reinforced concrete design EC 2 (1.11), NA: Deutschland 4H-EC2QB Version: 10/2023-1b

1. input protocol

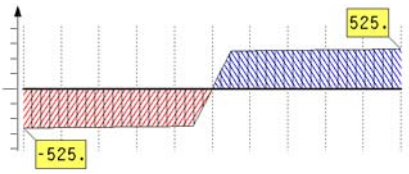


1.1. building material

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 32.5 N (class S), effective section thickness h_0 = 120.0 cm
stress-strain line of reinforcing steel: EC 2-1-1, 3.2.7 (bilinear)

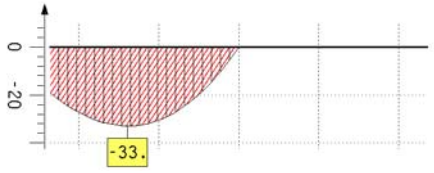


bottom:
σ in N/mm²
ε in ‰
max ε = 25.00
max σ = 525.00



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 $\gamma_c = 1.00$, reinforcement $\gamma_s = 1.00$

1.3. cross section

plate: h = 120.0 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, $a_{sbv0} = Ø\ 12 / 100.0 = 1.13$ cm²/m (1-cut)
max. reinforcement ratio $\rho_s = 8.00\%$

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, $\Delta c = 10$ mm, $c_{nom} = c_{min}+\Delta c = 22$ 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, $\Delta c = 15$ mm, $c_{nom} = c_{min}+\Delta c = 35$ 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 $t_{crit} = 1.2 \cdot t_{max,T}+20 = 78$ h,
$t_{max,T} = 48$ h for slow hardening concrete (CEM 32.5 N) and $h_0 = 120.0$ cm
concrete tensile strength during initial cracking $f_{ct,eff} = k_{ct} \cdot f_{ctm} = 1.57$ N/mm²,
coefficient $k_{ct} = k_j \cdot k_{ct(t)} = 0.61$ for slow hardening concrete (CEM 32.5 N) and $t_{crit} = 78$ h, $k_{ct(t)} = 0.61$,
$k_j = 1.0$ (spring/autumn)
calculation of the constraint force for base plates
dimensions of the base plate $L_p = 20.00$ m, $B_p = 14.00$ m, $t_p = 120.0$ cm
separation cracking in base plates (friction model)
constraint force $N_{ct,1} = \gamma_{ct} \cdot \mu_d \cdot \sigma_0 \cdot L_p/2 = 290.94$ kN/m, $\gamma_{ct} = 1.00$
design value of friction $\mu_d = \gamma_R \cdot \mu_0 = 0.875$, $\gamma_R = 1.25$, $\mu_0 = 0.70$
design value of ground compression $\sigma_{0d} = t_p \cdot \rho_p + q_p = 33.25$ kN/m², $\rho_p = 25.0$ kN/m³, $q_p = 3.25$ kN/m²
constraint force $N_{ct} = 290.94$ kN/m
constraint force (EC 2): $N_{ct,EC2} = f_{ct,eff} \cdot A_{c,eff} = 710.11$ kN/m, $f_{ct,eff} = 1.57$ N/mm², $A_{c,eff} = 4520.0$ cm²/m
constraint force $N_{ct} \le N_{ct,EC2}$ ⇒ crack resistance available ($N_{ct}/N_{ct,EC2} = 0.410 < 1$)
calculation of minimum reinforcement with $N_{ct,clc} = N_{ct} \cdot A_c / A_{c,eff} = 772.40$ kN/m, $A_c = 12000.0$ cm²/m, $A_{c,eff} = 4520.0$ 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, $\varepsilon_{c1} = -2.07‰$, $\varepsilon_{cu1} = -3.50‰$, $f_{cm} = 33.00$ N/mm², $E_{cm} = 31475.8$ N/mm²
σ-ε line acc. to EC 2, 3.2.7(2a): B500A, $\varepsilon_u = 25.00‰$, $f_{yk} = 500.0$ 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 $\sigma_{cr} = 0.64$ N/mm², coefficient for non-linear residual stresses k = 0.52
reinforcement above
perm. crack width $w_{o,lim} = 0.30$ mm
coefficient for stress distribution $k_{co} = 1.00$, tension zone $A_{cto} = 60.00$ dm², crack zone $A_{c,eff,o} = 22.60$ dm²
stress in reinforcement $\sigma_{sro} = 139.0$ N/mm²
reinforcement (minimum reinforcement) $A_{so,min} = 10.47$ cm²
reinforcement bottom
perm. crack width $w_{u,lim} = 0.30$ mm
coefficient for stress distribution $k_{cu} = 1.00$, tension zone $A_{ctu} = 60.00$ dm², crack zone $A_{c,eff,u} = 22.60$ dm²
stress in reinforcement $\sigma_{sru} = 139.0$ N/mm²
reinforcement (minimum reinforcement) $A_{su,min} = 10.47$ cm²

4. final result

maximum reinforcement: A_{so} = 10.47 cm², A_{su} = 10.47 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