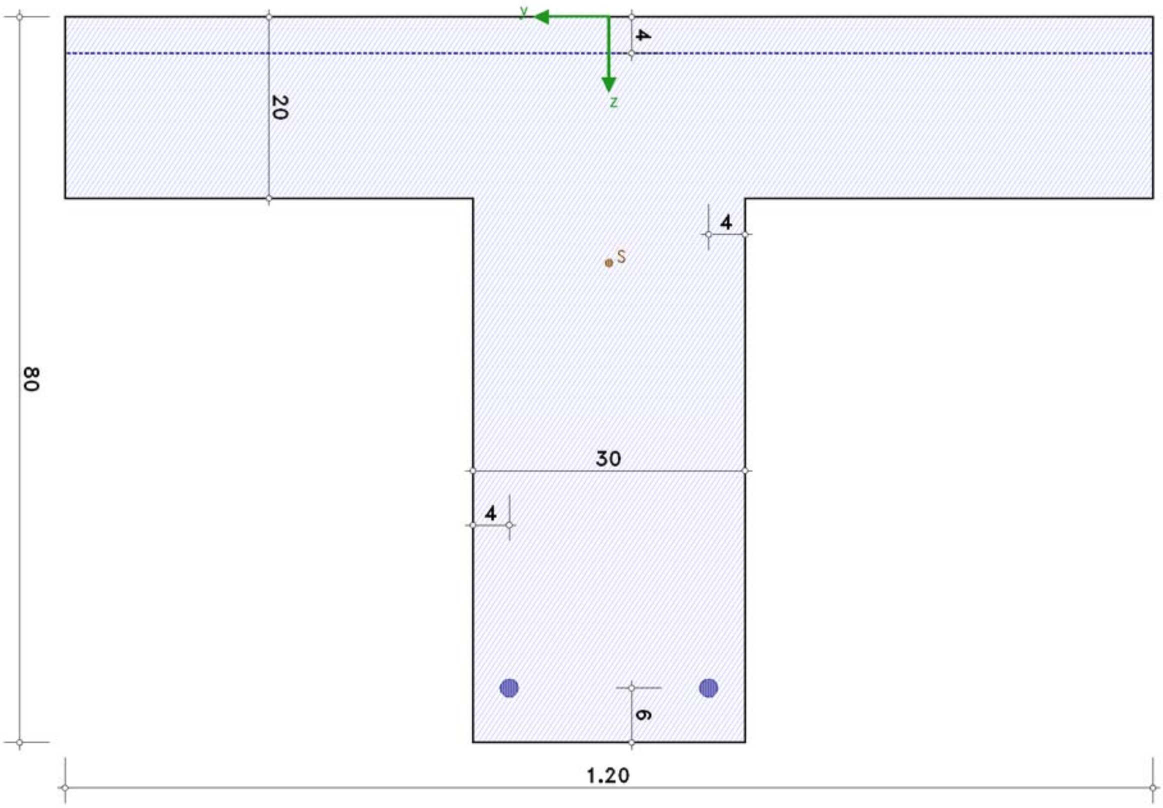
POS. 25: T-BEAM

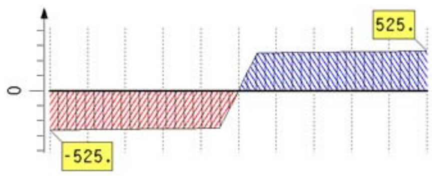
reinforced concrete design EC 2 (1.11), NA: Deutschland 4H-EC2QB Version: 10/2023-1b

1. input protocol

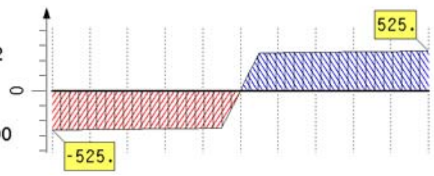


1.1. building material

reinforcing steel bottom B500A, above B500A, concrete C30/37
stress-strain line of reinforcing steel: EC 2-1-1, 3.2.7 (bilinear)

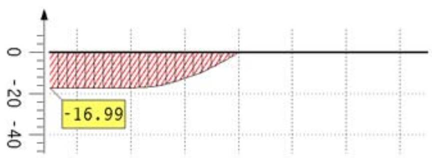


bottom:
σ in N/mm²
ε in ‰
max ε = 25.00
max σ = 525.00



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

stress-strain line of concrete: EC 2-1-1, 3.1.7 (parabola-rectangle diagram)



σ in N/mm²
ε in ‰
min ε = -3.50
min σ = -16.99

1.2. material safety factors

design situation: basic combination
design resistance: concrete γ_c = 1.50, reinforcement γ_s = 1.15

1.3. cross section

T-beam: h = 80.0 cm, b = 30.0 cm, h_p = 20.0 cm, b_p = 120.0 cm
axis distances: d_o = 4.0 cm, d_u = 6.0 cm, d_s = 4.0 cm
base reinforcement: A_{so0} = Ø 6 / 0.0 = 0.00 cm²/m, A_{su0} = 2 Ø 20 = 6.28 cm², a_{sbv0} = Ø 8 / 30.0 = 3.35 cm²/m (2-cut)
max. reinforcement ratio ρ_s = 8.00%

1.4. durability and concrete cover

minimum strength class, concrete cover for $Ø_s$ = 6 mm, $Ø_{sb}$ = 8 mm
due to reinforcement corrosion X0 ⇒ C12/15, c_{min} = 10 mm, Δc = 10 mm, $c_{nom} = c_{min}+\Delta c$ = 20 mm
minimum concrete quality C12/15 with f_{ck} = 12.0 N/mm² < 30.0 N/mm² ok
minimum axial spacing min d = $c_{nom}+Ø_{sb}+Ø_s/2$ = 31 mm
minimum strength class, concrete cover for $Ø_s$ = 20 mm, $Ø_{sb}$ = 8 mm
due to reinforcement corrosion XC3 ⇒ C20/25, $c_{min} = Ø_s$ = 20 mm, Δc = 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 < 30.0 N/mm² ok
minimum axial spacing min d = $c_{nom}+Ø_{sb}+Ø_s/2$ = 53 mm

1.5. design parameters

1.5.1. bending/shear design

1.5.1.1. bending design
minimum reinforcement for beams
limiting the compression zone height to x = 0.617·d
minimum center of compression normal force

1.5.1.2. shear design
only the web is designed !!
reinforcing steel like flexural reinforcemant
shear force
angle of the shear force reinforcement α = 90°
simplified approach of the compression strut angle
with minimum reinforcement (beam)
inner lever arm $z = 0.9 \cdot d \leq d-2 \cdot c_{v,l} \leq d-c_{v,l}-3$ cm
with concrete cover to longitudinal reinforcement in the compress. zone $c_{v,l}$ = 3.0 cm
limit the design value of the shear force resistance without shear force reinforcement $V_{Rd,c}$
connection of the belts to the web:
maximum difference moment $|\Delta M_{Ed}|$ = 135.240 kNm, corresponding entry length a_v = 50.0 cm
sum of the reinforcement portion transferred to the belt sides Σ = 60%
shear force transmission in horizontal joints:
design value of the shear force to be transmitted via the joint $v_{Ed,i} = \beta_i \cdot v_{Ed}$ with β_i = 1.00
design value of the normal force acting perpendicular to the joint n_{Ed} = 0.10 kN/m
contact surface (web width) b_j = 30.0 cm, rough joint surface
torsion
effective thickness of a wall t_{eff} acc. to design code

1.5.1.3. design calculation values
lc 1: $M_{y,Ed}$ = 283.60 kNm, $V_{z,Ed}$ = 321.80 kN

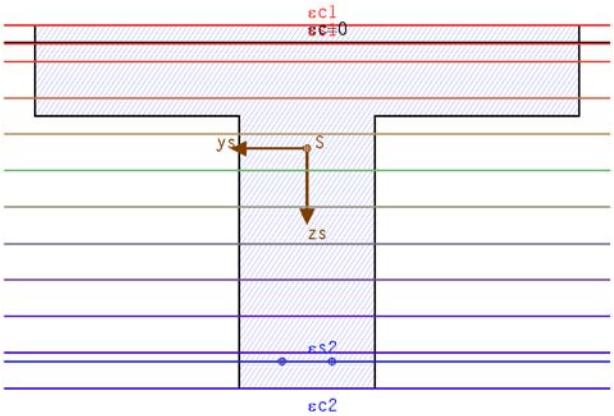
2. bending/shear design

material properties
bending design:
concrete acc. to EC 2, 3.1.7(1): C30/37, ε_{c2} = -2.00‰, ε_{cu2} = -3.50‰, f_{cd} = 17.00 N/mm²
reinf. bottom acc. to EC 2, 3.2.7(2a): B500A, ε_{ud} = 25.0‰, f_{yd} = 434.78 N/mm², f_{td} = 456.52 N/mm², E_s = 200000.0 N/mm²
reinf. above acc. to EC 2, 3.2.7(2a): B500A, ε_{ud} = 25.0‰, f_{yd} = 434.78 N/mm², f_{td} = 456.52 N/mm², E_s = 200000.0 N/mm²
shear design:
σ-ε line acc. to EC 2, 3.2.7(2a): B500A, ε_{ud} = 25.00‰, f_{yd} = 434.78 N/mm², f_{td} = 456.52 N/mm², E_s = 200000.0 N/mm²

2.1. lc 1

2.1.1. bending design (EC 2, 6.1)
bending/normal force
design calculation values: N_{Ed} = 0.00 kN, M_{Ed} = 283.60 kNm
design aid values:
statische Höhe d = 74.0 cm, Hebelarm der inneren Kräfte z = 74.0 cm, concretedruckzonenhöhe x = 3.71 cm
reinforcement
A_{so} = 0.00 cm², A_{su} = 8.55 cm²

limit strains



strains in the fracture state (ULS)
most pressed concrete fiber ε_{c1} = -1.321‰, most drawn steel fiber ε_{s2} = 25.000‰
most drawn concrete fiber ε_{c2} = 27.134‰, most pressed steel fiber ε_{s1} = 0.102‰
directional angle of the main strain α_k = 90.00°

2.1.2. shear design (EC 2, 6.2)
shear force (EC 2, 6.2)
design shear force V_{Ed} = 321.80 kN
longitudinal reinforcement ratio in the compress. zone ρ_l = 0.39%, lever arm of internal forces z' = 66.6 cm
compression zone height x = 3.71 cm, shear force resistance without shear force reinforcement $V_{Rd,c}$ = 76.27 kN
compression strut angle Θ = 39.81° (cot Θ = 1.200), maximum shear force resistance $V_{Rd,max}$ = 1252.84 kN
utilization range AB = 1 for $|V_{Ed}|/V_{Rd,max}$ = 0.257
tensile force component in the longitudinal reinforcement due to shear force $\Delta F_{s,Ed}$ = 193.08 kN
stirrup reinforcement a_{sbv} = 9.26 cm²/m
shear forces between beam web and belt (EC 2, 6.2.4)
longitudinal shear stress $v_{Ed,f}$ = 76.1 N/mm²
compression strut angle (simplified) Θ_f = 39.81° (cot Θ_f = 1.2), maximum shear resistance $v_{Rd,max,f}$ = 627.0 N/mm²
transverse reinforcement per section length $a_{sf} = A_{sf}/s_f$ = 2.92 cm²/m
shear force transmission in joints (EC 2, 6.2.5)
design shear force V_{Ed} = 321.80 kN
design value of shear force to be transmitted $v_{Ed,i} = \beta_i \cdot V_{Ed}/(z_i \cdot b_i)$ = 1610.6 kN/m²
lever arm of the composite section z_i = 66.6 cm
shear force capacity from joint roughness $v_{Rdi,c} = c \cdot f_{ctd} + \mu \cdot \sigma_n$ = -0.2 kN/m²
maximum shear resistance in der Fuge $v_{Rdi,max} = 0.5 \cdot \nu \cdot f_{cd}$ = 4250.0 kN/m²
interlocking reinforcement a_{sbi} = 13.23 cm²/m
reinforcement
a_{sbv} = 9.26 cm²/m, a_{sf} = 2.92 cm²/m, a_{sbi} = 13.23 cm²/m
messages for calculation run
shear design: longitudinal reinforcement considered

2.1.3. minimum reinforcement (EC 2, 9.2.1.1(1))
bending/normal force
design calculation values: N_{Ed} = 0.00 kN, M_{Ed} = 124.16 kNm
reinforcement
A_{so} = 0.00 cm², A_{su} = 3.39 cm²

2.2. result

resulting reinforcement: A_{so} = 0.00 cm², A_{su} = 8.55 cm²
a_{sbV} = 9.26 cm²/m, a_{sbT} = 0.00 cm²/m, A_{sT} = 0.00 cm², a_{sf} = 2.92 cm²/m, a_{sbi} = 13.23 cm²/m
incl. base reinforcement: A_{so} = 0.00 cm², A_{su} = 8.55 cm²
a_{sbV} = 9.26 cm²/m, a_{sbT} = 0.00 cm²/m, A_{sT} = 0.00 cm², a_{sf} = 2.92 cm²/m, a_{sbi} = 13.23 cm²/m

3. final result

maximum reinforcement: A_{so} = 0.00 cm², A_{su} = 8.55 cm²
a_{sbV} = 9.26 cm²/m, a_{sbT} = 0.00 cm²/m, A_{sT} = 0.00 cm², a_{sf} = 2.92 cm²/m, a_{sbi} = 13.23 cm²/m

design resistance ensured

4. selected reinforcement

lateral concrete cover c_{vr} = 2.0 cm
bottom:
concrete cover c_{vu} = 3.5 cm
longitudinal reinforcement from bending and normal force 3 x Ø20
reinforcement exst A_{su} = 9.42 cm² > req A_{su} = 8.55 cm² ok
bar distance min d_{vu} = 4.0 cm

center distance exst d_u = 5.5 cm < d_u = 6.00 cm² ok

above:

concrete cover c_{vo} = 2.0 cm

center distance exst d_o = 3.0 cm < d_o = 4.00 cm²/m ok

belt plate bottom:

concrete cover c_{vp} = 2.0 cm

reinforcement mat R188

reinforcement exst A_{sp} = 1.69 cm²

bar distance min d_{vp} = 2.6 cm

shear reinforcement:

stirrup reinforcement from shear force incl. bond Ø10 / 20.0 cm, 4-cut

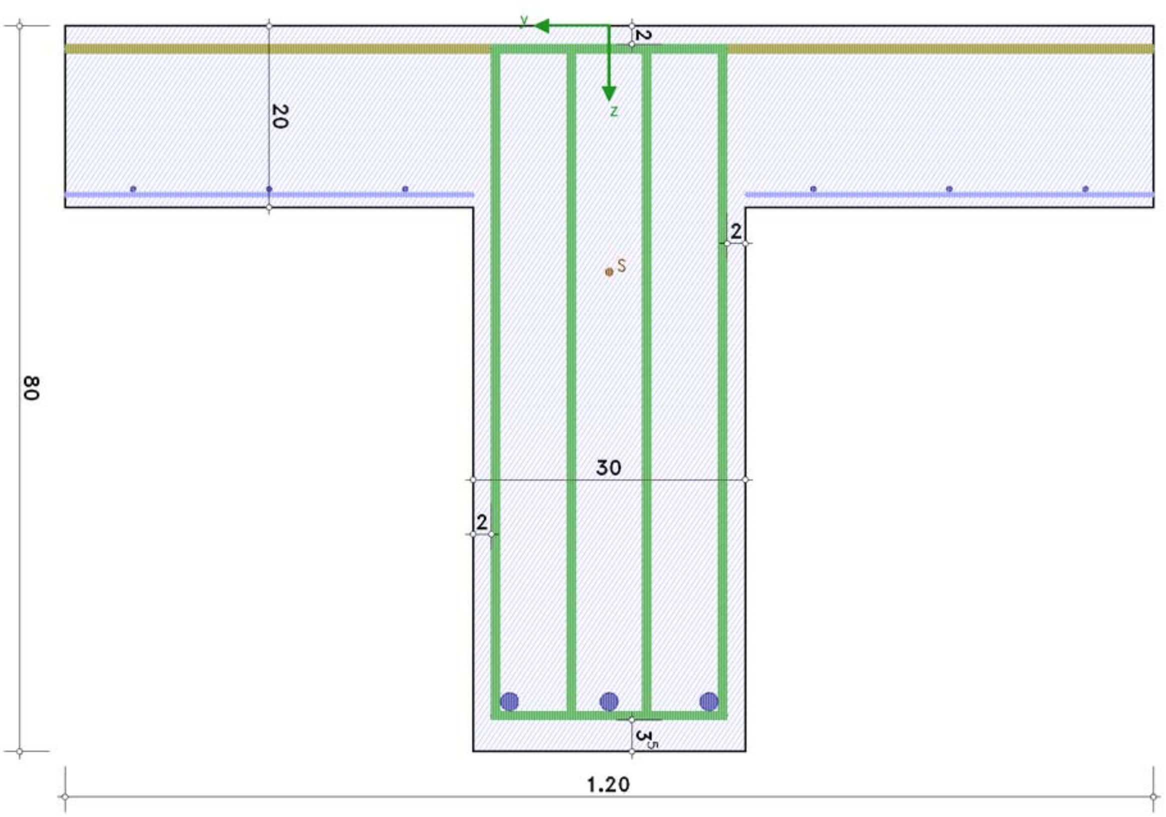
reinforcement exst a_{sbV} = 15.71 cm²/m > req a_{sbV} = 13.23 cm²/m ok

transverse reinforcement in the belt:

above: Ø10 / 20.0 cm

reinforcement exst a_{sfo} = 3.93 cm²/m > req a_{sfo} = 2.92 cm²/m ok

graphic:



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