RETAINING WALL ANALYSIS

In accordance with EN1997-1:2004 incorporating Corrigendum dated February 2009 and the UK National Annex incorporating Corrigendum No.1

Tedds calculation version 2.9.17

Analysis summary

Design summary

Overall design utilisation 0.991

Overall design status Pass

Description	Unit	Capacity	Applied	F o S	Result
Bearing pressure	kN/m^2	100	78.8	1.270	PASS

Design summary

Description	Unit	Provided	Required	Utilisation	Result
Shear resistance	kN/m	74.2	161.8	0.459	PASS
Stem p0 - Shear resistance	kN/m	103.9	85.7	0.825	PASS
Stem p1 front face - Flexural reinforcement	mm^2/m	754.0	216.9	0.288	PASS
Stem p1 - Shear resistance	kN/m	86.6	25.5	0.294	PASS
Base top face - Flexural reinforcement	mm^2/m	754.0	593.4	0.787	PASS
Base bottom face - Flexural reinforcement	mm^2/m	754.0	555.8	0.737	PASS
Base - Shear resistance	kN/m	161.8	74.2	0.459	PASS

Retaining wall details

Stem type Propped cantilever

Stem height h_{stem} = **3300** mm

Prop height h_{prop} = **3300** mm

Stem thickness t_{stem} = **200** mm

Angle to rear face of stem α = **90** deg

Stem density γ_{stem} = **25** kN/m^3

Toe length l_{toe} = **800** mm

Base thickness t_{base} = **450** mm

Base density γ_{base} = **25** kN/m^3

Height of retained soil h_{ret} = **3300** mm

Angle of soil surface β = **0** deg

Depth of cover d_{cover} = **0** mm

Height of water h_{water} = **1500** mm

Water density γ_w = **9.8** kN/m^3

Retained soil properties

Soil type Loose well graded sand and gravel

Moist density γ_{mr} = **19.5** kN/m^3

Saturated density γ_{sr} = **21.9** kN/m^3

Characteristic effective shear resistance angle $\phi'_{r.k}$ = **28** deg

Characteristic wall friction angle $\delta_{r.k}$ = **14** deg

Base soil properties

Soil type Stiff clay

Soil density γ_b = **19** kN/m^3

Characteristic effective shear resistance angle $\phi'_{b.k}$ = **18** deg

Characteristic wall friction angle $\delta_{b.k}$ = **9** deg

Characteristic base friction angle $\delta_{bb.k}$ = **12** deg

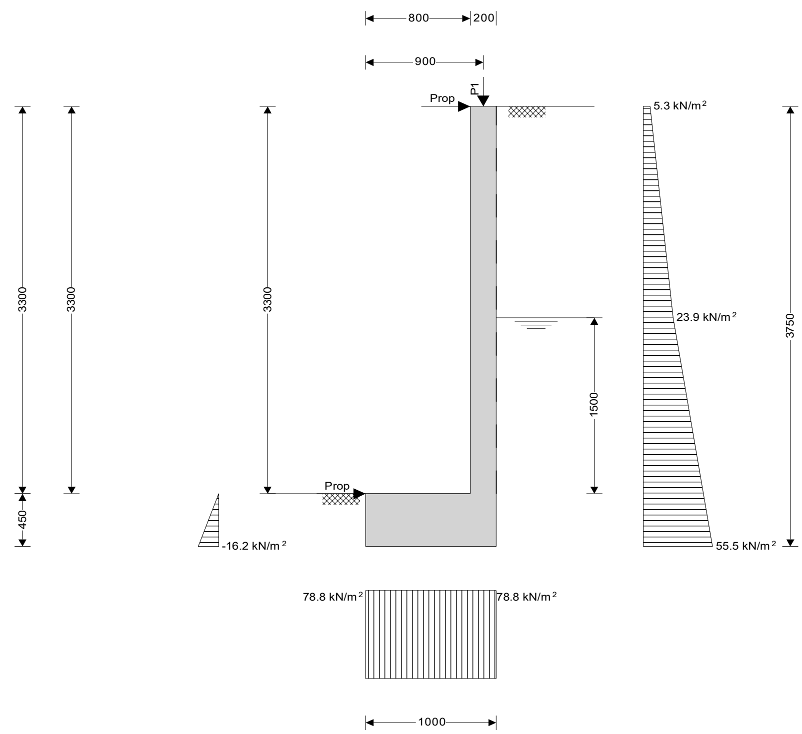
Presumed bearing capacity $P_{bearing}$ = **100** kN/m^2

Loading details

Variable surcharge load $Surcharge_Q$ = **10** kN/m^2

Vertical line load at 900 mm P_{G1} = **40** kN/m

P_{Q1} = **11** kN/m



General arrangement - sketch pressures relate to bearing check

Calculate retaining wall geometry

Base length $l_{base} = l_{toe} + t_{stem}$ = **1000** mm

Saturated soil height $h_{sat} = h_{water} + d_{cover}$ = **1500** mm

Moist soil height $h_{moist} = h_{ret} - h_{water}$ = **1800** mm

Length of surcharge load $l_{sur} = l_{heel}$ = **0** mm

- Distance to vertical component $x_{sur\_v} = l_{base} - l_{heel} / 2$ = **1000** mm

Effective height of wall $h_{eff} = h_{base} + d_{cover} + h_{ret}$ = **3750** mm

- Distance to horizontal component $x_{sur\_h} = h_{eff} / 2$ = **1875** mm

Area of wall stem $A_{stem} = h_{stem} \times t_{stem}$ = **0.66** m^2

- Distance to vertical component $x_{stem} = l_{toe} + t_{stem} / 2$ = **900** mm

Area of wall base $A_{base} = l_{base} \times t_{base}$ = **0.45** m^2

- Distance to vertical component $x_{base} = l_{base} / 2$ = **500** mm

Using Rankine theory

At rest pressure coefficient $K_0 = 1 - \sin(\phi'_{r.k})$ = **0.531**

Passive pressure coefficient $K_P = (1 + \sin(\phi'_{b.k})) / (1 - \sin(\phi'_{b.k}))$ = **1.894**

Bearing pressure check

Vertical forces on wall

Wall stem $F_{stem} = A_{stem} \times \gamma_{stem} =$ **16.5** kN/m

Wall base $F_{base} = A_{base} \times \gamma_{base} =$ **11.3** kN/m

Line loads $F_{P\_v} = P_{G1} + P_{Q1} =$ **51** kN/m

Total $F_{total\_v} = F_{stem} + F_{base} + F_{P\_v} + F_{water\_v} =$ **78.8** kN/m

Horizontal forces on wall

Surcharge load $F_{sur\_h} = K_0 \times Surcharge_Q \times h_{eff} =$ **19.9** kN/m

Saturated retained soil $F_{sat\_h} = K_0 \times (\gamma_{sr} - \gamma_w) \times (h_{sat} + h_{base})^2 / 2 =$ **12.2** kN/m

Water $F_{water\_h} = \gamma_w \times (h_{water} + d_{cover} + h_{base})^2 / 2 =$ **18.7** kN/m

Moist retained soil $F_{moist\_h} = K_0 \times \gamma_{mr} \times ((h_{eff} - h_{sat} - h_{base})^2 / 2 + (h_{eff} - h_{sat} - h_{base}) \times (h_{sat} + h_{base})) =$ **53.1** kN/m

Base soil $F_{pass\_h} = -K_P \times \gamma_b \times (d_{cover} + h_{base})^2 / 2 =$ **-3.6** kN/m

Total $F_{total\_h} = F_{sur\_h} + F_{sat\_h} + F_{water\_h} + F_{moist\_h} + F_{pass\_h} =$ **100.1** kN/m

Moments on wall

Wall stem $M_{stem} = F_{stem} \times x_{stem} =$ **14.9** kNm/m

Wall base $M_{base} = F_{base} \times x_{base} =$ **5.6** kNm/m

Surcharge load $M_{sur} = -F_{sur\_h} \times x_{sur\_h} =$ **-37.3** kNm/m

Line loads $M_P = (P_{G1} + P_{Q1}) \times p_1 =$ **45.9** kNm/m

Saturated retained soil $M_{sat} = -F_{sat\_h} \times x_{sat\_h} =$ **-7.9** kNm/m

Water $M_{water} = -F_{water\_h} \times x_{water\_h} =$ **-12.1** kNm/m

Moist retained soil $M_{moist} = -F_{moist\_h} \times x_{moist\_h} =$ **-78.1** kNm/m

Total $M_{total} = M_{stem} + M_{base} + M_{sur} + M_P + M_{sat} + M_{water} + M_{moist} =$ **-69.1** kNm/m

Check bearing pressure

Propping force to stem $F_{prop\_stem} = (F_{total\_v} \times l_{base} / 2 - M_{total}) / (h_{prop} + t_{base}) =$ **28.9** kN/m

Propping force to base $F_{prop\_base} = F_{total\_h} - F_{prop\_stem} =$ **71.2** kN/m

Moment from propping force $M_{prop} = F_{prop\_stem} \times (h_{prop} + t_{base}) =$ **108.5** kNm/m

Distance to reaction $\bar{x} = (M_{total} + M_{prop}) / F_{total\_v} =$ **500** mm

Eccentricity of reaction $e = \bar{x} - l_{base} / 2 =$ **0** mm

Loaded length of base $l_{load} = l_{base} =$ **1000** mm

Bearing pressure at toe $q_{toe} = F_{total\_v} / l_{base} \times (1 - 6 \times e / l_{base}) =$ **78.8** kN/m^2

Bearing pressure at heel $q_{heel} = F_{total\_v} / l_{base} \times (1 + 6 \times e / l_{base}) =$ **78.8** kN/m^2

Factor of safety $FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel}) =$ **1.27**

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

RETAINING WALL DESIGN

In accordance with EN1992-1-1:2004 incorporating Corrigendum dated January 2008 and the UK National Annex incorporating National Amendment No.1

Tedds calculation version 2.9.17

Concrete details - Table 3.1 - Strength and deformation characteristics for concrete

Concrete strength class C30/37

Characteristic compressive cylinder strength $f_{ck} =$ **30** N/mm^2

Characteristic compressive cube strength $f_{ck,cube} =$ **37** N/mm^2

Mean value of compressive cylinder strength $f_{cm} = f_{ck} + 8$ N/mm^2 = **38** N/mm^2

Mean value of axial tensile strength $f_{ctm} = 0.3$ N/mm$^2 \times (f_{ck} / 1$ N/mm$^2)^{2/3}$ = **2.9** N/mm^2

5% fractile of axial tensile strength $f_{ctk,0.05} = 0.7 \times f_{ctm} = \mathbf{2.0}$ N/mm^2

Secant modulus of elasticity of concrete $E_{cm} = 22$ kN/mm$^2 \times (f_{cm}$ / 10 N/mm$^2)^{0.3} = \mathbf{32837}$ N/mm^2

Partial factor for concrete - Table 2.1N $\gamma_C = \mathbf{1.50}$

Compressive strength coefficient - cl.3.1.6(1) $\alpha_{cc} = \mathbf{0.85}$

Design compressive concrete strength - exp.3.15 $f_{cd} = \alpha_{cc} \times f_{ck} / \gamma_C = \mathbf{17.0}$ N/mm^2

Maximum aggregate size $h_{agg} = \mathbf{20}$ mm

Ultimate strain - Table 3.1 $\varepsilon_{cu2} = \mathbf{0.0035}$

Shortening strain - Table 3.1 $\varepsilon_{cu3} = \mathbf{0.0035}$

Effective compression zone height factor $\lambda = \mathbf{0.80}$

Effective strength factor $\eta = \mathbf{1.00}$

Bending coefficient k_1 $K_1 = \mathbf{0.40}$

Bending coefficient k_2 $K_2 = 1.00 \times (0.6 + 0.0014/\varepsilon_{cu2}) = \mathbf{1.00}$

Bending coefficient k_3 $K_3 = \mathbf{0.40}$

Bending coefficient k_4 $K_4 = 1.00 \times (0.6 + 0.0014/\varepsilon_{cu2}) = \mathbf{1.00}$

Reinforcement details

Characteristic yield strength of reinforcement $f_{yk} = \mathbf{500}$ N/mm^2

Modulus of elasticity of reinforcement $E_s = \mathbf{200000}$ N/mm^2

Partial factor for reinforcing steel - Table 2.1N $\gamma_S = \mathbf{1.15}$

Design yield strength of reinforcement $f_{yd} = f_{yk} / \gamma_S = \mathbf{435}$ N/mm^2

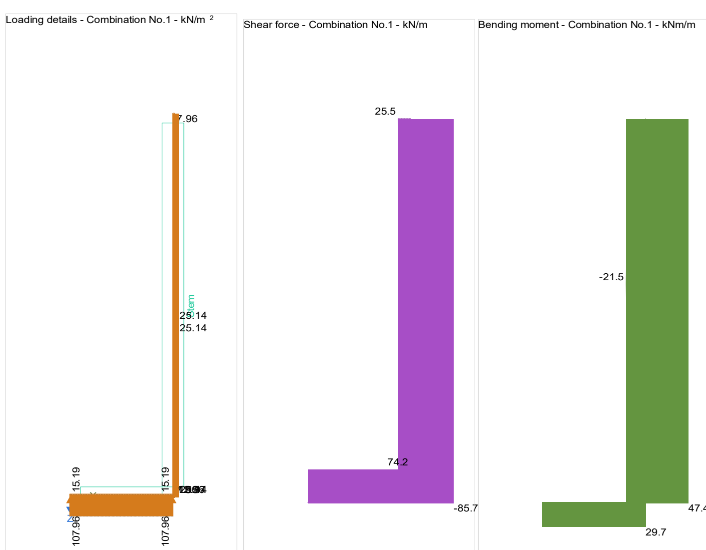
Cover to reinforcement

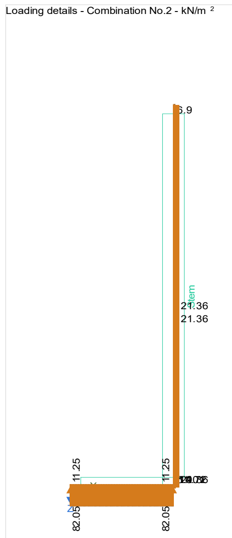
Front face of stem $c_{sf} = \mathbf{40}$ mm

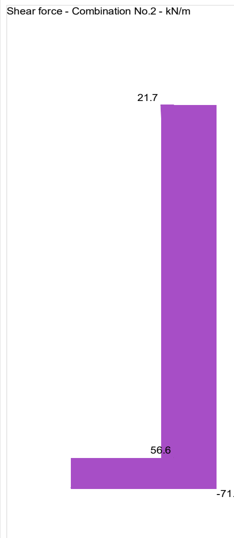
Rear face of stem $c_{sr} = \mathbf{50}$ mm

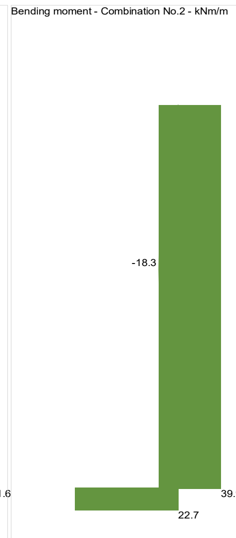
Top face of base $c_{bt} = \mathbf{50}$ mm

Bottom face of base $c_{bb} = \mathbf{75}$ mm









Check stem design at 1652 mm

Depth of section — $h = \mathbf{200}$ mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 1 — $M = \mathbf{21.5}$ kNm/m

Depth to tension reinforcement — $d = h - c_{sf} - \phi_{sx} - \phi_{sfM} / 2 = \mathbf{144}$ mm

$K = M / (d^2 \times f_{ck}) = \mathbf{0.035}$

$K' = (2 \times \eta \times \alpha_{cc}/\gamma_C)\times(1 - \lambda \times (\delta - K_1)/(2 \times K_2))\times(\lambda \times (\delta - K_1)/(2 \times K_2))$

$K' = \mathbf{0.207}$

K' > K - No compression reinforcement is required

Lever arm — $z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_C))^{0.5}, 0.95) \times d = \mathbf{137}$ mm

Depth of neutral axis — $x = 2.5 \times (d – z) = \mathbf{18}$ mm

Area of tension reinforcement required — $A_{sfM.req} = M / (f_{yd} \times z) = \mathbf{361}$ mm^2/m

Tension reinforcement provided — 12 dia.bars @ 150 c/c

Area of tension reinforcement provided — $A_{sfM.prov} = \pi \times \phi_{sfM}^2 / (4 \times s_{sfM}) = \mathbf{754}$ mm^2/m

Minimum area of reinforcement - exp.9.1N — $A_{sfM.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = \mathbf{217}$ mm^2/m

Maximum area of reinforcement - cl.9.2.1.1(3) — $A_{sfM.max} = 0.04 \times h = \mathbf{8000}$ mm^2/m

$\max(A_{sfM.req}, A_{sfM.min}) / A_{sfM.prov} = \mathbf{0.479}$

PASS - Area of reinforcement provided is greater than area of reinforcement required

Library item: Rectangular single output

Deflection control - Section 7.4

Reference reinforcement ratio — $\rho_0 = \sqrt{}(f_{ck} / 1\ N/mm^2) / 1000 = \mathbf{0.005}$

Required tension reinforcement ratio — $\rho = A_{sfM.req} / d = \mathbf{0.003}$

Required compression reinforcement ratio — $\rho' = A_{sfM.2.req} / d_2 = \mathbf{0.000}$

Structural system factor - Table 7.4N — $K_b = \mathbf{1}$

Reinforcement factor - exp.7.17 — $K_s = \min(500\ N/mm^2 / (f_{yk} \times A_{sfM.req} / A_{sfM.prov}), 1.5) = \mathbf{1.5}$

Limiting span to depth ratio - exp.7.16.a — $\min(K_s \times K_b \times [11 + 1.5 \times \sqrt{}(f_{ck} / 1\ N/mm^2) \times \rho_0 / \rho + 3.2 \times \sqrt{}(f_{ck} / 1\ N/mm^2) \times (\rho_0 / \rho - 1)^{3/2}], 40 \times K_b) = \mathbf{40}$

Actual span to depth ratio — $h_{prop} / d = \mathbf{22.9}$

PASS - Span to depth ratio is less than deflection control limit

Crack control - Section 7.3

Limiting crack width	w_{max} = **0.3** mm
Variable load factor - EN1990 – Table A1.1	ψ_2 = **0.6**
Serviceability bending moment	M_{sls} = **13.9** kNm/m
Tensile stress in reinforcement	$\sigma_s = M_{sls} / (A_{sfM.prov} \times z)$ = **134.7** N/mm^2
Load duration	Long term
Load duration factor	k_t = **0.4**
Effective area of concrete in tension	$A_{c.eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$
	$A_{c.eff}$ = **60667** mm^2/m
Mean value of concrete tensile strength	$f_{ct.eff} = f_{ctm}$ = **2.9** N/mm^2
Reinforcement ratio	$\rho_{p.eff} = A_{sfM.prov} / A_{c.eff}$ = **0.012**
Modular ratio	$\alpha_e = E_s / E_{cm}$ = **6.091**
Bond property coefficient	k_1 = **0.8**
Strain distribution coefficient	k_2 = **0.5**
	k_3 = **3.4**
	k_4 = **0.425**
Maximum crack spacing - exp.7.11	$s_{r.max} = k_3 \times c_{sf} + k_1 \times k_2 \times k_4 \times \phi_{sfM} / \rho_{p.eff}$ = **300** mm
Maximum crack width - exp.7.8	$w_k = s_{r.max} \times \max(\sigma_s - k_t \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_e \times \rho_{p.eff}), 0.6 \times \sigma_s) / E_s$
	w_k = **0.121** mm
	w_k / w_{max} = **0.404**

PASS - Maximum crack width is less than limiting crack width

Check stem design at base of stem

Depth of section	h = **200** mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 1	M = **47.4** kNm/m
Depth to tension reinforcement	$d = h - c_{sr} - \phi_{sr} / 2$ = **142** mm
	$K = M / (d^2 \times f_{ck})$ = **0.078**
	$K' = (2 \times \eta \times \alpha_{cc}/\gamma_C) \times (1 - \lambda \times (\delta - K_1)/(2 \times K_2)) \times (\lambda \times (\delta - K_1)/(2 \times K_2))$
	K' = **0.207**

K' > K - No compression reinforcement is required

Lever arm	$z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_C))^{0.5}, 0.95) \times d$ = **131** mm
Depth of neutral axis	$x = 2.5 \times (d - z)$ = **27** mm
Area of tension reinforcement required	$A_{sr.req} = M / (f_{yd} \times z)$ = **829** mm^2/m
Tension reinforcement provided	16 dia.bars @ 150 c/c
Area of tension reinforcement provided	$A_{sr.prov} = \pi \times \phi_{sr}^2 / (4 \times s_{sr})$ = **1340** mm^2/m
Minimum area of reinforcement - exp.9.1N	$A_{sr.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d$ = **214** mm^2/m
Maximum area of reinforcement - cl.9.2.1.1(3)	$A_{sr.max} = 0.04 \times h$ = **8000** mm^2/m
	$\max(A_{sr.req}, A_{sr.min}) / A_{sr.prov}$ = **0.619**

PASS - Area of reinforcement provided is greater than area of reinforcement required

Library item: Rectangular single output

Deflection control - Section 7.4

Reference reinforcement ratio	$\rho_0 = \sqrt{(f_{ck} / 1 \text{ N/mm}^2)} / 1000$ = **0.005**
Required tension reinforcement ratio	$\rho = A_{sr.req} / d$ = **0.006**
Required compression reinforcement ratio	$\rho' = A_{sr.2.req} / d_2$ = **0.000**
Structural system factor - Table 7.4N	K_b = **1**
Reinforcement factor - exp.7.17	$K_s = \min(500 \text{ N/mm}^2 / (f_{yk} \times A_{sr.req} / A_{sr.prov}), 1.5)$ = **1.5**

Limiting span to depth ratio - exp.7.16.b — $\min(K_s \times K_b \times [11 + 1.5 \times \sqrt{}(f_{ck} / 1\ N/mm^2) \times \rho_0 / (\rho - \rho') + \sqrt{}(f_{ck} / 1\ N/mm^2) \times \sqrt{}(\rho' / \rho_0) / 12], 40 \times K_b)$ = **28.1**

Actual span to depth ratio — h_{prop} / d = **23.2**

PASS - Span to depth ratio is less than deflection control limit

Crack control - Section 7.3

Limiting crack width — w_{max} = **0.3** mm

Variable load factor - EN1990 – Table A1.1 — ψ_2 = **0.6**

Serviceability bending moment — M_{sls} = **31.4** kNm/m

Tensile stress in reinforcement — $\sigma_s = M_{sls} / (A_{sr.prov} \times z)$ = **178.3** N/mm^2

Load duration — Long term

Load duration factor — k_t = **0.4**

Effective area of concrete in tension — $A_{c.eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$

$A_{c.eff}$ = **57831** mm^2/m

Mean value of concrete tensile strength — $f_{ct.eff} = f_{ctm}$ = **2.9** N/mm^2

Reinforcement ratio — $\rho_{p.eff} = A_{sr.prov} / A_{c.eff}$ = **0.023**

Modular ratio — $\alpha_e = E_s / E_{cm}$ = **6.091**

Bond property coefficient — k_1 = **0.8**

Strain distribution coefficient — k_2 = **0.5**

k_3 = **3.4**

k_4 = **0.425**

Maximum crack spacing - exp.7.11 — $s_{r.max} = k_3 \times c_{sr} + k_1 \times k_2 \times k_4 \times \phi_{sr} / \rho_{p.eff}$ = **287** mm

Maximum crack width - exp.7.8 — $w_k = s_{r.max} \times \max(\sigma_s - k_t \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_e \times \rho_{p.eff}), 0.6 \times \sigma_s) / E_s$

w_k = **0.174** mm

w_k / w_{max} = **0.581**

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force — V = **85.7** kN/m

$C_{Rd,c} = 0.18 / \gamma_C$ = **0.120**

$k = \min(1 + \sqrt{}(200\ mm / d), 2)$ = **2.000**

Longitudinal reinforcement ratio — $\rho_l = \min(A_{sr.prov} / d, 0.02)$ = **0.009**

$v_{min} = 0.035\ N^{1/2}/mm \times k^{3/2} \times f_{ck}^{0.5}$ = **0.542** N/mm^2

Design shear resistance - exp.6.2a & 6.2b — $V_{Rd.c} = \max(C_{Rd.c} \times k \times (100\ N^2/mm^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$

$V_{Rd.c}$ = **103.9** kN/m

$V / V_{Rd.c}$ = **0.825**

PASS - Design shear resistance exceeds design shear force

Check stem design at prop

Depth of section — h = **200** mm

Rectangular section in shear - Section 6.2

Design shear force — V = **25.5** kN/m

$C_{Rd,c} = 0.18 / \gamma_C$ = **0.120**

$k = \min(1 + \sqrt{}(200\ mm / d), 2)$ = **2.000**

Longitudinal reinforcement ratio — $\rho_l = \min(A_{sr1.prov} / d, 0.02)$ = **0.005**

$v_{min} = 0.035\ N^{1/2}/mm \times k^{3/2} \times f_{ck}^{0.5}$ = **0.542** N/mm^2

Design shear resistance - exp.6.2a & 6.2b — $V_{Rd.c} = \max(C_{Rd.c} \times k \times (100\ N^2/mm^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$

$V_{Rd.c}$ = **85.7** kN/m

$V / V_{Rd.c}$ = **0.297**

PASS - Design shear resistance exceeds design shear force

Horizontal reinforcement parallel to face of stem - Section 9.6

Minimum area of reinforcement – cl.9.6.3(1) $A_{sx.req} = \max(0.25 \times A_{sr.prov}, 0.001 \times t_{stem})$ = **335** mm^2/m

Maximum spacing of reinforcement – cl.9.6.3(2) s_{sx_max} = **400** mm

Transverse reinforcement provided 10 dia.bars @ 200 c/c

Area of transverse reinforcement provided $A_{sx.prov} = \pi \times \phi_{sx}^2 / (4 \times s_{sx})$ = **393** mm^2/m

PASS - Area of reinforcement provided is greater than area of reinforcement required

Check base design at toe

Depth of section h = **450** mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 1 M = **29.7** kNm/m

Depth to tension reinforcement $d = h - c_{bb} - \phi_{bb} / 2$ = **369** mm

$K = M / (d^2 \times f_{ck})$ = **0.007**

$K' = (2 \times \eta \times \alpha_{cc}/\gamma_C)\times(1 - \lambda \times (\delta - K_1)/(2 \times K_2))\times(\lambda \times (\delta - K_1)/(2 \times K_2))$

K' = **0.207**

K' > K - No compression reinforcement is required

Lever arm $z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_C))^{0.5}, 0.95) \times d$ = **351** mm

Depth of neutral axis $x = 2.5 \times (d – z)$ = **46** mm

Area of tension reinforcement required $A_{bb.req} = M / (f_{yd} \times z)$ = **195** mm^2/m

Tension reinforcement provided 12 dia.bars @ 150 c/c

Area of tension reinforcement provided $A_{bb.prov} = \pi \times \phi_{bb}^2 / (4 \times s_{bb})$ = **754** mm^2/m

Minimum area of reinforcement - exp.9.1N $A_{bb.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d$ = **556** mm^2/m

Maximum area of reinforcement - cl.9.2.1.1(3) $A_{bb.max} = 0.04 \times h$ = **18000** mm^2/m

$\max(A_{bb.req}, A_{bb.min}) / A_{bb.prov}$ = **0.737**

PASS - Area of reinforcement provided is greater than area of reinforcement required

Library item: Rectangular single output

Crack control - Section 7.3

Limiting crack width w_{max} = **0.3** mm

Variable load factor - EN1990 – Table A1.1 ψ_2 = **0.6**

Serviceability bending moment M_{sls} = **21.6** kNm/m

Tensile stress in reinforcement $\sigma_s = M_{sls} / (A_{bb.prov} \times z)$ = **81.7** N/mm^2

Load duration Long term

Load duration factor k_t = **0.4**

Effective area of concrete in tension $A_{c.eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$

$A_{c.eff}$ = **134625** mm^2/m

Mean value of concrete tensile strength $f_{ct.eff} = f_{ctm}$ = **2.9** N/mm^2

Reinforcement ratio $\rho_{p.eff} = A_{bb.prov} / A_{c.eff}$ = **0.006**

Modular ratio $\alpha_e = E_s / E_{cm}$ = **6.091**

Bond property coefficient k_1 = **0.8**

Strain distribution coefficient k_2 = **0.5**

k_3 = **3.4**

k_4 = **0.425**

Maximum crack spacing - exp.7.11 $s_{r.max} = k_3 \times c_{bb} + k_1 \times k_2 \times k_4 \times \phi_{bb} / \rho_{p.eff}$ = **619** mm

Maximum crack width - exp.7.8 $w_k = s_{r.max} \times \max(\sigma_s – k_t \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_e \times \rho_{p.eff}), 0.6 \times \sigma_s) / E_s$

w_k = **0.152** mm

w_k / w_{max} = **0.506**

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force: V = **74.2** kN/m

$C_{Rd,c}$ = 0.18 / γ_C = **0.120**

k = min(1 + √(200 mm / d), 2) = **1.736**

Longitudinal reinforcement ratio: ρ_l = min($A_{bb.prov}$ / d, 0.02) = **0.002**

v_{min} = 0.035 $N^{1/2}$/mm × $k^{3/2}$ × $f_{ck}^{0.5}$ = **0.439** N/mm^2

Design shear resistance - exp.6.2a & 6.2b: $V_{Rd.c}$ = max($C_{Rd.c}$ × k × (100 N^2/mm^4 × ρ_l × f_{ck})$^{1/3}$, v_{min}) × d

$V_{Rd.c}$ = **161.8** kN/m

V / $V_{Rd.c}$ = **0.459**

PASS - Design shear resistance exceeds design shear force

Secondary transverse reinforcement to base - Section 9.3

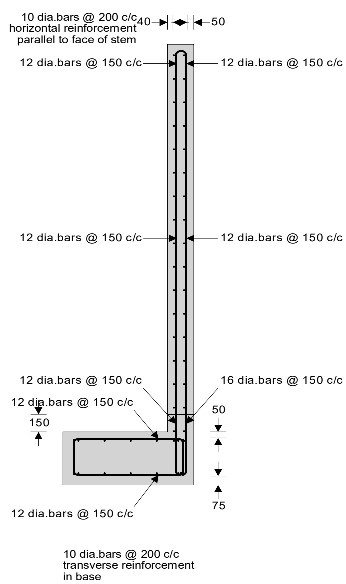
Minimum area of reinforcement – cl.9.3.1.1(2): $A_{bx.req}$ = 0.2 × $A_{bb.prov}$ = **151** mm^2/m

Maximum spacing of reinforcement – cl.9.3.1.1(3): s_{bx_max} = **450** mm

Transverse reinforcement provided: 10 dia.bars @ 200 c/c

Area of transverse reinforcement provided: $A_{bx.prov}$ = π × ϕ_{bx}^2 / (4 × s_{bx}) = **393** mm^2/m

PASS - Area of reinforcement provided is greater than area of reinforcement required



Reinforcement details