LOADINGS

ROOF LOADING (PITCHED TILED ROOF)

Roof slope θ = **40.0** °

Dead load

Tiles $Roof_{D1}$ = **0.60** kN/m^2

Battens $Roof_{D2}$ = **0.05** kN/m^2

Felt $Roof_{D3}$ = **0.05** kN/m^2

Rafters $Roof_{D4}$ = **0.10** kN/m^2

Dead load on slope

$Roof_{DL\_sroof}$ = sum($Roof_{D1}$,$Roof_{D2}$,$Roof_{D3}$,$Roof_{D4}$) = **0.80** kN/m^2

Ceiling joists $Roof_{D5}$ = **0.05** kN/m^2

Insulation $Roof_{D6}$ = **0.05** kN/m^2

Plasterboard and skim $Roof_{D7}$ = **0.15** kN/m^2

Services $Roof_{D8}$ = **0.05** kN/m^2

Dead load on plan

$Roof_{DL\_proof}$ = sum($Roof_{D5}$,$Roof_{D6}$,$Roof_{D7}$,$Roof_{D8}$) = **0.30** kN/m^2

Total dead load on plan

$Roof_{DL} = Roof_{DL\_sroof} / \cos(\theta) + Roof_{DL\_proof}$= **1.34** kN/m^2

Imposed load

Roof imposed load $Roof_{IL}$ = **0.75** kN/m^2 on plan

Total roof loads

Unfactored foundation design loads $w_{roof\_u} = Roof_{DL} + Roof_{IL}$ = **2.09** kN/m^2

Factored design loads $w_{roof\_f} = 1.4 \times Roof_{DL} + 1.6 \times Roof_{IL}$ = **3.08** kN/m^2

TIMBER FLOOR LOADING (2ND FLOOR)

Dead load

Boards $Floor_{2\_D1}$ = **0.20** kN/m^2

Joists $Floor_{2\_D2}$ = **0.15** kN/m^2

Ceiling $Floor_{2\_D3}$ = **0.15** kN/m^2

Total dead load $Floor_{2\_DL}$ = sum($Floor_{2\_D1}$,$Floor_{2\_D2}$,$Floor_{2\_D3}$) = **0.50** kN/m^2

Imposed load

Imposed load $Floor_{2\_I1}$ = **1.50** kN/m^2

Partitions $Floor_{2\_I2}$ = **0.50** kN/m^2

Total imposed load $Floor_{2\_IL}$ = sum($Floor_{2\_I1}$,$Floor_{2\_I2}$) = **2.00** kN/m^2

Total 2nd floor loads

Unfactored foundation design loads $w_{floor2\_u} = Floor_{2\_DL} + Floor_{2\_IL}$ = **2.50** kN/m^2

Factored design loads $w_{floor2\_f} = 1.4 \times Floor_{2\_DL} + 1.6 \times Floor_{2\_IL}$ = **3.90** kN/m^2

TIMBER FLOOR LOADING (1ST FLOOR)

Dead load

Boards $Floor_{1\_D1}$ = **0.20** kN/m^2

Joists $Floor_{1\_D2}$ = **0.15** kN/m^2

Ceiling $Floor_{1\_D3}$ = **0.15** kN/m^2

Total dead load $Floor_{1\_DL}$ = sum($Floor_{1\_D1}$,$Floor_{1\_D2}$,$Floor_{1\_D3}$) = **0.50** kN/m^2

Imposed load

Imposed load $Floor_{1\_I1}$ = **1.50** kN/m^2

Partitions $Floor_{1\_I2}$ = **0.50** kN/m^2

Total imposed load $Floor_{1\_IL}$ = sum($Floor_{1\_I1}$,$Floor_{1\_I2}$) = **2.00** kN/m^2

Total 1st floor loads

Unfactored foundation design loads w_{floor1_u} = $Floor_{1\_DL}$ + $Floor_{1\_IL}$ = **2.50** kN/m^2

Factored design loads w_{floor1_f} = 1.4 × $Floor_{1\_DL}$ + 1.6 × $Floor_{1\_IL}$ = **3.90** kN/m^2

PRECAST FLOOR LOADING (GROUND FLOOR)

Dead load

Finishes $Floor_{grnd\_D1}$ = **0.20** kN/m^2

Screed $Floor_{grnd\_D2}$ = **1.50** kN/m^2

Precast units $Floor_{grnd\_D3}$ = **3.00** kN/m^2

Services $Floor_{grnd\_D4}$ = **0.05** kN/m^2

Total dead load

$Floor_{grnd\_DL}$ = sum($Floor_{grnd\_D1}$,$Floor_{grnd\_D2}$,$Floor_{grnd\_D3}$,$Floor_{grnd\_D4}$) = **4.75** kN/m^2

Imposed load

Imposed load $Floor_{grnd\_I1}$ = **1.50** kN/m^2

Partitions $Floor_{grnd\_I2}$ = **0.50** kN/m^2

Total imposed load $Floor_{grnd\_IL}$ = sum($Floor_{grnd\_I1}$,$Floor_{grnd\_I2}$) = **2.00** kN/m^2

Total ground floor loads

Unfactored foundation design loads w_{grnd_u} = $Floor_{grnd\_DL}$ + $Floor_{grnd\_IL}$ = **6.75** kN/m^2

Factored design loads w_{grnd_f} = 1.4 × $Floor_{grnd\_DL}$ + 1.6 × $Floor_{grnd\_IL}$ = **9.85** kN/m^2

CAVITY WALL LOADING

Dead load

Masonry (outer leaf) CW_{D1} = **2.25** kN/m^2

Masonry (inner leaf) CW_{D2} = **1.50** kN/m^2

Plaster CW_{D3} = **0.15** kN/m^2

Total dead load CW_{DL} = sum(CW_{D1},CW_{D2},CW_{D3}) = **3.90** kN/m^2

Total cavity wall load

Unfactored foundation design loads w_{cw_u} = CW_{DL} = **3.90** kN/m^2

Factored design loads w_{cw_f} = 1.4 × CW_{DL} = **5.46** kN/m^2

INTERNAL WALL LOADING

Dead load

Masonry IW_{D1} = **1.50** kN/m^2

Plaster (2 sides) IW_{D2} = **0.30** kN/m^2

Total dead load IW_{DL} = sum(IW_{D1},IW_{D2}) = **1.80** kN/m^2

Total internal wall load

Unfactored foundation design loads w_{iw_u} = IW_{DL} = **1.80** kN/m^2

Factored design loads w_{iw_f} = 1.4 × IW_{DL} = **2.52** kN/m^2

PARTY WALL LOADING

Dead load

Plaster (one side) PW_{D1} = **0.15** kN/m^2

Masonry (one leaf) PW_{D2} = **1.50** kN/m^2

Masonry (other leaf) PW_{D3} = **1.50** kN/m^2

Plaster (other side) PW_{D4} = **0.15** kN/m^2

Total dead load PW_{DL} = sum(PW_{D1},PW_{D2},PW_{D3},PW_{D4}) = **3.30** kN/m^2

Total party wall load

Unfactored foundation design loads w_{pw_u} = PW_{DL} = **3.30** kN/m^2

Factored design loads w_{pw_f} = 1.4 × PW_{DL} = **4.62** kN/m^2

RETAINING WALL DESIGN REAR EAVES H=4.65M

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 2.9.14

Retaining wall details

Stem type	Cantilever
Stem height	h_{stem} = **4650** mm
Stem thickness	t_{stem} = **400** mm
Angle to rear face of stem	α = **90** deg
Stem density	γ_{stem} = **25** kN/m^3
Toe length	l_{toe} = **1900** mm
Heel length	l_{heel} = **500** mm
Base thickness	t_{base} = **400** mm
Base density	γ_{base} = **25** kN/m^3
Height of retained soil	h_{ret} = **3900** mm
Angle of soil surface	β = **0** deg
Depth of cover	d_{cover} = **750** mm
Depth of excavation	d_{exc} = **350** mm

Retained soil properties

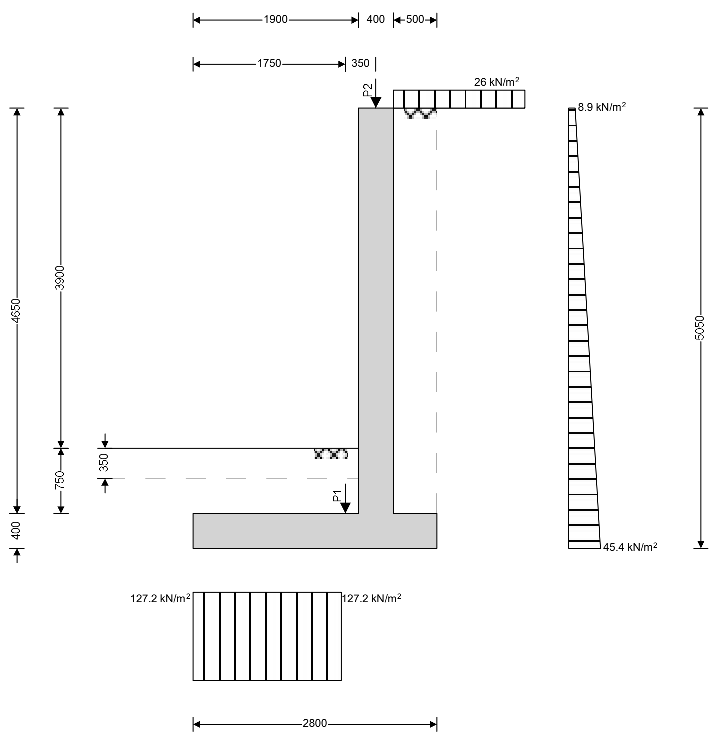
Soil type	Medium dense well graded sand
Moist density	γ_{mr} = **21** kN/m^3
Saturated density	γ_{sr} = **23** kN/m^3
Characteristic effective shear resistance angle	$\phi'_{r.k}$ = **35** deg
Characteristic wall friction angle	$\delta_{r.k}$ = **0** deg

Base soil properties

Soil type	Very Dense rock fill
Soil density	γ_b = **17.5** kN/m^3
Characteristic cohesion	$c'_{b.k}$ = **0** kN/m^2
Characteristic effective shear resistance angle	$\phi'_{b.k}$ = **42** deg
Characteristic wall friction angle	$\delta_{b.k}$ = **21** deg
Characteristic base friction angle	$\delta_{bb.k}$ = **35** deg

Loading details

Variable surcharge load	$Surcharge_Q$ = **20** kN/m^2
Vertical line load at 1750 mm	P_{G1} = **25.4** kN/m
	P_{Q1} = **9.8** kN/m
Vertical line load at 2100 mm	P_{G2} = **17.2** kN/m



General arrangement

Calculate retaining wall geometry

Base length	$l_{base} = l_{toe} + t_{stem} + l_{heel} = \mathbf{2800}$ mm
Moist soil height	$h_{moist} = h_{soil} = \mathbf{4650}$ mm
Length of surcharge load	$l_{sur} = l_{heel} = \mathbf{500}$ mm
- Distance to vertical component	$x_{sur\_v} = l_{base} - l_{heel} / 2 = \mathbf{2550}$ mm
Effective height of wall	$h_{eff} = h_{base} + d_{cover} + h_{ret} = \mathbf{5050}$ mm
- Distance to horizontal component	$x_{sur\_h} = h_{eff} / 2 = \mathbf{2525}$ mm
Area of wall stem	$A_{stem} = h_{stem} \times t_{stem} = \mathbf{1.86}$ m^2
- Distance to vertical component	$x_{stem} = l_{toe} + t_{stem} / 2 = \mathbf{2100}$ mm
Area of wall base	$A_{base} = l_{base} \times t_{base} = \mathbf{1.12}$ m^2
- Distance to vertical component	$x_{base} = l_{base} / 2 = \mathbf{1400}$ mm
Area of moist soil	$A_{moist} = h_{moist} \times l_{heel} = \mathbf{2.325}$ m^2
- Distance to vertical component	$x_{moist\_v} = l_{base} - (h_{moist} \times l_{heel}^2 / 2) / A_{moist} = \mathbf{2550}$ mm
- Distance to horizontal component	$x_{moist\_h} = h_{eff} / 3 = \mathbf{1683}$ mm
Area of base soil	$A_{pass} = d_{cover} \times l_{toe} = \mathbf{1.425}$ m^2
- Distance to vertical component	$x_{pass\_v} = l_{base} - (d_{cover} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{pass} = \mathbf{950}$ mm
- Distance to horizontal component	$x_{pass\_h} = (d_{cover} + h_{base}) / 3 = \mathbf{383}$ mm
Area of excavated base soil	$A_{exc} = h_{pass} \times l_{toe} = \mathbf{0.76}$ m^2
- Distance to vertical component	$x_{exc\_v} = l_{base} - (h_{pass} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{exc} = \mathbf{950}$ mm
- Distance to horizontal component	$x_{exc\_h} = (h_{pass} + h_{base}) / 3 = \mathbf{267}$ mm

Design approach 1

Partial factors on actions - Table A.3 - Combination 1

Partial factor set A1

Permanent unfavourable action γ_G = **1.35**

Permanent favourable action γ_{Gf} = **1.00**

Variable unfavourable action γ_Q = **1.50**

Variable favourable action γ_{Qf} = **0.00**

Partial factors for soil parameters – Table A.4 - Combination 1

Soil parameter set M1

Angle of shearing resistance $\gamma_{\phi'}$ = **1.00**

Effective cohesion $\gamma_{c'}$ = **1.00**

Weight density γ_γ = **1.00**

Library item Partial factors output

Retained soil properties

Design moist density $\gamma_{mr}' = \gamma_{mr} / \gamma_\gamma$ = **21** kN/m^3

Design saturated density $\gamma_{sr}' = \gamma_{sr} / \gamma_\gamma$ = **23** kN/m^3

Design effective shear resistance angle $\phi'_{r.d} = \text{atan}(\tan(\phi'_{r.k}) / \gamma_{\phi'})$ = **35** deg

Design wall friction angle $\delta_{r.d} = \text{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'})$ = **0** deg

Base soil properties

Design soil density $\gamma_b' = \gamma_b / \gamma_\gamma$ = **17.5** kN/m^3

Design effective shear resistance angle $\phi'_{b.d} = \text{atan}(\tan(\phi'_{b.k}) / \gamma_{\phi'})$ = **42** deg

Design wall friction angle $\delta_{b.d} = \text{atan}(\tan(\delta_{b.k}) / \gamma_{\phi'})$ = **21** deg

Design base friction angle $\delta_{bb.d} = \text{atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'})$ = **35** deg

Design effective cohesion $c'_{b.d} = c'_{b.k} / \gamma_{c'}$ = **0** kN/m^2

Using Coulomb theory

Active pressure coefficient $K_A = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times [1 + \sqrt{[\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))]}]^2)$ = **0.271**

Passive pressure coefficient $K_P = \sin(90 - \phi'_{b.d})^2 / (\sin(90 + \delta_{b.d}) \times [1 - \sqrt{[\sin(\phi'_{b.d} + \delta_{b.d}) \times \sin(\phi'_{b.d}) / (\sin(90 + \delta_{b.d}))]}]^2)$ = **14.662**

Sliding check

Vertical forces on wall

Wall stem $F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem}$ = **46.5** kN/m

Wall base $F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base}$ = **28** kN/m

Line loads $F_{P\_v} = \gamma_{Gf} \times P_{G1} + \gamma_{Qf} \times P_{Q1} + \gamma_{Gf} \times P_{G2}$ = **42.6** kN/m

Moist retained soil $F_{moist\_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}'$ = **48.8** kN/m

Base soil $F_{exc\_v} = \gamma_{Gf} \times A_{exc} \times \gamma_b'$ = **13.3** kN/m

Total $F_{total\_v} = F_{stem} + F_{base} + F_{P\_v} + F_{moist\_v} + F_{exc\_v}$ = **179.2** kN/m

Horizontal forces on wall

Surcharge load $F_{sur\_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff}$ = **41.1** kN/m

Moist retained soil $F_{moist\_h} = \gamma_G \times K_A \times \gamma_{mr}' \times h_{eff}^2 / 2$ = **98** kN/m

Total $F_{total\_h} = F_{sur\_h} + F_{moist\_h}$ = **139** kN/m

Check stability against sliding

Base soil resistance $F_{exc\_h} = \gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2$ = **76.7** kN/m

Base friction $F_{friction} = F_{total\_v} \times \tan(\delta_{bb.d})$ = **125.5** kN/m

Resistance to sliding $F_{rest} = F_{exc\_h} + F_{friction} = \mathbf{202.1}$ kN/m

Factor of safety $FoS_{sl} = F_{rest} / F_{total\_h} = \mathbf{1.454}$

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem $F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = \mathbf{46.5}$ kN/m

Wall base $F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = \mathbf{28}$ kN/m

Line loads $F_{P\_v} = \gamma_{Gf} \times P_{G1} + \gamma_{Qf} \times P_{Q1} + \gamma_{Gf} \times P_{G2} = \mathbf{42.6}$ kN/m

Moist retained soil $F_{moist\_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' = \mathbf{48.8}$ kN/m

Base soil $F_{exc\_v} = \gamma_{Gf} \times A_{exc} \times \gamma_{b}' = \mathbf{13.3}$ kN/m

Total $F_{total\_v} = F_{stem} + F_{base} + F_{P\_v} + F_{moist\_v} + F_{exc\_v} = \mathbf{179.2}$ kN/m

Horizontal forces on wall

Surcharge load $F_{sur\_h} = K_A \times \gamma_Q \times Surcharge_Q \times h_{eff} = \mathbf{41.1}$ kN/m

Moist retained soil $F_{moist\_h} = \gamma_G \times K_A \times \gamma_{mr}' \times h_{eff}^2 / 2 = \mathbf{98}$ kN/m

Base soil $F_{exc\_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = \mathbf{-76.7}$ kN/m

Total $F_{total\_h} = F_{sur\_h} + F_{moist\_h} + F_{exc\_h} = \mathbf{62.4}$ kN/m

Overturning moments on wall

Surcharge load $M_{sur\_OT} = F_{sur\_h} \times x_{sur\_h} = \mathbf{103.7}$ kNm/m

Moist retained soil $M_{moist\_OT} = F_{moist\_h} \times x_{moist\_h} = \mathbf{164.9}$ kNm/m

Total $M_{total\_OT} = M_{sur\_OT} + M_{moist\_OT} = \mathbf{268.6}$ kNm/m

Restoring moments on wall

Wall stem $M_{stem\_R} = F_{stem} \times x_{stem} = \mathbf{97.7}$ kNm/m

Wall base $M_{base\_R} = F_{base} \times x_{base} = \mathbf{39.2}$ kNm/m

Line loads $M_{P\_R} = (abs(\gamma_{Gf} \times P_{G1} + \gamma_{Qf} \times P_{Q1})) \times p_1 + abs(\gamma_{Gf} \times P_{G2}) \times p_2 = \mathbf{80.6}$ kNm/m

Moist retained soil $M_{moist\_R} = F_{moist\_v} \times x_{moist\_v} = \mathbf{124.5}$ kNm/m

Base soil $M_{exc\_R} = F_{exc\_v} \times x_{exc\_v} - F_{exc\_h} \times x_{exc\_h} = \mathbf{33.1}$ kNm/m

Total $M_{total\_R} = M_{stem\_R} + M_{base\_R} + M_{P\_R} + M_{moist\_R} + M_{exc\_R} = \mathbf{375}$ kNm/m

Check stability against overturning

Factor of safety $FoS_{ot} = M_{total\_R} / M_{total\_OT} = \mathbf{1.396}$

PASS - Maximum restoring moment is greater than overturning moment

Bearing pressure check

Vertical forces on wall

Wall stem $F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem} = \mathbf{62.8}$ kN/m

Wall base $F_{base} = \gamma_G \times A_{base} \times \gamma_{base} = \mathbf{37.8}$ kN/m

Surcharge load $F_{sur\_v} = \gamma_Q \times Surcharge_Q \times l_{heel} = \mathbf{15}$ kN/m

Line loads $F_{P\_v} = \gamma_G \times P_{G1} + \gamma_Q \times P_{Q1} + \gamma_G \times P_{G2} = \mathbf{72.2}$ kN/m

Moist retained soil $F_{moist\_v} = \gamma_G \times A_{moist} \times \gamma_{mr}' = \mathbf{65.9}$ kN/m

Base soil $F_{pass\_v} = \gamma_G \times A_{pass} \times \gamma_b' = \mathbf{33.7}$ kN/m

Total $F_{total\_v} = F_{stem} + F_{base} + F_{sur\_v} + F_{P\_v} + F_{moist\_v} + F_{pass\_v} = \mathbf{287.4}$ kN/m

Horizontal forces on wall

Surcharge load $F_{sur\_h} = K_A \times \gamma_Q \times Surcharge_Q \times h_{eff} = \mathbf{41.1}$ kN/m

Moist retained soil $F_{moist\_h} = \gamma_G \times K_A \times \gamma_{mr}' \times h_{eff}^2 / 2 = \mathbf{98}$ kN/m

Base soil $F_{pass\_h} = \max(-\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2, -(F_{moist\_h} + F_{sur\_h})) = \mathbf{-139}$ kN/m

Total $F_{total\_h} = \max(F_{sur\_h} + F_{moist\_h} + F_{pass\_h} - F_{total\_v} \times \tan(\delta_{bb.d}), 0 \text{ kN/m}) = \mathbf{0}$ kN/m

Moments on wall

Wall stem $M_{stem} = F_{stem} \times x_{stem} = \mathbf{131.8}$ kNm/m

Wall base $M_{base} = F_{base} \times x_{base} = \mathbf{52.9}$ kNm/m

Surcharge load $M_{sur} = F_{sur\_v} \times x_{sur\_v} - F_{sur\_h} \times x_{sur\_h} = \mathbf{-65.4}$ kNm/m

Line loads $M_P = (\gamma_G \times P_{G1} + \gamma_Q \times P_{Q1}) \times p_1 + (\gamma_G \times P_{G2}) \times p_2 = \mathbf{134.5}$ kNm/m

Moist retained soil $M_{moist} = F_{moist\_v} \times x_{moist\_v} - F_{moist\_h} \times x_{moist\_h} = \mathbf{3.2}$ kNm/m

Base soil $M_{pass} = F_{pass\_v} \times x_{pass\_v} - F_{pass\_h} \times x_{pass\_h} = \mathbf{85.3}$ kNm/m

Total $M_{total} = M_{stem} + M_{base} + M_{sur} + M_P + M_{moist} + M_{pass} = \mathbf{342.3}$ kNm/m

Check bearing pressure

Distance to reaction $\bar{x} = M_{total} / F_{total\_v} = \mathbf{1191}$ mm

Eccentricity of reaction $e = \bar{x} - l_{base} / 2 = \mathbf{-209}$ mm

Loaded length of base $l_{load} = 2 \times \bar{x} = \mathbf{2382}$ mm

Bearing pressure at toe $q_{toe} = F_{total\_v} / l_{load} = \mathbf{120.6}$ kN/m^2

Bearing pressure at heel $q_{heel} = \mathbf{0}$ kN/m^2

Effective overburden pressure $q = (t_{base} + d_{cover}) \times \gamma_b' = \mathbf{20.1}$ kN/m^2

Design effective overburden pressure $q' = q / \gamma_\gamma = \mathbf{20.1}$ kN/m^2

Bearing resistance factors $N_q = \mathrm{Exp}(\pi \times \tan(\phi'_{b.d})) \times (\tan(45 \text{ deg} + \phi'_{b.d} / 2))^2 = \mathbf{85.374}$

$N_c = (N_q - 1) \times \cot(\phi'_{b.d}) = \mathbf{93.706}$

$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b.d}) = \mathbf{151.941}$

Foundation shape factors $s_q = 1$

$s_\gamma = 1$

$s_c = 1$

Load inclination factors $H = F_{sur\_h} + F_{moist\_h} + F_{pass\_h} = \mathbf{0}$ kN/m

$V = F_{total\_v} = \mathbf{287.4}$ kN/m

$m = 2$

$i_q = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^m = \mathbf{1}$

$i_\gamma = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^{(m + 1)} = \mathbf{1}$

$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b.d})) = \mathbf{1}$

Net ultimate bearing capacity

$n_f = c'_{b.d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_b' \times l_{load} \times N_\gamma \times s_\gamma \times i_\gamma = \mathbf{4885.2}$ kN/m^2

Factor of safety $FoS_{bp} = n_f / \max(q_{toe}, q_{heel}) = \mathbf{40.497}$

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

Design approach 1

Partial factors on actions - Table A.3 - Combination 2

Partial factor set A2

Permanent unfavourable action $\gamma_G = \mathbf{1.00}$

Permanent favourable action $\gamma_{Gf} = \mathbf{1.00}$

Variable unfavourable action $\gamma_Q = \mathbf{1.30}$

Variable favourable action $\gamma_{Qf} = \mathbf{0.00}$

Partial factors for soil parameters – Table A.4 - Combination 2

Soil parameter set M2

Angle of shearing resistance $\gamma_{\phi'}$ = **1.25**

Effective cohesion $\gamma_{c'}$ = **1.25**

Weight density γ_{γ} = **1.00**

Library item Partial factors output

Retained soil properties

Design moist density $\gamma_{mr}' = \gamma_{mr} / \gamma_{\gamma}$ = **21** kN/m^3

Design saturated density $\gamma_{sr}' = \gamma_{sr} / \gamma_{\gamma}$ = **23** kN/m^3

Design effective shear resistance angle $\phi'_{r.d} = \text{atan}(\tan(\phi'_{r.k}) / \gamma_{\phi'})$ = **29.3** deg

Design wall friction angle $\delta_{r.d} = \text{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'})$ = **0** deg

Base soil properties

Design soil density $\gamma_b' = \gamma_b / \gamma_{\gamma}$ = **17.5** kN/m^3

Design effective shear resistance angle $\phi'_{b.d} = \text{atan}(\tan(\phi'_{b.k}) / \gamma_{\phi'})$ = **35.8** deg

Design wall friction angle $\delta_{b.d} = \text{atan}(\tan(\delta_{b.k}) / \gamma_{\phi'})$ = **17.1** deg

Design base friction angle $\delta_{bb.d} = \text{atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'})$ = **29.3** deg

Design effective cohesion $c'_{b.d} = c'_{b.k} / \gamma_{c'}$ = **0** kN/m^2

Using Coulomb theory

Active pressure coefficient $K_A = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times [1 + \sqrt{[\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))]}]^2)$ = **0.343**

Passive pressure coefficient $K_P = \sin(90 - \phi'_{b.d})^2 / (\sin(90 + \delta_{b.d}) \times [1 - \sqrt{[\sin(\phi'_{b.d} + \delta_{b.d}) \times \sin(\phi'_{b.d}) / (\sin(90 + \delta_{b.d}))]}]^2)$ = **7.553**

Sliding check

Vertical forces on wall

Wall stem $F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem}$ = **46.5** kN/m

Wall base $F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base}$ = **28** kN/m

Line loads $F_{P\_v} = \gamma_{Gf} \times P_{G1} + \gamma_{Qf} \times P_{Q1} + \gamma_{Gf} \times P_{G2}$ = **42.6** kN/m

Moist retained soil $F_{moist\_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}'$ = **48.8** kN/m

Base soil $F_{exc\_v} = \gamma_{Gf} \times A_{exc} \times \gamma_b'$ = **13.3** kN/m

Total $F_{total\_v} = F_{stem} + F_{base} + F_{P\_v} + F_{moist\_v} + F_{exc\_v}$ = **179.2** kN/m

Horizontal forces on wall

Surcharge load $F_{sur\_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff}$ = **45.1** kN/m

Moist retained soil $F_{moist\_h} = \gamma_G \times K_A \times \gamma_{mr}' \times h_{eff}^2 / 2$ = **92** kN/m

Total $F_{total\_h} = F_{sur\_h} + F_{moist\_h}$ = **137.1** kN/m

Check stability against sliding

Base soil resistance $F_{exc\_h} = \gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2$ = **40.4** kN/m

Base friction $F_{friction} = F_{total\_v} \times \tan(\delta_{bb.d})$ = **100.4** kN/m

Resistance to sliding $F_{rest} = F_{exc\_h} + F_{friction}$ = **140.8** kN/m

Factor of safety $FoS_{sl} = F_{rest} / F_{total\_h}$ = **1.028**

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem $F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem}$ = **46.5** kN/m

Wall base $F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base}$ = **28** kN/m

Line loads $F_{P\_v} = \gamma_{Gf} \times P_{G1} + \gamma_{Qf} \times P_{Q1} + \gamma_{Gf} \times P_{G2}$ = **42.6** kN/m

Moist retained soil $F_{moist\_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}'$ = **48.8** kN/m

Base soil	$F_{exc\_v} = \gamma_{Gf} \times A_{exc} \times \gamma_b' =$ **13.3** kN/m
Total	$F_{total\_v} = F_{stem} + F_{base} + F_{P\_v} + F_{moist\_v} + F_{exc\_v} =$ **179.2** kN/m

Horizontal forces on wall

Surcharge load	$F_{sur\_h} = K_A \times \gamma_Q \times Surcharge_Q \times h_{eff} =$ **45.1** kN/m
Moist retained soil	$F_{moist\_h} = \gamma_G \times K_A \times \gamma_{mr}' \times h_{eff}^2 / 2 =$ **92** kN/m
Base soil	$F_{exc\_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 =$ **-40.4** kN/m
Total	$F_{total\_h} = F_{sur\_h} + F_{moist\_h} + F_{exc\_h} =$ **96.6** kN/m

Overturning moments on wall

Surcharge load	$M_{sur\_OT} = F_{sur\_h} \times x_{sur\_h} =$ **113.9** kNm/m
Moist retained soil	$M_{moist\_OT} = F_{moist\_h} \times x_{moist\_h} =$ **154.8** kNm/m
Total	$M_{total\_OT} = M_{sur\_OT} + M_{moist\_OT} =$ **268.7** kNm/m

Restoring moments on wall

Wall stem	$M_{stem\_R} = F_{stem} \times x_{stem} =$ **97.7** kNm/m
Wall base	$M_{base\_R} = F_{base} \times x_{base} =$ **39.2** kNm/m
Line loads	$M_{P\_R} = (abs(\gamma_{Gf} \times P_{G1} + \gamma_{Qf} \times P_{Q1})) \times p_1 + abs(\gamma_{Gf} \times P_{G2}) \times p_2 =$ **80.6** kNm/m
Moist retained soil	$M_{moist\_R} = F_{moist\_v} \times x_{moist\_v} =$ **124.5** kNm/m
Base soil	$M_{exc\_R} = F_{exc\_v} \times x_{exc\_v} - F_{exc\_h} \times x_{exc\_h} =$ **23.4** kNm/m
Total	$M_{total\_R} = M_{stem\_R} + M_{base\_R} + M_{P\_R} + M_{moist\_R} + M_{exc\_R} =$ **365.3** kNm/m

Check stability against overturning

Factor of safety	$FoS_{ot} = M_{total\_R} / M_{total\_OT} =$ **1.36**

PASS - Maximum restoring moment is greater than overturning moment

Bearing pressure check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem} =$ **46.5** kN/m
Wall base	$F_{base} = \gamma_G \times A_{base} \times \gamma_{base} =$ **28** kN/m
Surcharge load	$F_{sur\_v} = \gamma_Q \times Surcharge_Q \times l_{heel} =$ **13** kN/m
Line loads	$F_{P\_v} = \gamma_G \times P_{G1} + \gamma_Q \times P_{Q1} + \gamma_G \times P_{G2} =$ **55.3** kN/m
Moist retained soil	$F_{moist\_v} = \gamma_G \times A_{moist} \times \gamma_{mr}' =$ **48.8** kN/m
Base soil	$F_{pass\_v} = \gamma_G \times A_{pass} \times \gamma_b' =$ **24.9** kN/m
Total	$F_{total\_v} = F_{stem} + F_{base} + F_{sur\_v} + F_{P\_v} + F_{moist\_v} + F_{pass\_v} =$ **216.6** kN/m

Horizontal forces on wall

Surcharge load	$F_{sur\_h} = K_A \times \gamma_Q \times Surcharge_Q \times h_{eff} =$ **45.1** kN/m
Moist retained soil	$F_{moist\_h} = \gamma_G \times K_A \times \gamma_{mr}' \times h_{eff}^2 / 2 =$ **92** kN/m
Base soil	$F_{pass\_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2 =$ **-83.6** kN/m
Total	$F_{total\_h} = \max(F_{sur\_h} + F_{moist\_h} + F_{pass\_h} - F_{total\_v} \times \tan(\delta_{bb.d}), 0 \text{ kN/m}) =$ **0** kN/m

Moments on wall

Wall stem	$M_{stem} = F_{stem} \times x_{stem} =$ **97.7** kNm/m
Wall base	$M_{base} = F_{base} \times x_{base} =$ **39.2** kNm/m
Surcharge load	$M_{sur} = F_{sur\_v} \times x_{sur\_v} - F_{sur\_h} \times x_{sur\_h} =$ **-80.7** kNm/m
Line loads	$M_P = (\gamma_G \times P_{G1} + \gamma_Q \times P_{Q1}) \times p_1 + (\gamma_G \times P_{G2}) \times p_2 =$ **102.9** kNm/m
Moist retained soil	$M_{moist} = F_{moist\_v} \times x_{moist\_v} - F_{moist\_h} \times x_{moist\_h} =$ **-30.3** kNm/m
Base soil	$M_{pass} = F_{pass\_v} \times x_{pass\_v} - F_{pass\_h} \times x_{pass\_h} =$ **55.7** kNm/m

Total $M_{total} = M_{stem} + M_{base} + M_{sur} + M_P + M_{moist} + M_{pass} = \mathbf{184.4}$ kNm/m

Check bearing pressure

Distance to reaction	$\bar{x} = M_{total} / F_{total\_v} = \mathbf{851}$ mm
Eccentricity of reaction	$e = \bar{x} - l_{base} / 2 = \mathbf{-549}$ mm
Loaded length of base	$l_{load} = 2 \times \bar{x} = \mathbf{1703}$ mm
Bearing pressure at toe	$q_{toe} = F_{total\_v} / l_{load} = \mathbf{127.2}$ kN/m^2
Bearing pressure at heel	$q_{heel} = \mathbf{0}$ kN/m^2
Effective overburden pressure	$q = (t_{base} + d_{cover}) \times \gamma_b' = \mathbf{20.1}$ kN/m^2
Design effective overburden pressure	$q' = q / \gamma_\gamma = \mathbf{20.1}$ kN/m^2
Bearing resistance factors	$N_q = \text{Exp}(\pi \times \tan(\phi'_{b.d})) \times (\tan(45\text{ deg} + \phi'_{b.d} / 2))^2 = \mathbf{36.651}$
	$N_c = (N_q - 1) \times \cot(\phi'_{b.d}) = \mathbf{49.493}$
	$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b.d}) = \mathbf{51.36}$
Foundation shape factors	$s_q = 1$
	$s_\gamma = 1$
	$s_c = 1$
Load inclination factors	$H = F_{sur\_h} + F_{moist\_h} + F_{pass\_h} = \mathbf{53.5}$ kN/m
	$V = F_{total\_v} = \mathbf{216.6}$ kN/m
	$m = 2$
	$i_q = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^m = \mathbf{0.567}$
	$i_\gamma = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^{(m + 1)} = \mathbf{0.427}$
	$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b.d})) = \mathbf{0.555}$

Net ultimate bearing capacity

$n_f = c'_{b.d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_b' \times l_{load} \times N_\gamma \times s_\gamma \times i_\gamma = \mathbf{744.9}$ kN/m^2

Factor of safety $FoS_{bp} = n_f / \max(q_{toe}, q_{heel}) = \mathbf{5.856}$

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 2.9.14

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

Concrete strength class	C32/40
Characteristic compressive cylinder strength	$f_{ck} = \mathbf{32}$ N/mm^2
Characteristic compressive cube strength	$f_{ck,cube} = \mathbf{40}$ N/mm^2
Mean value of compressive cylinder strength	$f_{cm} = f_{ck} + 8$ N/mm^2 $= \mathbf{40}$ N/mm^2
Mean value of axial tensile strength	$f_{ctm} = 0.3$ N/mm$^2 \times (f_{ck} / 1$ N/mm$^2)^{2/3} = \mathbf{3.0}$ N/mm^2
5% fractile of axial tensile strength	$f_{ctk,0.05} = 0.7 \times f_{ctm} = \mathbf{2.1}$ N/mm^2
Secant modulus of elasticity of concrete	$E_{cm} = 22$ kN/mm$^2 \times (f_{cm} / 10$ N/mm$^2)^{0.3} = \mathbf{33346}$ 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	$f_{cd} = \alpha_{cc} \times f_{ck} / \gamma_C = \mathbf{18.1}$ 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 = **0.40**

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

Bending coefficient k_3 — K_3 =**0.40**

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

Reinforcement details

Characteristic yield strength of reinforcement — f_{yk} = **500** N/mm^2

Modulus of elasticity of reinforcement — E_s = **200000** N/mm^2

Partial factor for reinforcing steel - Table 2.1N — γ_S = **1.15**

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

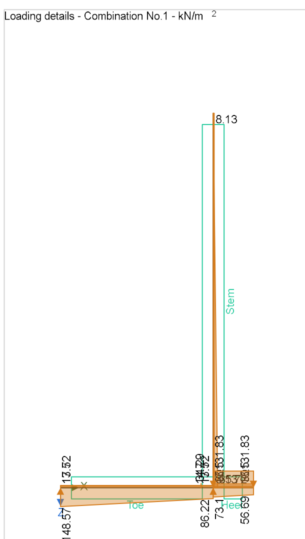
Cover to reinforcement

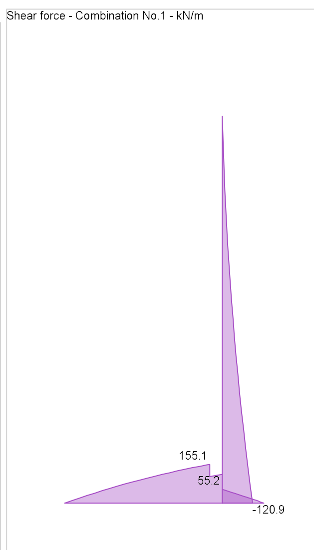
Front face of stem — c_{sf} = **50** mm

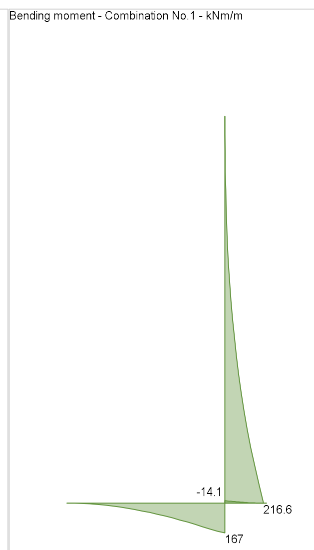
Rear face of stem — c_{sr} = **50** mm

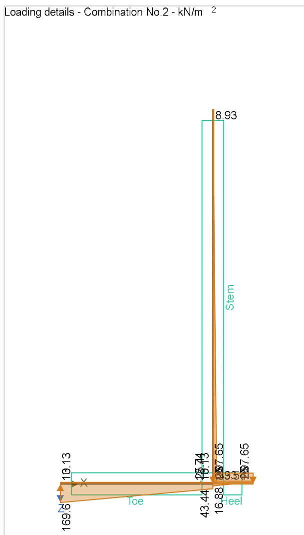
Top face of base — c_{bt} = **50** mm

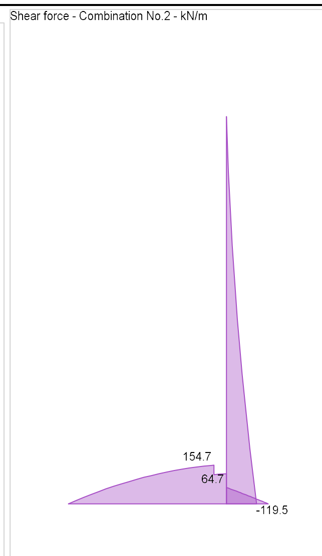
Bottom face of base — c_{bb} = **50** mm

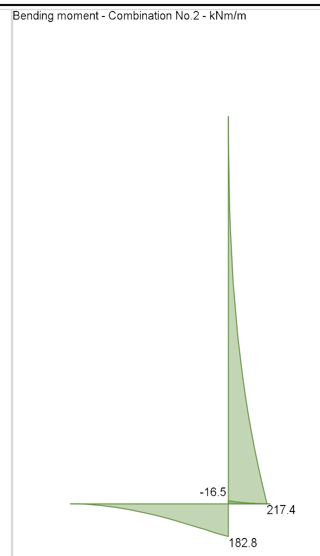












Check stem design at base of stem

Depth of section $h = \mathbf{400}$ mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 2 $M = \mathbf{217.4}$ kNm/m

Depth to tension reinforcement $d = h - c_{sr} - \phi_{sr} / 2 = \mathbf{340}$ mm

$K = M / (d^2 \times f_{ck}) = \mathbf{0.059}$

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

$K' = \mathbf{0.207}$

K' > K - No compression reinforcement is required

Lever arm $z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_C))^{0.5}, 0.95) \times d = \mathbf{321}$ mm

Depth of neutral axis $x = 2.5 \times (d - z) = \mathbf{47}$ mm

Area of tension reinforcement required $A_{sr.req} = M / (f_{yd} \times z) = \mathbf{1556}$ mm^2/m

Tension reinforcement provided 20 dia.bars @ 100 c/c

Area of tension reinforcement provided $A_{sr.prov} = \pi \times \phi_{sr}^2 / (4 \times s_{sr}) = \mathbf{3142}$ mm^2/m

Minimum area of reinforcement - exp.9.1N $A_{sr.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = \mathbf{535}$ mm^2/m

Maximum area of reinforcement - cl.9.2.1.1(3) $A_{sr.max} = 0.04 \times h = \mathbf{16000}$ mm^2/m

$\max(A_{sr.req}, A_{sr.min}) / A_{sr.prov} = \mathbf{0.495}$

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 $\rho_0 = \sqrt{}(f_{ck} / 1\ \text{N/mm}^2) / 1000 = \mathbf{0.006}$

Required tension reinforcement ratio $\rho = A_{sr.req} / d = \mathbf{0.005}$

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

Structural system factor - Table 7.4N $K_b = \mathbf{0.4}$

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

Limiting span to depth ratio - exp.7.16.a $\min(K_s \times K_b \times [11 + 1.5 \times \sqrt{}(f_{ck} / 1\ \text{N/mm}^2) \times \rho_0 / \rho + 3.2 \times \sqrt{}(f_{ck} / 1\ \text{N/mm}^2) \times (\rho_0 / \rho - 1)^{3/2}], 40 \times K_b) = \mathbf{14.1}$

Actual span to depth ratio $h_{stem} / d = \mathbf{13.7}$

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} = **130.5** kNm/m
Tensile stress in reinforcement	$\sigma_s = M_{sls} / (A_{sr.prov} \times z)$ = **129.3** N/mm^2
Load duration	Long term
Load duration factor	k_t = **0.4**
Effective area of concrete in tension	$A_{c.eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$
	$A_{c.eff}$ = **117788** mm^2/m
Mean value of concrete tensile strength	$f_{ct.eff} = f_{ctm}$ = **3.0** N/mm^2
Reinforcement ratio	$\rho_{p.eff} = A_{sr.prov} / A_{c.eff}$ = **0.027**
Modular ratio	$\alpha_e = E_s / E_{cm}$ = **5.998**
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	$s_{r.max} = k_3 \times c_{sr} + k_1 \times k_2 \times k_4 \times \phi_{sr} / \rho_{p.eff}$ = **297** 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 = **0.115** mm
	w_k / w_{max} = **0.385**

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force	V = **120.9** kN/m
	$C_{Rd,c} = 0.18 / \gamma_C$ = **0.120**
	$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2)$ = **1.767**
Longitudinal reinforcement ratio	$\rho_l = \min(A_{sr.prov} / d, 0.02)$ = **0.009**
	$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5}$ = **0.465** N/mm^2
Design shear resistance - exp.6.2a & 6.2b	$V_{Rd.c} = \max(C_{Rd.c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$
	$V_{Rd.c}$ = **222.9** kN/m
	$V / V_{Rd.c}$ = **0.542**

PASS - Design shear resistance exceeds design shear force

Check stem design at 800 mm

Depth of section	h = **400** mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 2	M = **134.8** kNm/m
Depth to tension reinforcement	$d = h - c_{sr} - \phi_{sr1} / 2$ = **344** mm
	$K = M / (d^2 \times f_{ck})$ = **0.036**
	$K' = (2 \times \eta \times \alpha_{cc}/\gamma_C)\times(1 - \lambda \times (\delta - K_1)/(2 \times K_2))\times(\lambda \times (\delta - K_1)/(2 \times K_2))$
	K' = **0.207**

K' > K - No compression reinforcement is required

Lever arm	$z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_C))^{0.5}, 0.95) \times d$ = **327** mm
Depth of neutral axis	$x = 2.5 \times (d – z)$ = **43** mm
Area of tension reinforcement required	$A_{sr1.req} = M / (f_{yd} \times z)$ = **949** mm^2/m
Tension reinforcement provided	12 dia.bars @ 100 c/c
Area of tension reinforcement provided	$A_{sr1.prov} = \pi \times \phi_{sr1}^2 / (4 \times s_{sr1})$ = **1131** mm^2/m
Minimum area of reinforcement - exp.9.1N	$A_{sr1.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d$ = **541** mm^2/m

Maximum area of reinforcement - cl.9.2.1.1(3) $A_{sr1.max} = 0.04 \times h =$ **16000** mm^2/m

$\max(A_{sr1.req}, A_{sr1.min}) / A_{sr1.prov} =$ **0.839**

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 $\rho_0 = \sqrt{(f_{ck} / 1\ N/mm^2)} / 1000 =$ **0.006**

Required tension reinforcement ratio $\rho = A_{sr1.req} / d =$ **0.003**

Required compression reinforcement ratio $\rho' = A_{sr1.2.req} / d_2 =$ **0.000**

Structural system factor - Table 7.4N $K_b =$ **0.4**

Reinforcement factor - exp.7.17 $K_s = \min(500\ N/mm^2 / (f_{yk} \times A_{sr1.req} / A_{sr1.prov}), 1.5) =$ **1.192**

Limiting span to depth ratio - exp.7.16.a $\min(K_s \times K_b \times [11 + 1.5 \times \sqrt{(f_{ck} / 1\ N/mm^2)} \times \rho_0 / \rho + 3.2 \times \sqrt{(f_{ck} / 1\ N/mm^2)} \times (\rho_0 / \rho - 1)^{3/2}], 40 \times K_b) =$ **16**

Actual span to depth ratio $(h_{stem} - 800\ mm) / d =$ **11.2**

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 $\psi_2 =$ **0.6**

Serviceability bending moment $M_{sls} =$ **78.2** kNm/m

Tensile stress in reinforcement $\sigma_s = M_{sls} / (A_{sr1.prov} \times z) =$ **211.6** N/mm^2

Load duration Long term

Load duration factor $k_t =$ **0.4**

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

$A_{c.eff} =$ **119000** mm^2/m

Mean value of concrete tensile strength $f_{ct.eff} = f_{ctm} =$ **3.0** N/mm^2

Reinforcement ratio $\rho_{p.eff} = A_{sr1.prov} / A_{c.eff} =$ **0.010**

Modular ratio $\alpha_e = E_s / E_{cm} =$ **5.998**

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 $s_{r.max} = k_3 \times c_{sr} + k_1 \times k_2 \times k_4 \times \phi_{sr1} / \rho_{p.eff} =$ **385** mm

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

$w_k =$ **0.244** mm

$w_k / w_{max} =$ **0.814**

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force $V =$ **88.2** kN/m

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

$k = \min(1 + \sqrt{(200\ mm / d)}, 2) =$ **1.762**

Longitudinal reinforcement ratio $\rho_l = \min(A_{sr1.prov} / d, 0.02) =$ **0.003**

$v_{min} = 0.035\ N^{1/2}/mm \times k^{3/2} \times f_{ck}^{0.5} =$ **0.463** N/mm^2

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

$V_{Rd.c} =$ **159.4** kN/m

$V / V_{Rd.c} =$ **0.553**

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) $A_{sx.req} = \max(0.25 \times A_{sr.prov}, 0.001 \times t_{stem})$ = **785** mm²/m

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

Transverse reinforcement provided 16 dia.bars @ 200 c/c

Area of transverse reinforcement provided $A_{sx.prov} = \pi \times \phi_{sx}^2 / (4 \times s_{sx})$ = **1005** mm²/m

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

Check base design at toe

Depth of section h = **400** mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 2 M = **182.8** kNm/m

Depth to tension reinforcement $d = h - c_{bb} - \phi_{bb} / 2$ = **342** mm

$K = M / (d^2 \times f_{ck})$ = **0.049**

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

K' = **0.207**

K' > K - No compression reinforcement is required

Lever arm $z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_C))^{0.5}, 0.95) \times d$ = **325** mm

Depth of neutral axis $x = 2.5 \times (d - z)$ = **43** mm

Area of tension reinforcement required $A_{bb.req} = M / (f_{yd} \times z)$ = **1294** mm²/m

Tension reinforcement provided 16 dia.bars @ 100 c/c

Area of tension reinforcement provided $A_{bb.prov} = \pi \times \phi_{bb}^2 / (4 \times s_{bb})$ = **2011** mm²/m

Minimum area of reinforcement - exp.9.1N $A_{bb.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d$ = **538** mm²/m

Maximum area of reinforcement - cl.9.2.1.1(3) $A_{bb.max} = 0.04 \times h$ = **16000** mm²/m

$\max(A_{bb.req}, A_{bb.min}) / A_{bb.prov}$ = **0.643**

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} = **119.3** kNm/m

Tensile stress in reinforcement $\sigma_s = M_{sls} / (A_{bb.prov} \times z)$ = **182.7** N/mm²

Load duration Long term

Load duration factor k_t = **0.4**

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

$A_{c.eff}$ = **119083** mm²/m

Mean value of concrete tensile strength $f_{ct.eff} = f_{ctm}$ = **3.0** N/mm²

Reinforcement ratio $\rho_{p.eff} = A_{bb.prov} / A_{c.eff}$ = **0.017**

Modular ratio $\alpha_e = E_s / E_{cm}$ = **5.998**

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 $s_{r.max} = k_3 \times c_{bb} + k_1 \times k_2 \times k_4 \times \phi_{bb} / \rho_{p.eff}$ = **331** 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 = **0.181** mm

w_k / w_{max} = **0.605**

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force — $V = \mathbf{155.1}$ kN/m

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

$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = \mathbf{1.765}$

Longitudinal reinforcement ratio — $\rho_l = \min(A_{bb.prov} / d, 0.02) = \mathbf{0.006}$

$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5} = \mathbf{0.464}$ N/mm^2

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

$V_{Rd.c} = \mathbf{192.6}$ kN/m

$V / V_{Rd.c} = \mathbf{0.805}$

PASS - Design shear resistance exceeds design shear force

Check base design at heel

Depth of section — $h = \mathbf{400}$ mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 2 — $M = \mathbf{16.5}$ kNm/m

Depth to tension reinforcement — $d = h - c_{bt} - \phi_{bt} / 2 = \mathbf{342}$ mm

$K = M / (d^2 \times f_{ck}) = \mathbf{0.004}$

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

$K' = \mathbf{0.207}$

K' > K - No compression reinforcement is required

Lever arm — $z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_C))^{0.5}, 0.95) \times d = \mathbf{325}$ mm

Depth of neutral axis — $x = 2.5 \times (d - z) = \mathbf{43}$ mm

Area of tension reinforcement required — $A_{bt.req} = M / (f_{yd} \times z) = \mathbf{117}$ mm^2/m

Tension reinforcement provided — 16 dia.bars @ 100 c/c

Area of tension reinforcement provided — $A_{bt.prov} = \pi \times \phi_{bt}^2 / (4 \times s_{bt}) = \mathbf{2011}$ mm^2/m

Minimum area of reinforcement - exp.9.1N — $A_{bt.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = \mathbf{538}$ mm^2/m

Maximum area of reinforcement - cl.9.2.1.1(3) — $A_{bt.max} = 0.04 \times h = \mathbf{16000}$ mm^2/m

$\max(A_{bt.req}, A_{bt.min}) / A_{bt.prov} = \mathbf{0.267}$

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 — $w_{max} = \mathbf{0.3}$ mm

Variable load factor - EN1990 – Table A1.1 — $\psi_2 = \mathbf{0.6}$

Serviceability bending moment — $M_{sls} = \mathbf{8.9}$ kNm/m

Tensile stress in reinforcement — $\sigma_s = M_{sls} / (A_{bt.prov} \times z) = \mathbf{13.6}$ N/mm^2

Load duration — Long term

Load duration factor — $k_t = \mathbf{0.4}$

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

$A_{c.eff} = \mathbf{119083}$ mm^2/m

Mean value of concrete tensile strength — $f_{ct.eff} = f_{ctm} = \mathbf{3.0}$ N/mm^2

Reinforcement ratio — $\rho_{p.eff} = A_{bt.prov} / A_{c.eff} = \mathbf{0.017}$

Modular ratio — $\alpha_e = E_s / E_{cm} = \mathbf{5.998}$

Bond property coefficient — $k_1 = \mathbf{0.8}$

Strain distribution coefficient — $k_2 = \mathbf{0.5}$

$k_3 = \mathbf{3.4}$

$k_4 = \mathbf{0.425}$

Maximum crack spacing - exp.7.11 — $s_{r.max} = k_3 \times c_{bt} + k_1 \times k_2 \times k_4 \times \phi_{bt} / \rho_{p.eff} = \mathbf{331}$ 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 = **0.014** mm

w_k / w_{max} = **0.045**

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force V = **64.7** kN/m

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

$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2)$ = **1.765**

Longitudinal reinforcement ratio $\rho_l = \min(A_{bt.prov} / d, 0.02)$ = **0.006**

$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5}$ = **0.464** N/mm²

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

$V_{Rd.c}$ = **192.6** kN/m

$V / V_{Rd.c}$ = **0.336**

PASS - Design shear resistance exceeds design shear force

Secondary transverse reinforcement to base - Section 9.3

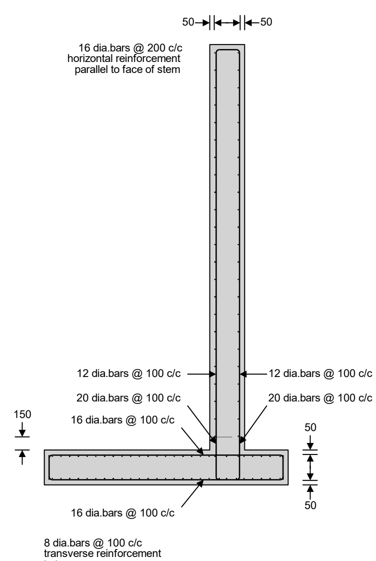
Minimum area of reinforcement – cl.9.3.1.1(2) $A_{bx.req} = 0.2 \times A_{bb.prov}$ = **402** mm²/m

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

Transverse reinforcement provided 8 dia.bars @ 100 c/c

Area of transverse reinforcement provided $A_{bx.prov} = \pi \times \phi_{bx}^2 / (4 \times s_{bx})$ = **503** mm²/m

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



Reinforcement details