



Project 33 Baker Street, Reading				Job no.	
Calcs for Light Well Retaining Wall				Start page no./Revision 1 A	
Calcs by ST	Calcs date 15/12/2024	Checked by ST	Checked date 15/12/2024	Approved by	Approved date

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	$h_{\text{stem}} = 1700 \text{ mm}$
Stem thickness	$t_{\text{stem}} = 200 \text{ mm}$
Angle to rear face of stem	$\alpha = 90 \text{ deg}$
Stem density	$\gamma_{\text{stem}} = 25 \text{ kN/m}^3$
Toe length	$l_{\text{toe}} = 1400 \text{ mm}$
Base thickness	$t_{\text{base}} = 200 \text{ mm}$
Base density	$\gamma_{\text{base}} = 25 \text{ kN/m}^3$
Height of retained soil	$h_{\text{ret}} = 1600 \text{ mm}$
Angle of soil surface	$\beta = 0 \text{ deg}$
Depth of cover	$d_{\text{cover}} = 0 \text{ mm}$

Retained soil properties

Soil type	Medium dense well graded sand
Moist density	$\gamma_{\text{mr}} = 21 \text{ kN/m}^3$
Saturated density	$\gamma_{\text{sr}} = 23 \text{ kN/m}^3$
Characteristic effective shear resistance angle	$\phi'_{\text{r,k}} = 30 \text{ deg}$
Characteristic wall friction angle	$\delta_{\text{r,k}} = 0 \text{ deg}$

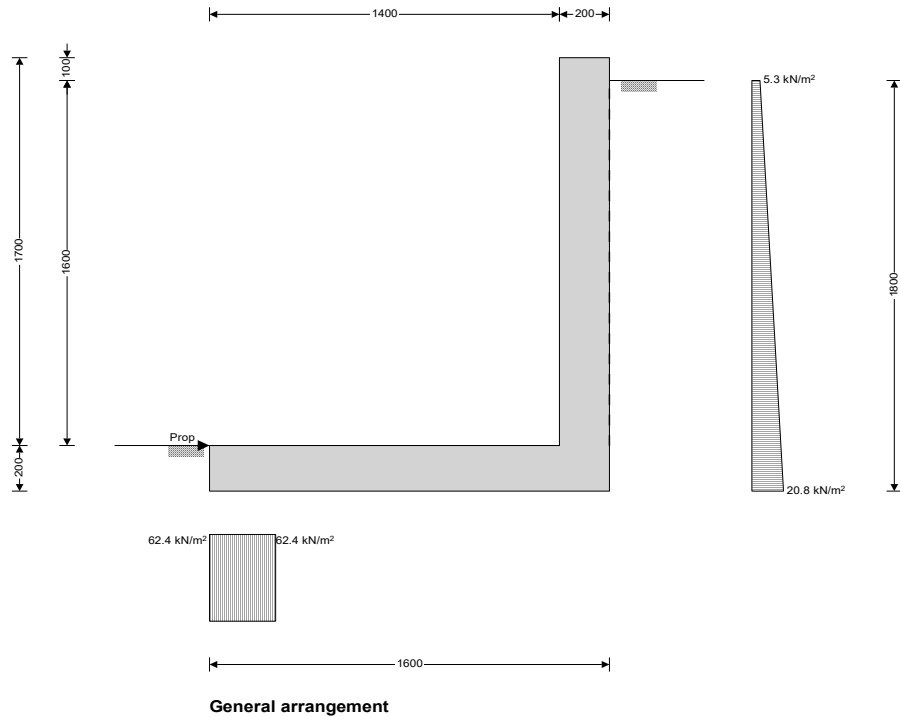
Base soil properties

Soil type	Dense brick hardcore
Soil density	$\gamma_{\text{b}} = 16.4 \text{ kN/m}^3$
Characteristic cohesion	$c'_{\text{b,k}} = 0 \text{ kN/m}^2$
Characteristic effective shear resistance angle	$\phi'_{\text{b,k}} = 36 \text{ deg}$
Characteristic wall friction angle	$\delta_{\text{b,k}} = 18 \text{ deg}$
Characteristic base friction angle	$\delta_{\text{bb,k}} = 24 \text{ deg}$

Loading details

Variable surcharge load	Surcharge _Q = 10 kN/m ²
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Calculate retaining wall geometry

Base length

$$l_{base} = l_{toe} + t_{stem} = \mathbf{1600 \text{ mm}}$$

Moist soil height

$$h_{moist} = h_{soil} = \mathbf{1600 \text{ mm}}$$

Length of surcharge load

$$l_{sur} = l_{heel} = \mathbf{0 \text{ mm}}$$

- Distance to vertical component

$$x_{sur_v} = l_{base} - l_{heel} / 2 = \mathbf{1600 \text{ mm}}$$

Effective height of wall

$$h_{eff} = h_{base} + d_{cover} + h_{ret} = \mathbf{1800 \text{ mm}}$$

- Distance to horizontal component

$$x_{sur_h} = h_{eff} / 2 = \mathbf{900 \text{ mm}}$$

Area of wall stem

$$A_{stem} = h_{stem} \times t_{stem} = \mathbf{0.34 \text{ m}^2}$$

- Distance to vertical component

$$x_{stem} = l_{toe} + t_{stem} / 2 = \mathbf{1500 \text{ mm}}$$

Area of wall base

$$A_{base} = l_{base} \times t_{base} = \mathbf{0.32 \text{ m}^2}$$

- Distance to vertical component

$$x_{base} = l_{base} / 2 = \mathbf{800 \text{ mm}}$$

Design approach 1

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

Partial factor set

$$A1$$

Permanent unfavourable action

$$\gamma_G = \mathbf{1.35}$$

Permanent favourable action

$$\gamma_{Gf} = \mathbf{1.00}$$

Variable unfavourable action

$$\gamma_Q = \mathbf{1.50}$$

Variable favourable action

$$\gamma_{Qf} = \mathbf{0.00}$$

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

Soil parameter set

$$M1$$

Angle of shearing resistance

$$\gamma_{\phi'} = \mathbf{1.00}$$



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

Weight density $\gamma_{\gamma} = 1.00$

Library item Partial factors output

Retained soil properties

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

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

Design effective shear resistance angle $\phi'_{r.d} = \text{atan}(\tan(\phi'_{r.k}) / \gamma_{\phi'}) = 30 \text{ deg}$

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

Base soil properties

Design soil density $\gamma_b' = \gamma_b / \gamma_{\gamma} = 16.4 \text{ kN/m}^3$

Design effective shear resistance angle $\phi'_{b.d} = \text{atan}(\tan(\phi'_{b.k}) / \gamma_{\phi'}) = 36 \text{ deg}$

Design wall friction angle $\delta_{b.d} = \text{atan}(\tan(\delta_{b.k}) / \gamma_{\phi'}) = 18 \text{ deg}$

Design base friction angle $\delta_{bb.d} = \text{atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'}) = 24 \text{ deg}$

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

Using Coulomb theory

Active pressure coefficient $K_A = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times [1 + \sqrt{(\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))}]^2) = 0.333$

Passive pressure coefficient $K_P = \sin(90 - \phi'_{b.d})^2 / (\sin(90 + \delta_{b.d}) \times [1 - \sqrt{(\sin(\phi'_{b.d} + \delta_{b.d}) \times \sin(\phi'_{b.d}) / (\sin(90 + \delta_{b.d}))}]^2) = 8.022$

Overturning check

Vertical forces on wall

Wall stem $F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = 8.5 \text{ kN/m}$

Wall base $F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = 8 \text{ kN/m}$

Total $F_{total_v} = F_{stem} + F_{base} = 16.5 \text{ kN/m}$

Horizontal forces on wall

Surcharge load $F_{sur_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} = 9 \text{ kN/m}$

Moist retained soil $F_{moist_h} = \gamma_G \times K_A \times \gamma_{mr}' \times h_{eff}^2 / 2 = 15.3 \text{ kN/m}$

Base soil $F_{exc_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = -2.5 \text{ kN/m}$

Total $F_{total_h} = F_{sur_h} + F_{moist_h} + F_{exc_h} = 21.8 \text{ kN/m}$

Overturning moments on wall

Surcharge load $M_{sur_OT} = F_{sur_h} \times X_{sur_h} = 8.1 \text{ kNm/m}$

Moist retained soil $M_{moist_OT} = F_{moist_h} \times X_{moist_h} = 9.2 \text{ kNm/m}$

Total $M_{total_OT} = M_{sur_OT} + M_{moist_OT} = 17.3 \text{ kNm/m}$

Restoring moments on wall

Wall stem $M_{stem_R} = F_{stem} \times X_{stem} = 12.8 \text{ kNm/m}$

Wall base $M_{base_R} = F_{base} \times X_{base} = 6.4 \text{ kNm/m}$

Total $M_{total_R} = M_{stem_R} + M_{base_R} = 19.2 \text{ kNm/m}$

Check stability against overturning

Factor of safety $FoS_{ot} = M_{total_R} / M_{total_OT} = 1.108$

PASS - Maximum restoring moment is greater than overturning moment

Bearing pressure check

Vertical forces on wall

Wall stem $F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem} = 11.5 \text{ kN/m}$



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Wall base	$F_{base} = \gamma_G \times A_{base} \times \gamma_{base} = 10.8 \text{ kN/m}$
Total	$F_{total_v} = F_{stem} + F_{base} = 22.3 \text{ kN/m}$
Horizontal forces on wall	
Surcharge load	$F_{sur_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} = 9 \text{ kN/m}$
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \gamma_{mr}' \times h_{eff}^2 / 2 = 15.3 \text{ kN/m}$
Base soil	$F_{pass_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2 = -2.5 \text{ kN/m}$
Total	$F_{total_h} = F_{sur_h} + F_{moist_h} + F_{pass_h} = 21.8 \text{ kN/m}$
Moments on wall	
Wall stem	$M_{stem} = F_{stem} \times X_{stem} = 17.2 \text{ kNm/m}$
Wall base	$M_{base} = F_{base} \times X_{base} = 8.6 \text{ kNm/m}$
Surcharge load	$M_{sur} = -F_{sur_h} \times X_{sur_h} = -8.1 \text{ kNm/m}$
Moist retained soil	$M_{moist} = -F_{moist_h} \times X_{moist_h} = -9.2 \text{ kNm/m}$
Total	$M_{total} = M_{stem} + M_{base} + M_{sur} + M_{moist} = 8.6 \text{ kNm/m}$
Check bearing pressure	
Propping force	$F_{prop_base} = F_{total_h} = 21.8 \text{ kN/m}$
Distance to reaction	$\bar{x} = M_{total} / F_{total_v} = 385 \text{ mm}$
Eccentricity of reaction	$e = \bar{x} - l_{base} / 2 = -415 \text{ mm}$
Loaded length of base	$l_{load} = 2 \times \bar{x} = 769 \text{ mm}$
Bearing pressure at toe	$q_{toe} = F_{total_v} / l_{load} = 29 \text{ kN/m}^2$
Bearing pressure at heel	$q_{heel} = 0 \text{ kN/m}^2$
Effective overburden pressure	$q = (t_{base} + d_{cover}) \times \gamma_b' = 3.3 \text{ kN/m}^2$
Design effective overburden pressure	$q' = q / \gamma_\gamma = 3.3 \text{ kN/m}^2$
Bearing resistance factors	$N_q = \text{Exp}(\pi \times \tan(\phi'_{b,d})) \times (\tan(45 \text{ deg} + \phi'_{b,d} / 2))^2 = 37.752$
	$N_c = (N_q - 1) \times \cot(\phi'_{b,d}) = 50.585$
	$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b,d}) = 53.405$
Foundation shape factors	$s_q = 1$
	$s_\gamma = 1$
	$s_c = 1$
Load inclination factors	$H = F_{sur_h} + F_{moist_h} + F_{pass_h} - F_{prop_base} = 0 \text{ kN/m}$
	$V = F_{total_v} = 22.3 \text{ kN/m}$
	$m = 2$
	$i_q = [1 - H / (V + l_{load} \times c'_{b,d} \times \cot(\phi'_{b,d}))]^m = 1$
	$i_\gamma = [1 - H / (V + l_{load} \times c'_{b,d} \times \cot(\phi'_{b,d}))]^{(m+1)} = 1$
	$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b,d})) = 1$
Net ultimate bearing capacity	
	$n_f = c'_{b,d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_b' \times l_{load} \times N_\gamma \times s_\gamma \times i_\gamma = 460 \text{ kN/m}^2$
Factor of safety	$FoS_{bp} = n_f / \max(q_{toe}, q_{heel}) = 15.884$
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	$\gamma_G = 1.00$
Permanent favourable action	$\gamma_{Gf} = 1.00$
Variable unfavourable action	$\gamma_Q = 1.30$
Variable favourable action	$\gamma_{Qf} = 0.00$



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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	$\gamma_{\gamma} = 1.00$

Library item Partial factors output

Retained soil properties

Design moist density	$\gamma_{mr'} = \gamma_{mr} / \gamma_{\gamma} = 21 \text{ kN/m}^3$
Design saturated density	$\gamma_{sr'} = \gamma_{sr} / \gamma_{\gamma} = 23 \text{ kN/m}^3$
Design effective shear resistance angle	$\phi'_{r,d} = \text{atan}(\tan(\phi'_{r,k}) / \gamma_{\phi'}) = 24.8 \text{ deg}$
Design wall friction angle	$\delta_{r,d} = \text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}) = 0 \text{ deg}$

Base soil properties

Design soil density	$\gamma_{b'} = \gamma_b / \gamma_{\gamma} = 16.4 \text{ kN/m}^3$
Design effective shear resistance angle	$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_{\phi'}) = 30.2 \text{ deg}$
Design wall friction angle	$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_{\phi'}) = 14.6 \text{ deg}$
Design base friction angle	$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_{\phi'}) = 19.6 \text{ deg}$
Design effective cohesion	$c'_{b,d} = c'_{b,k} / \gamma_{c'} = 0 \text{ kN/m}^2$

Using Coulomb theory

Active pressure coefficient	$K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times [1 + \sqrt{[\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))]}]^2) = 0.409$
Passive pressure coefficient	$K_P = \sin(90 - \phi'_{b,d})^2 / (\sin(90 + \delta_{b,d}) \times [1 - \sqrt{[\sin(\phi'_{b,d} + \delta_{b,d}) \times \sin(\phi'_{b,d}) / (\sin(90 + \delta_{b,d}))]}]^2) = 4.938$

Overturning check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = 8.5 \text{ kN/m}$
Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = 8 \text{ kN/m}$
Total	$F_{total_v} = F_{stem} + F_{base} = 16.5 \text{ kN/m}$

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} = 9.6 \text{ kN/m}$
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \gamma_{mr'} \times h_{eff}^2 / 2 = 13.9 \text{ kN/m}$
Base soil	$F_{exc_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b,d}) \times \gamma_{b'} \times (h_{pass} + h_{base})^2 / 2 = -1.6 \text{ kN/m}$
Total	$F_{total_h} = F_{sur_h} + F_{moist_h} + F_{exc_h} = 21.9 \text{ kN/m}$

Overturning moments on wall

Surcharge load	$M_{sur_OT} = F_{sur_h} \times X_{sur_h} = 8.6 \text{ kNm/m}$
Moist retained soil	$M_{moist_OT} = F_{moist_h} \times X_{moist_h} = 8.4 \text{ kNm/m}$
Total	$M_{total_OT} = M_{sur_OT} + M_{moist_OT} = 17 \text{ kNm/m}$

Restoring moments on wall

Wall stem	$M_{stem_R} = F_{stem} \times X_{stem} = 12.8 \text{ kNm/m}$
Wall base	$M_{base_R} = F_{base} \times X_{base} = 6.4 \text{ kNm/m}$
Total	$M_{total_R} = M_{stem_R} + M_{base_R} = 19.2 \text{ kNm/m}$

Check stability against overturning

Factor of safety	$FoS_{ot} = M_{total_R} / M_{total_OT} = 1.129$
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PASS - Maximum restoring moment is greater than overturning moment



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Bearing pressure check

Vertical forces on wall

Wall stem $F_{\text{stem}} = \gamma G \times A_{\text{stem}} \times \gamma_{\text{stem}} = 8.5 \text{ kN/m}$

Wall base $F_{\text{base}} = \gamma G \times A_{\text{base}} \times \gamma_{\text{base}} = 8 \text{ kN/m}$

Total $F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} = 16.5 \text{ kN/m}$

Horizontal forces on wall

Surcharge load $F_{\text{sur}_h} = K_A \times \gamma Q \times \text{Surcharge}_Q \times h_{\text{eff}} = 9.6 \text{ kN/m}$

Moist retained soil $F_{\text{moist}_h} = \gamma G \times K_A \times \gamma_{\text{mr}}' \times h_{\text{eff}}^2 / 2 = 13.9 \text{ kN/m}$

Base soil $F_{\text{pass}_h} = -\gamma G_f \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (d_{\text{cover}} + h_{\text{base}})^2 / 2 = -1.6 \text{ kN/m}$

Total $F_{\text{total}_h} = F_{\text{sur}_h} + F_{\text{moist}_h} + F_{\text{pass}_h} = 21.9 \text{ kN/m}$

Moments on wall

Wall stem $M_{\text{stem}} = F_{\text{stem}} \times x_{\text{stem}} = 12.8 \text{ kNm/m}$

Wall base $M_{\text{base}} = F_{\text{base}} \times x_{\text{base}} = 6.4 \text{ kNm/m}$

Surcharge load $M_{\text{sur}} = -F_{\text{sur}_h} \times x_{\text{sur}_h} = -8.6 \text{ kNm/m}$

Moist retained soil $M_{\text{moist}} = -F_{\text{moist}_h} \times x_{\text{moist}_h} = -8.4 \text{ kNm/m}$

Total $M_{\text{total}} = M_{\text{stem}} + M_{\text{base}} + M_{\text{sur}} + M_{\text{moist}} = 2.2 \text{ kNm/m}$

Check bearing pressure

Propping force $F_{\text{prop}_base} = F_{\text{total}_h} = 21.9 \text{ kN/m}$

Distance to reaction $\bar{x} = M_{\text{total}} / F_{\text{total}_v} = 132 \text{ mm}$

Eccentricity of reaction $e = \bar{x} - l_{\text{base}} / 2 = -668 \text{ mm}$

Loaded length of base $l_{\text{load}} = 2 \times \bar{x} = 265 \text{ mm}$

Bearing pressure at toe $q_{\text{toe}} = F_{\text{total}_v} / l_{\text{load}} = 62.4 \text{ kN/m}^2$

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

Effective overburden pressure $q = (t_{\text{base}} + d_{\text{cover}}) \times \gamma_b' = 3.3 \text{ kN/m}^2$

Design effective overburden pressure $q' = q / \gamma_r = 3.3 \text{ kN/m}^2$

Bearing resistance factors $N_q = \text{Exp}(\pi \times \tan(\phi'_{b,d})) \times (\tan(45 \text{ deg} + \phi'_{b,d} / 2))^2 = 18.753$

$N_c = (N_q - 1) \times \cot(\phi'_{b,d}) = 30.543$

$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b,d}) = 20.637$

Foundation shape factors

$s_q = 1$

$s_\gamma = 1$

$s_c = 1$

Load inclination factors

$H = F_{\text{sur}_h} + F_{\text{moist}_h} + F_{\text{pass}_h} - F_{\text{prop}_base} = 0 \text{ kN/m}$

$V = F_{\text{total}_v} = 16.5 \text{ kN/m}$

$m = 2$

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

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

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

Net ultimate bearing capacity

$n_f = c'_{b,d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_b' \times l_{\text{load}} \times N_\gamma \times s_\gamma \times i_\gamma = 106.1 \text{ kN/m}^2$

Factor of safety

$\text{FoS}_{bp} = n_f / \max(q_{\text{toe}}, q_{\text{heel}}) = 1.701$

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure



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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	C30/37
Characteristic compressive cylinder strength	$f_{ck} = 30 \text{ N/mm}^2$
Characteristic compressive cube strength	$f_{ck,cube} = 37 \text{ N/mm}^2$
Mean value of compressive cylinder strength	$f_{cm} = f_{ck} + 8 \text{ N/mm}^2 = 38 \text{ N/mm}^2$
Mean value of axial tensile strength	$f_{ctm} = 0.3 \text{ N/mm}^2 \times (f_{ck} / 1 \text{ N/mm}^2)^{2/3} = 2.9 \text{ N/mm}^2$
5% fractile of axial tensile strength	$f_{ctk,0.05} = 0.7 \times f_{ctm} = 2.0 \text{ N/mm}^2$
Secant modulus of elasticity of concrete	$E_{cm} = 22 \text{ kN/mm}^2 \times (f_{cm} / 10 \text{ N/mm}^2)^{0.3} = 32837 \text{ N/mm}^2$
Partial factor for concrete - Table 2.1N	$\gamma_C = 1.50$
Compressive strength coefficient - cl.3.1.6(1)	$\alpha_{cc} = 0.85$
Design compressive concrete strength - exp.3.15	$f_{cd} = \alpha_{cc} \times f_{ck} / \gamma_C = 17.0 \text{ N/mm}^2$
Maximum aggregate size	$h_{agg} = 20 \text{ mm}$
Ultimate strain - Table 3.1	$\epsilon_{cu2} = 0.0035$
Shortening strain - Table 3.1	$\epsilon_{cu3} = 0.0035$
Effective compression zone height factor	$\lambda = 0.80$
Effective strength factor	$\eta = 1.00$
Bending coefficient k_1	$K_1 = 0.40$
Bending coefficient k_2	$K_2 = 1.00 \times (0.6 + 0.0014/\epsilon_{cu2}) = 1.00$
Bending coefficient k_3	$K_3 = 0.40$
Bending coefficient k_4	$K_4 = 1.00 \times (0.6 + 0.0014/\epsilon_{cu2}) = 1.00$

Reinforcement details

Characteristic yield strength of reinforcement	$f_{yk} = 500 \text{ N/mm}^2$
Modulus of elasticity of reinforcement	$E_s = 200000 \text{ N/mm}^2$
Partial factor for reinforcing steel - Table 2.1N	$\gamma_s = 1.15$
Design yield strength of reinforcement	$f_{yd} = f_{yk} / \gamma_s = 435 \text{ N/mm}^2$

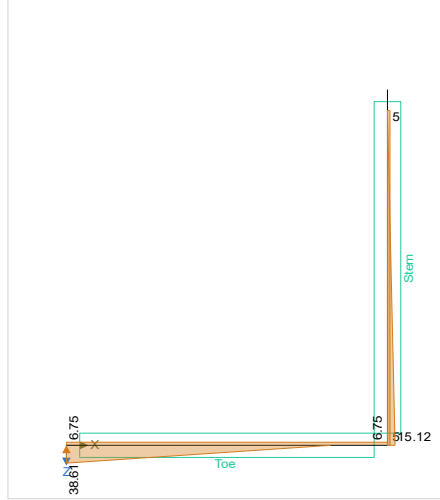
Cover to reinforcement

Front face of stem	$c_{sf} = 40 \text{ mm}$
Rear face of stem	$c_{sr} = 50 \text{ mm}$
Top face of base	$c_{bt} = 50 \text{ mm}$
Bottom face of base	$c_{bb} = 75 \text{ mm}$

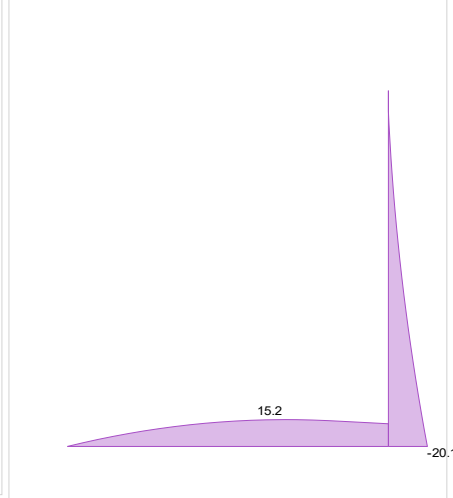


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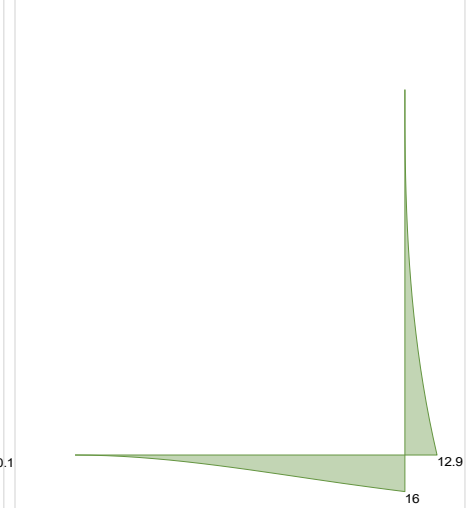
Loading details - Combination No.1 - kN/m²



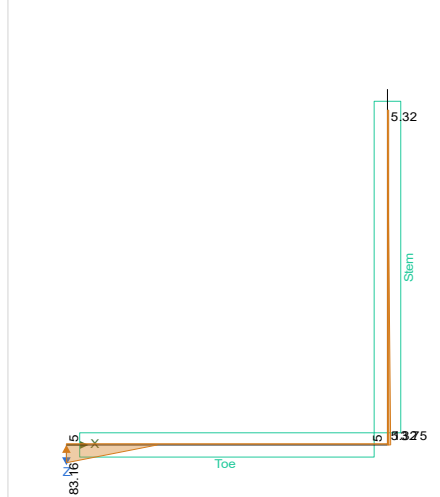
Shear force - Combination No.1 - kN/m



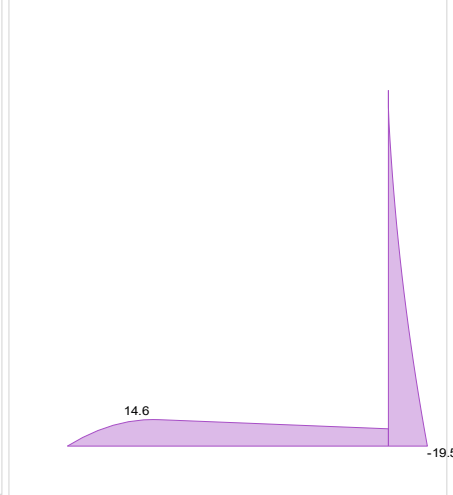
Bending moment - Combination No.1 - kNm/m



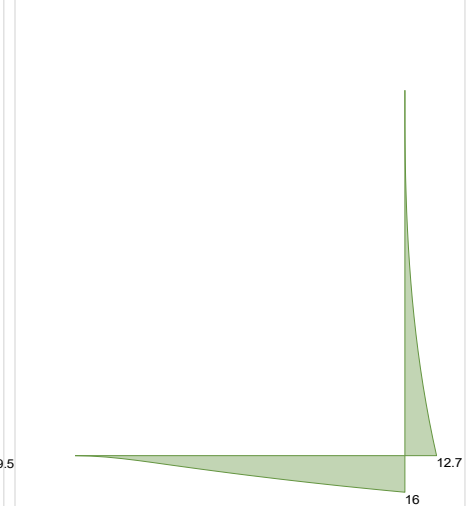
Loading details - Combination No.2 - kN/m²



Shear force - Combination No.2 - kN/m



Bending moment - Combination No.2 - kNm/m



Check stem design at base of stem

Depth of section

$h = 200 \text{ mm}$

Rectangular section in flexure - Section 6.1

Design bending moment combination 1

$M = 12.9 \text{ kNm/m}$

Depth to tension reinforcement

$d = h - c_{sr} - \phi_{sr} / 2 = 144 \text{ mm}$

$K = M / (d^2 \times f_{ck}) = 0.021$

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

$K' = 0.207$

$K' > K$ - No compression reinforcement is required

Lever arm

$z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_c))^{0.5}, 0.95) \times d = 137 \text{ mm}$

Depth of neutral axis

$x = 2.5 \times (d - z) = 18 \text{ mm}$

Area of tension reinforcement required

$A_{sr, req} = M / (f_{yd} \times z) = 216 \text{ mm}^2/\text{m}$

Tension reinforcement provided

12 dia.bars @ 200 c/c

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Area of tension reinforcement provided

$$A_{sr,prov} = \pi \times \phi_{sr}^2 / (4 \times s_{sr}) = \mathbf{565 \text{ mm}^2/m}$$

Minimum area of reinforcement - exp.9.1N

$$A_{sr,min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = \mathbf{217 \text{ mm}^2/m}$$

Maximum area of reinforcement - cl.9.2.1.1(3)

$$A_{sr,max} = 0.04 \times h = \mathbf{8000 \text{ mm}^2/m}$$

$$\max(A_{sr,req}, A_{sr,min}) / A_{sr,prov} = \mathbf{0.384}$$

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

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

Required tension reinforcement ratio

$$\rho = A_{sr,req} / d = \mathbf{0.002}$$

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

$$\min(K_s \times K_b \times [11 + 1.5 \times \sqrt{(f_{ck} / 1 \text{ N/mm}^2)} \times \rho_0 / \rho + 3.2 \times \sqrt{(f_{ck} / 1 \text{ N/mm}^2)} \times (\rho_0 / \rho - 1)^{3/2}], 40 \times K_b) = \mathbf{16}$$

Actual span to depth ratio

$$h_{stem} / d = \mathbf{11.8}$$

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

Crack control - Section 7.3

Limiting crack width

$$w_{max} = \mathbf{0.3 \text{ mm}}$$

Variable load factor - EN1990 – Table A1.1

$$\psi_2 = \mathbf{0.6}$$

Serviceability bending moment

$$M_{sls} = \mathbf{7.3 \text{ kNm/m}}$$

Tensile stress in reinforcement

$$\sigma_s = M_{sls} / (A_{sr,prov} \times z) = \mathbf{94.9 \text{ N/mm}^2}$$

Load duration

Long term

Load duration factor

$$k_t = \mathbf{0.4}$$

Effective area of concrete in tension

$$A_{c,eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$$

$$A_{c,eff} = \mathbf{60667 \text{ mm}^2/m}$$

Mean value of concrete tensile strength

$$f_{ct,eff} = f_{ctm} = \mathbf{2.9 \text{ N/mm}^2}$$

Reinforcement ratio

$$\rho_{p,eff} = A_{sr,prov} / A_{c,eff} = \mathbf{0.009}$$

Modular ratio

$$\alpha_e = E_s / E_{cm} = \mathbf{6.091}$$

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

$$s_{r,max} = k_3 \times C_{sr} + k_1 \times k_2 \times k_4 \times \phi_{sr} / \rho_{p,eff} = \mathbf{389 \text{ mm}}$$

Maximum crack width - exp.7.8

$$w_k = s_{r,max} \times \max(\sigma_s - k_t \times (f_{ct,eff} / \rho_{p,eff}) \times (1 + \alpha_e \times \rho_{p,eff}), 0.6 \times \sigma_s) / E_s$$

$$w_k = \mathbf{0.111 \text{ mm}}$$

$$w_k / w_{max} = \mathbf{0.369}$$

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force

$$V = \mathbf{20.1 \text{ kN/m}}$$

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

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

Longitudinal reinforcement ratio

$$\rho_l = \min(A_{sr,prov} / d, 0.02) = \mathbf{0.004}$$

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

Design shear resistance - exp.6.2a & 6.2b

$$V_{Rd,c} = \max(C_{Rd,c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$$

$$V_{Rd,c} = \mathbf{78.6 \text{ kN/m}}$$

$$V / V_{Rd,c} = \mathbf{0.256}$$

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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) $A_{sx.req} = \max(0.25 \times A_{sr.prov}, 0.001 \times t_{stem}) = 200 \text{ mm}^2/\text{m}$
Maximum spacing of reinforcement – cl.9.6.3(2) $s_{sx.max} = 400 \text{ mm}$
Transverse reinforcement provided 10 dia.bars @ 200 c/c
Area of transverse reinforcement provided $A_{sx.prov} = \pi \times \phi_{sx}^2 / (4 \times s_{sx}) = 393 \text{ mm}^2/\text{m}$

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

Check base design at toe

Depth of section $h = 200 \text{ mm}$

Rectangular section in flexure - Section 6.1

Design bending moment combination 2 $M = 16 \text{ kNm/m}$
Depth to tension reinforcement $d = h - c_{bb} - \phi_{bb} / 2 = 119 \text{ mm}$
 $K = M / (d^2 \times f_{ck}) = 0.038$
 $K' = (2 \times \eta \times \alpha_{cc} / \gamma_c) \times (1 - \lambda \times (\delta - K_1) / (2 \times K_2)) \times (\lambda \times (\delta - K_1) / (2 \times K_2))$
 $K' = 0.207$

K' > K - No compression reinforcement is required

Lever arm $z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_c))^{0.5}, 0.95) \times d = 113 \text{ mm}$
Depth of neutral axis $x = 2.5 \times (d - z) = 15 \text{ mm}$
Area of tension reinforcement required $A_{bb.req} = M / (f_{yd} \times z) = 326 \text{ mm}^2/\text{m}$
Tension reinforcement provided 12 dia.bars @ 200 c/c
Area of tension reinforcement provided $A_{bb.prov} = \pi \times \phi_{bb}^2 / (4 \times s_{bb}) = 565 \text{ mm}^2/\text{m}$
Minimum area of reinforcement - exp.9.1N $A_{bb.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = 179 \text{ mm}^2/\text{m}$
Maximum area of reinforcement - cl.9.2.1.1(3) $A_{bb.max} = 0.04 \times h = 8000 \text{ mm}^2/\text{m}$
 $\max(A_{bb.req}, A_{bb.min}) / A_{bb.prov} = 0.576$

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 $w_{max} = 0.3 \text{ mm}$
Variable load factor - EN1990 – Table A1.1 $\psi_2 = 0.6$
Serviceability bending moment $M_{sls} = 11.3 \text{ kNm/m}$
Tensile stress in reinforcement $\sigma_s = M_{sls} / (A_{bb.prov} \times z) = 176 \text{ N/mm}^2$
Load duration Long term
Load duration factor $k_t = 0.4$
Effective area of concrete in tension $A_{c.eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$
 $A_{c.eff} = 61708 \text{ mm}^2/\text{m}$
Mean value of concrete tensile strength $f_{ct.eff} = f_{ctm} = 2.9 \text{ N/mm}^2$
Reinforcement ratio $\rho_{p.eff} = A_{bb.prov} / A_{c.eff} = 0.009$
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 $s_{r.max} = k_3 \times c_{bb} + k_1 \times k_2 \times k_4 \times \phi_{bb} / \rho_{p.eff} = 478 \text{ mm}$
Maximum crack width - exp.7.8 $w_k = s_{r.max} \times \max(\sigma_s - k_t \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_e \times \rho_{p.eff}), 0.6 \times \sigma_s) / E_s$
 $w_k = 0.252 \text{ mm}$
 $w_k / w_{max} = 0.841$

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PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force

$$V = 15.2 \text{ kN/m}$$

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

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

Longitudinal reinforcement ratio

$$\rho_l = \min(A_{bb,prov} / d, 0.02) = 0.005$$

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

Design shear resistance - exp.6.2a & 6.2b

$$V_{Rd,c} = \max(C_{Rd,c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$$

$$V_{Rd,c} = 69.3 \text{ kN/m}$$

$$V / V_{Rd,c} = 0.219$$

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)

$$A_{bx,req} = 0.2 \times A_{bb,prov} = 113 \text{ mm}^2/\text{m}$$

Maximum spacing of reinforcement – cl.9.3.1.1(3)

$$s_{bx,max} = 450 \text{ mm}$$

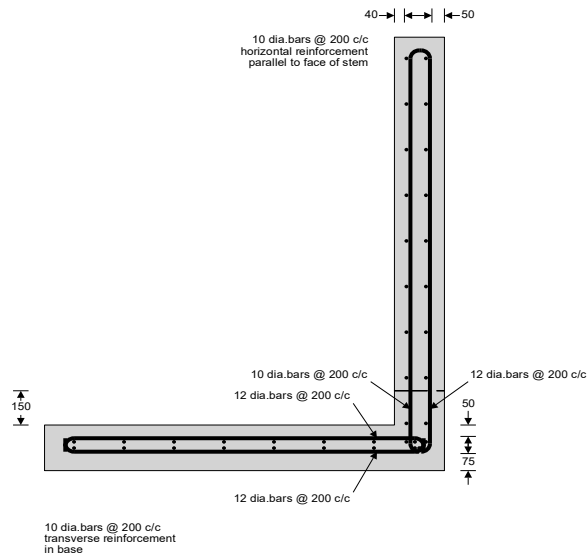
Transverse reinforcement provided

$$10 \text{ dia.bars @ } 200 \text{ c/c}$$

Area of transverse reinforcement provided

$$A_{bx,prov} = \pi \times \phi_{bx}^2 / (4 \times s_{bx}) = 393 \text{ mm}^2/\text{m}$$

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



Reinforcement details