

Project 29 Bryn Llewelyn, Alltwn				Job no.	
Calcs for GARDEN RETAINING WALL				Start page no./Revision 1	
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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 2.9.25

Analysis summary

Design summary

Overall design utilisation 0.84
Overall design status Pass

Description	Unit	Capacity	Applied	F o S	Result
Sliding stability	kN/m	22.2	18.6	1.190	PASS
Overtuning stability	kNm/m	64.1	18.2	3.521	PASS
Bearing pressure	kN/m ²	200	70.3	2.845	PASS

Retaining wall details

Stem type Cantilever with stepped rear face
Stem height $h_{\text{stem}} = 2250$ mm
Number of steps $N_{\text{steps}} = 4$
Height of step 1 $h_{s1} = 675$ mm
Thickness of step 1 $t_{s1} = 900$ mm
Height of step 2 $h_{s2} = 675$ mm
Thickness of step 2 $t_{s2} = 675$ mm
Height of step 3 $h_{s3} = 450$ mm
Thickness of step 3 $t_{s3} = 450$ mm
Height of step 4 $h_{s4} = 450$ mm
Thickness of step 4 $t_{s4} = 225$ mm
Angle to rear face of stem $\alpha = 90$ deg
Stem density $\gamma_{\text{stem}} = 25$ kN/m³
Toe length $l_{\text{toe}} = 300$ mm
Heel length $l_{\text{heel}} = 300$ mm
Base thickness $t_{\text{base}} = 350$ mm
Base density $\gamma_{\text{base}} = 25$ kN/m³
Height of retained soil $h_{\text{ret}} = 1950$ mm
Angle of soil surface $\beta = 0$ deg
Depth of cover $d_{\text{cover}} = 300$ mm

Retained soil properties

Soil type Very dense gravel
Moist density $\gamma_{\text{mr}} = 18$ kN/m³
Saturated density $\gamma_{\text{sr}} = 21$ kN/m³
Characteristic effective shear resistance angle $\phi'_{r,k} = 42$ deg
Characteristic wall friction angle $\delta_{r,k} = 21$ deg

Base soil properties

Soil type Stiff or hard glacial clay
Soil density $\gamma_b = 21$ kN/m³
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 $P_{\text{bearing}} = 200$ kN/m²

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Loading details

Permanent surcharge load

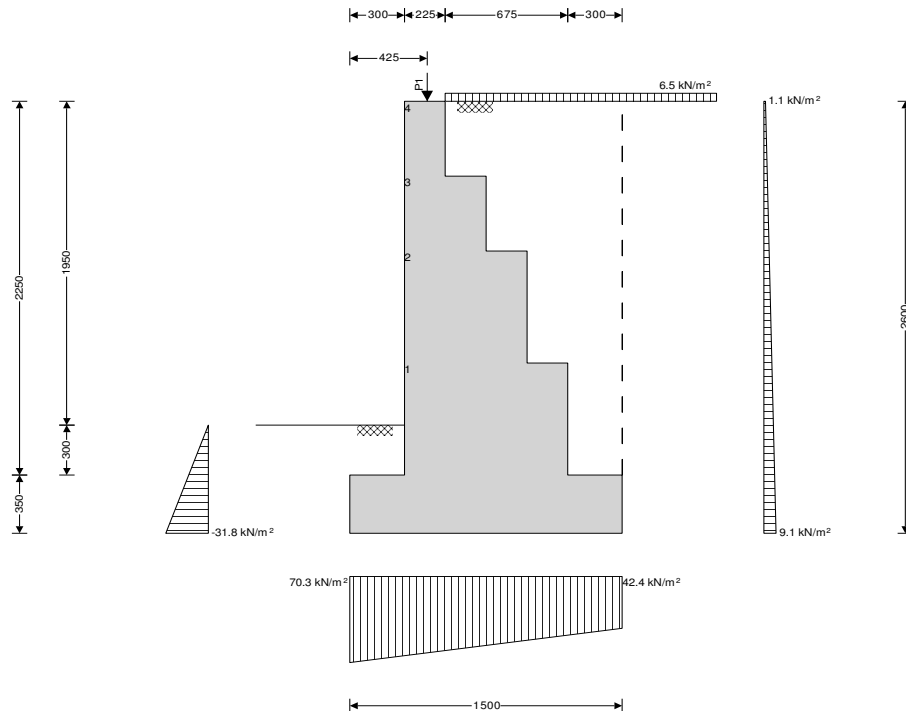
Variable surcharge load

Vertical line load at 425 mm

$$\text{Surcharge}_G = 1.5 \text{ kN/m}^2$$

$$\text{Surcharge}_Q = 5 \text{ kN/m}^2$$

$$P_{G1} = 5 \text{ kN/m}$$



General arrangement - sketch pressures relate to bearing check

Calculate retaining wall geometry

Base length

Moist soil height

Length of surcharge load

- Distance to vertical component

Effective height of wall

- Distance to horizontal component

Area of wall stem

- Distance to vertical component

Area of wall base

- Distance to vertical component

Area of moist soil

- Distance to vertical component

$$l_{base} = l_{toe} + t_{s1} + l_{heel} = 1500 \text{ mm}$$

$$h_{moist} = h_{soil} = 2250 \text{ mm}$$

$$l_{sur} = (l_{heel} + t_{s1} - t_{s4}) = 975 \text{ mm}$$

$$X_{sur_v} = l_{base} - (l_{heel} + t_{s1} - t_{s4}) / 2 = 1012 \text{ mm}$$

$$h_{eff} = h_{base} + d_{cover} + h_{ret} = 2600 \text{ mm}$$

$$X_{sur_h} = h_{eff} / 2 = 1300 \text{ mm}$$

$$A_{stem} = h_{s1} \times t_{s1} + h_{s2} \times t_{s2} + h_{s3} \times t_{s3} + h_{s4} \times t_{s4} = 1.367 \text{ m}^2$$

$$X_{stem} = l_{base} - (h_{s1} \times t_{s1} \times (l_{heel} + t_{s1} - t_{s1} / 2) + h_{s2} \times t_{s2} \times (l_{heel} + t_{s1} - t_{s2} / 2) + h_{s3} \times t_{s3} \times (l_{heel} + t_{s1} - t_{s3} / 2) + h_{s4} \times t_{s4} \times (l_{heel} + t_{s1} - t_{s4} / 2)) / A_{stem} = 654 \text{ mm}$$

$$A_{base} = l_{base} \times t_{base} = 0.525 \text{ m}^2$$

$$X_{base} = l_{base} / 2 = 750 \text{ mm}$$

$$A_{moist} = l_{heel} \times h_{s1} + (l_{heel} + t_{s1} - t_{s2}) \times h_{s2} + (l_{heel} + t_{s1} - t_{s3}) \times h_{s3} + (l_{heel} + t_{s1} - t_{s4}) \times h_{s4} = 1.333 \text{ m}^2$$

$$X_{moist_v} = l_{base} - (l_{heel} \times h_{s1} \times l_{heel} / 2 + (l_{heel} + t_{s1} - t_{s2}) \times h_{s2} \times (l_{heel} + t_{s1} - t_{s2}) / 2 + (l_{heel} + t_{s1} - t_{s3}) \times h_{s3} \times (l_{heel} + t_{s1} - t_{s3}) / 2 + (l_{heel} + t_{s1} - t_{s4}) \times h_{s4} \times (l_{heel} + t_{s1} - t_{s4}) / 2) / A_{moist} = 1152 \text{ mm}$$

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- Distance to horizontal component

Area of base soil

- Distance to vertical component

- Distance to horizontal component

Area of excavated base soil

- Distance to vertical component

- Distance to horizontal component

$$X_{moist_h} = h_{eff} / 3 = \mathbf{867 \text{ mm}}$$

$$A_{pass} = d_{cover} \times l_{toe} = \mathbf{0.09 \text{ m}^2}$$

$$X_{pass_v} = l_{base} - (d_{cover} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{pass} = \mathbf{150 \text{ mm}}$$

$$X_{pass_h} = (d_{cover} + h_{base}) / 3 = \mathbf{217 \text{ mm}}$$

$$A_{exc} = h_{pass} \times l_{toe} = \mathbf{0.09 \text{ m}^2}$$

$$X_{exc_v} = l_{base} - (h_{pass} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{exc} = \mathbf{150 \text{ mm}}$$

$$X_{exc_h} = (h_{pass} + h_{base}) / 3 = \mathbf{217 \text{ mm}}$$

Using Coulomb theory

Active pressure coefficient

$$K_A = \sin(\alpha + \phi'_{r,k})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,k}) \times [1 + \sqrt{[\sin(\phi'_{r,k} + \delta_{r,k}) \times \sin(\phi'_{r,k} - \beta) / (\sin(\alpha - \delta_{r,k}) \times \sin(\alpha + \beta))]}])^2 = \mathbf{0.183}$$

Passive pressure coefficient

$$K_P = \sin(90 - \phi'_{b,k})^2 / (\sin(90 + \delta_{b,k}) \times [1 - \sqrt{[\sin(\phi'_{b,k} + \delta_{b,k}) \times \sin(\phi'_{b,k} / (\sin(90 + \delta_{b,k}))]}])^2 = \mathbf{2.359}$$

Bearing pressure check

Vertical forces on wall

Wall stem

$$F_{stem} = A_{stem} \times \gamma_{stem} = \mathbf{34.2 \text{ kN/m}}$$

Wall base

$$F_{base} = A_{base} \times \gamma_{base} = \mathbf{13.1 \text{ kN/m}}$$

Surcharge load

$$F_{sur_v} = (Surcharge_G + Surcharge_Q) \times (l_{heel} + t_{s1} - t_{s4}) = \mathbf{6.3 \text{ kN/m}}$$

Line loads

$$F_{P_v} = P_{G1} = \mathbf{5 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_v} = A_{moist} \times \gamma_{mr} = \mathbf{24 \text{ kN/m}}$$

Base soil

$$F_{pass_v} = A_{pass} \times \gamma_b = \mathbf{1.9 \text{ kN/m}}$$

Total

$$F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{P_v} + F_{moist_v} + F_{pass_v} = \mathbf{84.5 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{sur_h} = K_A \times \cos(\delta_{r,k}) \times (Surcharge_G + Surcharge_Q) \times h_{eff} = \mathbf{2.9 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_h} = K_A \times \cos(\delta_{r,k}) \times \gamma_{mr} \times h_{eff}^2 / 2 = \mathbf{10.4 \text{ kN/m}}$$

Base soil

$$F_{pass_h} = -K_P \times \cos(\delta_{b,k}) \times \gamma_b \times (d_{cover} + h_{base})^2 / 2 = \mathbf{-10.3 \text{ kN/m}}$$

Total

$$F_{total_h} = \max(F_{sur_h} + F_{moist_h} + F_{pass_h} - F_{total_v} \times \tan(\delta_{bb,k}), 0 \text{ kN/m}) = \mathbf{0 \text{ kN/m}}$$

Moments on wall

Wall stem

$$M_{stem} = F_{stem} \times X_{stem} = \mathbf{22.4 \text{ kNm/m}}$$

Wall base

$$M_{base} = F_{base} \times X_{base} = \mathbf{9.8 \text{ kNm/m}}$$

Surcharge load

$$M_{sur} = F_{sur_v} \times X_{sur_v} - F_{sur_h} \times X_{sur_h} = \mathbf{2.7 \text{ kNm/m}}$$

Line loads

$$M_P = P_{G1} \times p_1 = \mathbf{2.1 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist} = F_{moist_v} \times X_{moist_v} - F_{moist_h} \times X_{moist_h} = \mathbf{18.6 \text{ kNm/m}}$$

Base soil

$$M_{pass} = F_{pass_v} \times X_{pass_v} - F_{pass_h} \times X_{pass_h} = \mathbf{2.5 \text{ kNm/m}}$$

Total

$$M_{total} = M_{stem} + M_{base} + M_{sur} + M_P + M_{moist} + M_{pass} = \mathbf{58.2 \text{ kNm/m}}$$

Check bearing pressure

Distance to reaction

$$\bar{x} = M_{total} / F_{total_v} = \mathbf{688 \text{ mm}}$$

Eccentricity of reaction

$$e = \bar{x} - l_{base} / 2 = \mathbf{-62 \text{ mm}}$$

Loaded length of base

$$l_{load} = l_{base} = \mathbf{1500 \text{ mm}}$$

Bearing pressure at toe

$$q_{toe} = F_{total_v} / l_{base} \times (1 - 6 \times e / l_{base}) = \mathbf{70.3 \text{ kN/m}^2}$$

Bearing pressure at heel

$$q_{heel} = F_{total_v} / l_{base} \times (1 + 6 \times e / l_{base}) = \mathbf{42.4 \text{ kN/m}^2}$$

Factor of safety

$$FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel}) = \mathbf{2.845}$$

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

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Design approach 1

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

Partial factor set	A1
Permanent unfavourable action	$\gamma_G = 1.350$
Permanent favourable action	$\gamma_{Gf} = 1.000$
Variable unfavourable action	$\gamma_Q = 1.500$
Variable favourable action	$\gamma_{Qf} = 0.000$

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	$\gamma_\gamma = 1.00$

Retained soil properties

Design moist density	$\gamma_{mr}' = \gamma_{mr} / \gamma_\gamma = 18 \text{ kN/m}^3$
Design saturated density	$\gamma_{sr}' = \gamma_{sr} / \gamma_\gamma = 21 \text{ kN/m}^3$
Design effective shear resistance angle	$\phi'_{r,d} = \text{atan}(\tan(\phi'_{r,k}) / \gamma_{\phi'}) = 42 \text{ deg}$
Design wall friction angle	$\delta_{r,d} = \text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}) = 21 \text{ deg}$

Base soil properties

Design soil density	$\gamma_b' = \gamma_b / \gamma_\gamma = 21 \text{ kN/m}^3$
Design effective shear resistance angle	$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_{\phi'}) = 18 \text{ deg}$
Design wall friction angle	$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_{\phi'}) = 9 \text{ deg}$
Design base friction angle	$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_{\phi'}) = 12 \text{ deg}$
Design effective cohesion	$c'_{b,d} = c'_{b,k} / \gamma_{c'} = 0 \text{ kN/m}^2$

Using Coulomb theory

Active pressure coefficient	$K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times [1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))}]^2) = 0.183$
Passive pressure coefficient	$K_P = \sin(90 - \phi'_{b,d})^2 / (\sin(90 + \delta_{b,d}) \times [1 - \sqrt{(\sin(\phi'_{b,d} + \delta_{b,d}) \times \sin(\phi'_{b,d} - \beta) / (\sin(90 + \delta_{b,d}))}]^2) = 2.359$

Sliding check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = 34.2 \text{ kN/m}$
Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = 13.1 \text{ kN/m}$
Surcharge load	$F_{sur_v} = (\gamma_{Gf} \times \text{Surcharge}_G + \gamma_{Qf} \times \text{Surcharge}_Q) \times (l_{heel} + t_{s1} - t_{s4}) = 1.5 \text{ kN/m}$
Line loads	$F_{P_v} = \gamma_{Gf} \times P_{G1} = 5 \text{ kN/m}$
Moist retained soil	$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' = 24 \text{ kN/m}$
Base soil	$F_{exc_v} = \gamma_{Gf} \times A_{exc} \times \gamma_b' = 1.9 \text{ kN/m}$
Total	$F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{P_v} + F_{moist_v} + F_{exc_v} = 79.6 \text{ kN/m}$

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \cos(\delta_{r,d}) \times (\gamma_G \times \text{Surcharge}_G + \gamma_Q \times \text{Surcharge}_Q) \times h_{eff} = 4.2 \text{ kN/m}$
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 = 14 \text{ kN/m}$

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Total

$$F_{total_h} = F_{sur_h} + F_{moist_h} = \mathbf{18.2 \text{ kN/m}}$$

Check stability against sliding

Base soil resistance

$$F_{exc_h} = \gamma_{Gf} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = \mathbf{10.3 \text{ kN/m}}$$

Base friction

$$F_{friction} = F_{total_v} \times \tan(\delta_{bb,d}) = \mathbf{16.9 \text{ kN/m}}$$

Resistance to sliding

$$F_{rest} = F_{exc_h} + F_{friction} = \mathbf{27.3 \text{ kN/m}}$$

Factor of safety

$$FoS_{sl} = F_{rest} / F_{total_h} = \mathbf{1.495}$$

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem

$$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = \mathbf{34.2 \text{ kN/m}}$$

Wall base

$$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = \mathbf{13.1 \text{ kN/m}}$$

Surcharge load

$$F_{sur_v} = (\gamma_{Gf} \times \text{Surcharge}_G + \gamma_{Qf} \times \text{Surcharge}_Q) \times (l_{heel} + t_{s1} - t_{s4}) = \mathbf{1.5 \text{ kN/m}}$$

Line loads

$$F_{P_v} = \gamma_{Gf} \times P_{G1} = \mathbf{5 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' = \mathbf{24 \text{ kN/m}}$$

Base soil

$$F_{exc_v} = \gamma_{Gf} \times A_{exc} \times \gamma_b' = \mathbf{1.9 \text{ kN/m}}$$

Total

$$F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{P_v} + F_{moist_v} + F_{exc_v} = \mathbf{79.6 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{sur_h} = K_A \times \cos(\delta_{r,d}) \times (\gamma_G \times \text{Surcharge}_G + \gamma_Q \times \text{Surcharge}_Q) \times h_{eff} = \mathbf{4.2 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 = \mathbf{14 \text{ kN/m}}$$

Base soil

$$F_{exc_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = \mathbf{-10.3 \text{ kN/m}}$$

Total

$$F_{total_h} = F_{sur_h} + F_{moist_h} + F_{exc_h} = \mathbf{7.9 \text{ kN/m}}$$

Overturning moments on wall

Surcharge load

$$M_{sur_OT} = F_{sur_h} \times X_{sur_h} = \mathbf{5.5 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist_OT} = F_{moist_h} \times X_{moist_h} = \mathbf{12.1 \text{ kNm/m}}$$

Total

$$M_{total_OT} = M_{sur_OT} + M_{moist_OT} = \mathbf{17.6 \text{ kNm/m}}$$

Restoring moments on wall

Wall stem

$$M_{stem_R} = F_{stem} \times X_{stem} = \mathbf{22.4 \text{ kNm/m}}$$

Wall base

$$M_{base_R} = F_{base} \times X_{base} = \mathbf{9.8 \text{ kNm/m}}$$

Line loads

$$M_{P_R} = \text{abs}(\gamma_{Gf} \times P_{G1}) \times p_1 = \mathbf{2.1 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist_R} = F_{moist_v} \times X_{moist_v} = \mathbf{27.6 \text{ kNm/m}}$$

Base soil

$$M_{exc_R} = F_{exc_v} \times X_{exc_v} - F_{exc_h} \times X_{exc_h} = \mathbf{2.5 \text{ kNm/m}}$$

Total

$$M_{total_R} = M_{stem_R} + M_{base_R} + M_{P_R} + M_{moist_R} + M_{exc_R} = \mathbf{64.5 \text{ kNm/m}}$$

Check stability against overturning

Factor of safety

$$FoS_{ot} = M_{total_R} / M_{total_OT} = \mathbf{3.656}$$

PASS - Maximum restoring moment is greater than overturning moment

Design approach 1

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

Partial factor set

A2

Permanent unfavourable action

$$\gamma_G = \mathbf{1.000}$$

Permanent favourable action

$$\gamma_{Gf} = \mathbf{1.000}$$

Variable unfavourable action

$$\gamma_Q = \mathbf{1.300}$$

Variable favourable action

$$\gamma_{Qf} = \mathbf{0.000}$$

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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	$\gamma_{\gamma} = 1.00$

Retained soil properties

Design moist density	$\gamma_{mr}' = \gamma_{mr} / \gamma_{\gamma} = 18 \text{ kN/m}^3$
Design saturated density	$\gamma_{sr}' = \gamma_{sr} / \gamma_{\gamma} = 21 \text{ kN/m}^3$
Design effective shear resistance angle	$\phi'_{r,d} = \text{atan}(\tan(\phi'_{r,k}) / \gamma_{\phi'}) = 35.8 \text{ deg}$
Design wall friction angle	$\delta_{r,d} = \text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}) = 17.1 \text{ deg}$

Base soil properties

Design soil density	$\gamma_b' = \gamma_b / \gamma_{\gamma} = 21 \text{ kN/m}^3$
Design effective shear resistance angle	$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_{\phi'}) = 14.6 \text{ deg}$
Design wall friction angle	$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_{\phi'}) = 7.2 \text{ deg}$
Design base friction angle	$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_{\phi'}) = 9.7 \text{ deg}$
Design effective cohesion	$c'_{b,d} = c'_{b,k} / \gamma_{c'} = 0 \text{ kN/m}^2$

Using Coulomb theory

Active pressure coefficient	$K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times [1 + \sqrt{[\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))]}]^2) = 0.239$
Passive pressure coefficient	$K_P = \sin(90 - \phi'_{b,d})^2 / (\sin(90 + \delta_{b,d}) \times [1 - \sqrt{[\sin(\phi'_{b,d} + \delta_{b,d}) \times \sin(\phi'_{b,d} - \beta) / (\sin(90 + \delta_{b,d}))]}]^2) = 1.965$

Sliding check

Vertical forces on wall

Wall stem	$F_{\text{stem}} = \gamma_{Gf} \times A_{\text{stem}} \times \gamma_{\text{stem}} = 34.2 \text{ kN/m}$
Wall base	$F_{\text{base}} = \gamma_{Gf} \times A_{\text{base}} \times \gamma_{\text{base}} = 13.1 \text{ kN/m}$
Surcharge load	$F_{\text{sur}_v} = (\gamma_{Gf} \times \text{Surcharge}_G + \gamma_{Qf} \times \text{Surcharge}_Q) \times (l_{\text{heel}} + t_{s1} - t_{s4}) = 1.5 \text{ kN/m}$
Line loads	$F_{P_v} = \gamma_{Gf} \times P_{G1} = 5 \text{ kN/m}$
Moist retained soil	$F_{\text{moist}_v} = \gamma_{Gf} \times A_{\text{moist}} \times \gamma_{mr}' = 24 \text{ kN/m}$
Base soil	$F_{\text{exc}_v} = \gamma_{Gf} \times A_{\text{exc}} \times \gamma_b' = 1.9 \text{ kN/m}$
Total	$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{sur}_v} + F_{P_v} + F_{\text{moist}_v} + F_{\text{exc}_v} = 79.6 \text{ kN/m}$

Horizontal forces on wall

Surcharge load	$F_{\text{sur}_h} = K_A \times \cos(\delta_{r,d}) \times (\gamma_G \times \text{Surcharge}_G + \gamma_Q \times \text{Surcharge}_Q) \times h_{\text{eff}} = 4.7 \text{ kN/m}$
Moist retained soil	$F_{\text{moist}_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{mr}' \times h_{\text{eff}}^2 / 2 = 13.9 \text{ kN/m}$
Total	$F_{\text{total}_h} = F_{\text{sur}_h} + F_{\text{moist}_h} = 18.6 \text{ kN/m}$

Check stability against sliding

Base soil resistance	$F_{\text{exc}_h} = \gamma_{Gf} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (h_{\text{pass}} + h_{\text{base}})^2 / 2 = 8.6 \text{ kN/m}$
Base friction	$F_{\text{friction}} = F_{\text{total}_v} \times \tan(\delta_{bb,d}) = 13.5 \text{ kN/m}$
Resistance to sliding	$F_{\text{rest}} = F_{\text{exc}_h} + F_{\text{friction}} = 22.2 \text{ kN/m}$
Factor of safety	$F_{\text{Ossl}} = F_{\text{rest}} / F_{\text{total}_h} = 1.19$

PASS - Resistance to sliding is greater than sliding force

Project 29 Bryn Llewelyn, Alltwn				Job no.	
Calcs for GARDEN RETAINING WALL				Start page no./Revision 7	
Calcs by CM	Calcs date 14/01/2026	Checked by	Checked date	Approved by	Approved date

Overturning check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = \gamma_{\text{Gf}} \times A_{\text{stem}} \times \gamma_{\text{stem}} = \mathbf{34.2 \text{ kN/m}}$$

Wall base

$$F_{\text{base}} = \gamma_{\text{Gf}} \times A_{\text{base}} \times \gamma_{\text{base}} = \mathbf{13.1 \text{ kN/m}}$$

Surcharge load

$$F_{\text{sur}_v} = (\gamma_{\text{Gf}} \times \text{Surcharge}_G + \gamma_{\text{Gf}} \times \text{Surcharge}_Q) \times (l_{\text{heel}} + t_{s1} - t_{s4}) = \mathbf{1.5 \text{ kN/m}}$$

Line loads

$$F_{P_v} = \gamma_{\text{Gf}} \times P_{G1} = \mathbf{5 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_v} = \gamma_{\text{Gf}} \times A_{\text{moist}} \times \gamma_{\text{mr}}' = \mathbf{24 \text{ kN/m}}$$

Base soil

$$F_{\text{exc}_v} = \gamma_{\text{Gf}} \times A_{\text{exc}} \times \gamma_b' = \mathbf{1.9 \text{ kN/m}}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{sur}_v} + F_{P_v} + F_{\text{moist}_v} + F_{\text{exc}_v} = \mathbf{79.6 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_A \times \cos(\delta_{r,d}) \times (\gamma_G \times \text{Surcharge}_G + \gamma_Q \times \text{Surcharge}_Q) \times h_{\text{eff}} = \mathbf{4.7 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{\text{mr}}' \times h_{\text{eff}}^2 / 2 = \mathbf{13.9 \text{ kN/m}}$$

Base soil

$$F_{\text{exc}_h} = -\gamma_{\text{Gf}} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (h_{\text{pass}} + h_{\text{base}})^2 / 2 = \mathbf{-8.6 \text{ kN/m}}$$

Total

$$F_{\text{total}_h} = F_{\text{sur}_h} + F_{\text{moist}_h} + F_{\text{exc}_h} = \mathbf{10 \text{ kN/m}}$$

Overturning moments on wall

Surcharge load

$$M_{\text{sur}_OT} = F_{\text{sur}_h} \times X_{\text{sur}_h} = \mathbf{6.2 \text{ kNm/m}}$$

Moist retained soil

$$M_{\text{moist}_OT} = F_{\text{moist}_h} \times X_{\text{moist}_h} = \mathbf{12 \text{ kNm/m}}$$

Total

$$M_{\text{total}_OT} = M_{\text{sur}_OT} + M_{\text{moist}_OT} = \mathbf{18.2 \text{ kNm/m}}$$

Restoring moments on wall

Wall stem

$$M_{\text{stem}_R} = F_{\text{stem}} \times X_{\text{stem}} = \mathbf{22.4 \text{ kNm/m}}$$

Wall base

$$M_{\text{base}_R} = F_{\text{base}} \times X_{\text{base}} = \mathbf{9.8 \text{ kNm/m}}$$

Line loads

$$M_{P_R} = \text{abs}(\gamma_{\text{Gf}} \times P_{G1}) \times p_1 = \mathbf{2.1 \text{ kNm/m}}$$

Moist retained soil

$$M_{\text{moist}_R} = F_{\text{moist}_v} \times X_{\text{moist}_v} = \mathbf{27.6 \text{ kNm/m}}$$

Base soil

$$M_{\text{exc}_R} = F_{\text{exc}_v} \times X_{\text{exc}_v} - F_{\text{exc}_h} \times X_{\text{exc}_h} = \mathbf{2.2 \text{ kNm/m}}$$

Total

$$M_{\text{total}_R} = M_{\text{stem}_R} + M_{\text{base}_R} + M_{P_R} + M_{\text{moist}_R} + M_{\text{exc}_R} = \mathbf{64.1 \text{ kNm/m}}$$

Check stability against overturning

Factor of safety

$$FoS_{ot} = M_{\text{total}_R} / M_{\text{total}_OT} = \mathbf{3.521}$$

PASS - Maximum restoring moment is greater than overturning moment