



Cwm Planning & Design Ltd.
(Civil, Structural & Architectural)

STRUCTURAL CALCULATIONS

**Garden Retaining wall
(Supporting car parking space)**

at:

**85 Alltwen Hill
Alltwen
Pontardawe**

Date: 8th April 2019

BRIEF:

- 1) Produce Design Calculations and retaining wall specification for a proposed retaining wall at 85 Alltwen Hill, Alltwen. The wall is to support an elevated car parking space above the rear garden.

REFERENCES:

TEDDS structural computer package.

DESIGN LOADINGS:

Refer to structural calculations attached.

Assumed height taken as **2.7m** (2.3m + 400mm cover to front)

Surcharge acting on wall = **10kN/m²**

**RETAINING WALL
DESIGN CALCULATIONS**



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Project Mr. S. Rees, Alltwen Hill, Alltwen				Job no.	
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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 2.9.04

Retaining wall details

Stem type	Cantilever with stepped rear face
Stem height	$h_{\text{stem}} = 2700 \text{ mm}$
Number of steps	$N_{\text{steps}} = 5$
Height of step 1	$h_{s1} = 675 \text{ mm}$
Thickness of step 1	$t_{s1} = 1125 \text{ mm}$
Height of step 2	$h_{s2} = 675 \text{ mm}$
Thickness of step 2	$t_{s2} = 900 \text{ mm}$
Height of step 3	$h_{s3} = 450 \text{ mm}$
Thickness of step 3	$t_{s3} = 675 \text{ mm}$
Height of step 4	$h_{s4} = 450 \text{ mm}$
Thickness of step 4	$t_{s4} = 450 \text{ mm}$
Height of step 5	$h_{s5} = 450 \text{ mm}$
Thickness of step 5	$t_{s5} = 215 \text{ mm}$
Angle to rear face of stem	$\alpha = 90 \text{ deg}$
Stem density	$\gamma_{\text{stem}} = 25 \text{ kN/m}^3$
Toe length	$l_{\text{toe}} = 300 \text{ mm}$
Heel length	$l_{\text{heel}} = 250 \text{ mm}$
Base thickness	$t_{\text{base}} = 300 \text{ mm}$
Base density	$\gamma_{\text{base}} = 25 \text{ kN/m}^3$
Height of retained soil	$h_{\text{ret}} = 2300 \text{ mm}$
Angle of soil surface	$\beta = 0 \text{ deg}$
Depth of cover	$d_{\text{cover}} = 400 \text{ mm}$

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	$\phi'_{r,k} = 30 \text{ deg}$
Characteristic wall friction angle	$\delta_{r,k} = 0 \text{ deg}$

Base soil properties

Soil type	Medium dense well graded sand
Soil density	$\gamma_b = 18 \text{ kN/m}^3$
Characteristic effective shear resistance angle	$\phi'_{b,k} = 30 \text{ deg}$
Characteristic wall friction angle	$\delta_{b,k} = 15 \text{ deg}$
Characteristic base friction angle	$\delta_{bb,k} = 30 \text{ deg}$
Presumed bearing capacity	$P_{\text{bearing}} = 200 \text{ kN/m}^2$

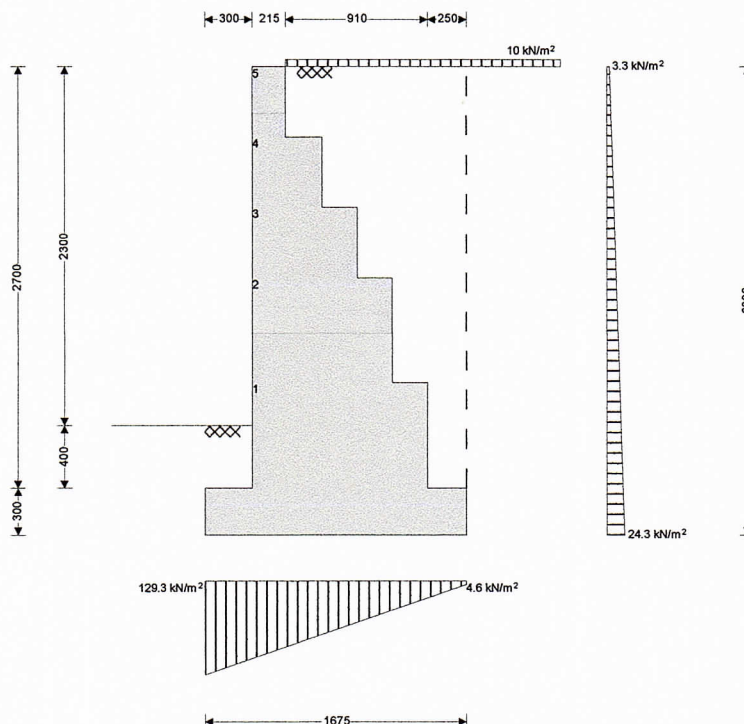
Loading details

Variable surcharge load	Surcharge _Q = 10 kN/m ²
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General arrangement

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

- Distance to horizontal component

Area of base soil

$$l_{base} = l_{toe} + t_{s1} + l_{heel} = 1675 \text{ mm}$$

$$h_{moist} = h_{soil} = 2700 \text{ mm}$$

$$l_{sur} = (l_{heel} + t_{s1} - t_{s5}) = 1160 \text{ mm}$$

$$x_{sur_v} = l_{base} - (l_{heel} + t_{s1} - t_{s5}) / 2 = 1095 \text{ mm}$$

$$h_{eff} = h_{base} + d_{cover} + h_{ret} = 3000 \text{ mm}$$

$$x_{sur_h} = h_{eff} / 2 = 1500 \text{ mm}$$

$$A_{stem} = h_{s1} \times t_{s1} + h_{s2} \times t_{s2} + h_{s3} \times t_{s3} + h_{s4} \times t_{s4} + h_{s5} \times t_{s5} = 1.97 \text{ m}^2$$

$$x_{stem} = l_{base} - (h_{s1} \times t_{s1} \times (l_{heel} + t_{s1} - t_{s1} / 2) + h_{s2} \times t_{s2} \times (l_{heel} + t_{s1} - t_{s2} / 2) + h_{s3} \times t_{s3} \times (l_{heel} + t_{s1} - t_{s3} / 2) + h_{s4} \times t_{s4} \times (l_{heel} + t_{s1} - t_{s4} / 2) + h_{s5} \times t_{s5} \times (l_{heel} + t_{s1} - t_{s5} / 2)) / A_{stem} = 736 \text{ mm}$$

$$A_{base} = l_{base} \times t_{base} = 0.502 \text{ m}^2$$

$$x_{base} = l_{base} / 2 = 838 \text{ mm}$$

$$A_{moist} = l_{heel} \times h_{s1} + (l_{heel} + t_{s1} - t_{s2}) \times h_{s2} + (l_{heel} + t_{s1} - t_{s3}) \times h_{s3} + (l_{heel} + t_{s1} - t_{s4}) \times h_{s4} + (l_{heel} + t_{s1} - t_{s5}) \times h_{s5} = 1.743 \text{ m}^2$$

$$x_{moist_v} = l_{base} - (l_{heel} \times h_{s1} \times l_{heel} / 2 + (l_{heel} + t_{s1} - t_{s2}) \times h_{s2} \times (l_{heel} + t_{s1} - t_{s2}) / 2 + (l_{heel} + t_{s1} - t_{s3}) \times h_{s3} \times (l_{heel} + t_{s1} - t_{s3}) / 2 + (l_{heel} + t_{s1} - t_{s4}) \times h_{s4} \times (l_{heel} + t_{s1} - t_{s4}) / 2 + (l_{heel} + t_{s1} - t_{s5}) \times h_{s5} \times (l_{heel} + t_{s1} - t_{s5}) / 2) / A_{moist} = 1272 \text{ mm}$$

$$x_{moist_h} = h_{eff} / 3 = 1000 \text{ mm}$$

$$A_{pass} = d_{cover} \times l_{toe} = 0.12 \text{ m}^2$$



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- Distance to vertical component
- Distance to horizontal component

Area of excavated base soil

- Distance to vertical component
- Distance to horizontal component

Using Coulomb theory

Active pressure coefficient

Passive pressure coefficient

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

$$X_{pass_h} = (d_{cover} + h_{base}) / 3 = \mathbf{233 \text{ mm}}$$

$$A_{exc} = h_{pass} \times l_{toe} = \mathbf{0.12 \text{ m}^2}$$

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

$$X_{exc_h} = (h_{pass} + h_{base}) / 3 = \mathbf{233 \text{ mm}}$$

$$K_A = \sin(\alpha + \phi'_{r,k})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,k}) \times [1 + \sqrt{(\sin(\phi'_{r,k} + \delta_{r,k}) \times \sin(\phi'_{r,k} - \beta)) / (\sin(\alpha - \delta_{r,k}) \times \sin(\alpha + \beta))}]^2) = \mathbf{0.333}$$

$$K_P = \sin(90 - \phi'_{b,k})^2 / (\sin(90 + \delta_{b,k}) \times [1 - \sqrt{(\sin(\phi'_{b,k} + \delta_{b,k}) \times \sin(\phi'_{b,k} - (\sin(90 + \delta_{b,k})))^2}]^2) = \mathbf{4.977}$$

Bearing pressure check

Vertical forces on wall

Wall stem

$$F_{stem} = A_{stem} \times \gamma_{stem} = \mathbf{49.2 \text{ kN/m}}$$

Wall base

$$F_{base} = A_{base} \times \gamma_{base} = \mathbf{12.6 \text{ kN/m}}$$

Surcharge load

$$F_{sur_v} = \text{Surcharge}_Q \times (l_{heel} + t_{s1} - t_{s5}) = \mathbf{11.6 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_v} = A_{moist} \times \gamma_{mr} = \mathbf{36.6 \text{ kN/m}}$$

Base soil

$$F_{pass_v} = A_{pass} \times \gamma_b = \mathbf{2.2 \text{ kN/m}}$$

Total

$$F_{total_v} = F_{stem} + F_{base} + F_{moist_v} + F_{pass_v} + F_{sur_v} = \mathbf{112.2 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{sur_h} = K_A \times \text{Surcharge}_Q \times h_{eff} = \mathbf{10 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_h} = K_A \times \gamma_{mr} \times h_{eff}^2 / 2 = \mathbf{31.5 \text{ kN/m}}$$

Base soil

$$F_{pass_h} = -K_P \times \cos(\delta_{b,k}) \times \gamma_b \times (d_{cover} + h_{base})^2 / 2 = \mathbf{-21.2 \text{ kN/m}}$$

Total

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

Moments on wall

Wall stem

$$M_{stem} = F_{stem} \times X_{stem} = \mathbf{36.2 \text{ kNm/m}}$$

Wall base

$$M_{base} = F_{base} \times X_{base} = \mathbf{10.5 \text{ kNm/m}}$$

Surcharge load

$$M_{sur} = F_{sur_v} \times X_{sur_v} - F_{sur_h} \times X_{sur_h} = \mathbf{-2.3 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist} = F_{moist_v} \times X_{moist_v} - F_{moist_h} \times X_{moist_h} = \mathbf{15 \text{ kNm/m}}$$

Base soil

$$M_{pass} = F_{pass_v} \times X_{pass_v} - F_{pass_h} \times X_{pass_h} = \mathbf{5.3 \text{ kNm/m}}$$

Total

$$M_{total} = M_{stem} + M_{base} + M_{moist} + M_{pass} + M_{sur} = \mathbf{64.8 \text{ kNm/m}}$$

Check bearing pressure

Distance to reaction

$$\bar{x} = M_{total} / F_{total_v} = \mathbf{578 \text{ mm}}$$

Eccentricity of reaction

$$e = \bar{x} - l_{base} / 2 = \mathbf{-260 \text{ mm}}$$

Loaded length of base

$$l_{load} = l_{base} = \mathbf{1675 \text{ mm}}$$

Bearing pressure at toe

$$q_{toe} = F_{total_v} / l_{base} \times (1 - 6 \times e / l_{base}) = \mathbf{129.3 \text{ kN/m}^2}$$

Bearing pressure at heel

$$q_{heel} = F_{total_v} / l_{base} \times (1 + 6 \times e / l_{base}) = \mathbf{4.6 \text{ kN/m}^2}$$

Factor of safety

$$FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel}) = \mathbf{1.547}$$

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

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

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



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Variable unfavourable action $\gamma_Q = 1.50$
Variable favourable action $\gamma_{Qf} = 0.00$

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 $\gamma_\gamma = 1.00$

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 $\gamma_b' = \gamma_b / \gamma_\gamma = 18 \text{ kN/m}^3$
Design effective shear resistance angle $\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_{\phi'}) = 30 \text{ deg}$
Design wall friction angle $\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_{\phi'}) = 15 \text{ deg}$
Design base friction angle $\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_{\phi'}) = 30 \text{ deg}$
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 $K_P = \sin(90 - \phi'_{b,d})^2 / (\sin(90 + \delta_{b,d}) \times [1 - \sqrt{[\sin(\phi'_{b,d} + \delta_{b,d}) \times \sin(\phi'_{b,d}) / (\sin(90 + \delta_{b,d}))]}]^2) = 4.977$

Sliding check

Vertical forces on wall

Wall stem $F_{\text{stem}} = \gamma_{Gf} \times A_{\text{stem}} \times \gamma_{\text{stem}} = 49.2 \text{ kN/m}$
Wall base $F_{\text{base}} = \gamma_{Gf} \times A_{\text{base}} \times \gamma_{\text{base}} = 12.6 \text{ kN/m}$
Moist retained soil $F_{\text{moist}_v} = \gamma_{Gf} \times A_{\text{moist}} \times \gamma_{mr}' = 36.6 \text{ kN/m}$
Base soil $F_{\text{exc}_v} = \gamma_{Gf} \times A_{\text{exc}} \times \gamma_b' = 2.2 \text{ kN/m}$
Total $F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{moist}_v} + F_{\text{exc}_v} = 100.6 \text{ kN/m}$

Horizontal forces on wall

Surcharge load $F_{\text{sur}_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{\text{eff}} = 15 \text{ kN/m}$
Moist retained soil $F_{\text{moist}_h} = \gamma_G \times K_A \times \gamma_{mr}' \times h_{\text{eff}}^2 / 2 = 42.5 \text{ kN/m}$
Total $F_{\text{total}_h} = F_{\text{moist}_h} + F_{\text{sur}_h} = 57.5 \text{ kN/m}$

Check stability against sliding

Base soil resistance $F_{\text{exc}_h} = \gamma_{Gf} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (h_{\text{pass}} + h_{\text{base}})^2 / 2 = 21.2 \text{ kN/m}$
Base friction $F_{\text{friction}} = F_{\text{total}_v} \times \tan(\delta_{bb,d}) = 58.1 \text{ kN/m}$
Resistance to sliding $F_{\text{rest}} = F_{\text{exc}_h} + F_{\text{friction}} = 79.3 \text{ kN/m}$
Factor of safety $FoS_{\text{sl}} = F_{\text{rest}} / F_{\text{total}_h} = 1.378$

PASS - Resistance to sliding is greater than sliding force



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Overturning check

Vertical forces on wall

Wall stem	$F_{\text{stem}} = \gamma_{\text{Gf}} \times A_{\text{stem}} \times \gamma_{\text{stem}} = \mathbf{49.2 \text{ kN/m}}$
Wall base	$F_{\text{base}} = \gamma_{\text{Gf}} \times A_{\text{base}} \times \gamma_{\text{base}} = \mathbf{12.6 \text{ kN/m}}$
Moist retained soil	$F_{\text{moist}_v} = \gamma_{\text{Gf}} \times A_{\text{moist}} \times \gamma_{\text{mr}}' = \mathbf{36.6 \text{ kN/m}}$
Base soil	$F_{\text{exc}_v} = \gamma_{\text{Gf}} \times A_{\text{exc}} \times \gamma_b' = \mathbf{2.2 \text{ kN/m}}$
Total	$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{moist}_v} + F_{\text{exc}_v} = \mathbf{100.6 \text{ kN/m}}$

Horizontal forces on wall

Surcharge load	$F_{\text{sur}_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{\text{eff}} = \mathbf{15 \text{ kN/m}}$
Moist retained soil	$F_{\text{moist}_h} = \gamma_G \times K_A \times \gamma_{\text{mr}}' \times h_{\text{eff}}^2 / 2 = \mathbf{42.5 \text{ kN/m}}$
Base soil	$F_{\text{exc}_h} = -\gamma_{\text{Gf}} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (h_{\text{pass}} + h_{\text{base}})^2 / 2 = \mathbf{-21.2 \text{ kN/m}}$
Total	$F_{\text{total}_h} = F_{\text{moist}_h} + F_{\text{exc}_h} + F_{\text{sur}_h} = \mathbf{36.3 \text{ kN/m}}$

Overturning moments on wall

Surcharge load	$M_{\text{sur}_{\text{OT}}} = F_{\text{sur}_h} \times X_{\text{sur}_h} = \mathbf{22.5 \text{ kNm/m}}$
Moist retained soil	$M_{\text{moist}_{\text{OT}}} = F_{\text{moist}_h} \times X_{\text{moist}_h} = \mathbf{42.5 \text{ kNm/m}}$
Total	$M_{\text{total}_{\text{OT}}} = M_{\text{moist}_{\text{OT}}} + M_{\text{sur}_{\text{OT}}} = \mathbf{65 \text{ kNm/m}}$

Restoring moments on wall

Wall stem	$M_{\text{stem}_R} = F_{\text{stem}} \times X_{\text{stem}} = \mathbf{36.2 \text{ kNm/m}}$
Wall base	$M_{\text{base}_R} = F_{\text{base}} \times X_{\text{base}} = \mathbf{10.5 \text{ kNm/m}}$
Moist retained soil	$M_{\text{moist}_R} = F_{\text{moist}_v} \times X_{\text{moist}_v} = \mathbf{46.5 \text{ kNm/m}}$
Base soil	$M_{\text{exc}_R} = F_{\text{exc}_v} \times X_{\text{exc}_v} - F_{\text{exc}_h} \times X_{\text{exc}_h} = \mathbf{5.3 \text{ kNm/m}}$
Total	$M_{\text{total}_R} = M_{\text{stem}_R} + M_{\text{base}_R} + M_{\text{moist}_R} + M_{\text{exc}_R} = \mathbf{98.6 \text{ kNm/m}}$

Check stability against overturning

Factor of safety	$\text{FoS}_{\text{ot}} = M_{\text{total}_R} / M_{\text{total}_{\text{OT}}} = \mathbf{1.516}$
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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	$\gamma_G = \mathbf{1.00}$
Permanent favourable action	$\gamma_{\text{Gf}} = \mathbf{1.00}$
Variable unfavourable action	$\gamma_Q = \mathbf{1.30}$
Variable favourable action	$\gamma_{\text{Qf}} = \mathbf{0.00}$

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

Soil parameter set	M2
Angle of shearing resistance	$\gamma_{\phi'} = \mathbf{1.25}$
Effective cohesion	$\gamma_{c'} = \mathbf{1.25}$
Weight density	$\gamma_{\gamma} = \mathbf{1.00}$

Library item Partial factors output

Retained soil properties

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



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Base soil properties

Design soil density

$$\gamma_{b'} = \gamma_b / \gamma_\gamma = \mathbf{18 \text{ kN/m}^3}$$

Design effective shear resistance angle

$$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_\psi) = \mathbf{24.8 \text{ deg}}$$

Design wall friction angle

$$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_\psi) = \mathbf{12.1 \text{ deg}}$$

Design base friction angle

$$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_\psi) = \mathbf{24.8 \text{ deg}}$$

Design effective cohesion

$$c'_{b,d} = c'_{b,k} / \gamma_c = \mathbf{0 \text{ kN/m}^2}$$

Using Coulomb theory

Active pressure coefficient

$$K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times [1 + \sqrt{[\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))]}]^2) = \mathbf{0.409}$$

Passive pressure coefficient

$$K_P = \sin(90 - \phi'_{b,d})^2 / (\sin(90 + \delta_{b,d}) \times [1 - \sqrt{[\sin(\phi'_{b,d} + \delta_{b,d}) \times \sin(\phi'_{b,d}) / (\sin(90 + \delta_{b,d}))]}]^2) = \mathbf{3.473}$$

Sliding check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = \gamma_{\text{Gf}} \times A_{\text{stem}} \times \gamma_{\text{stem}} = \mathbf{49.2 \text{ kN/m}}$$

Wall base

$$F_{\text{base}} = \gamma_{\text{Gf}} \times A_{\text{base}} \times \gamma_{\text{base}} = \mathbf{12.6 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_v} = \gamma_{\text{Gf}} \times A_{\text{moist}} \times \gamma_{\text{mr}'} = \mathbf{36.6 \text{ kN/m}}$$

Base soil

$$F_{\text{exc}_v} = \gamma_{\text{Gf}} \times A_{\text{exc}} \times \gamma_{b'} = \mathbf{2.2 \text{ kN/m}}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{moist}_v} + F_{\text{exc}_v} = \mathbf{100.6 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{\text{eff}} = \mathbf{16 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_h} = \gamma_G \times K_A \times \gamma_{\text{mr}'} \times h_{\text{eff}}^2 / 2 = \mathbf{38.7 \text{ kN/m}}$$

Total

$$F_{\text{total}_h} = F_{\text{moist}_h} + F_{\text{sur}_h} = \mathbf{54.6 \text{ kN/m}}$$

Check stability against sliding

Base soil resistance

$$F_{\text{exc}_h} = \gamma_{\text{Gf}} \times K_P \times \cos(\delta_{b,d}) \times \gamma_{b'} \times (h_{\text{pass}} + h_{\text{base}})^2 / 2 = \mathbf{15 \text{ kN/m}}$$

Base friction

$$F_{\text{friction}} = F_{\text{total}_v} \times \tan(\delta_{bb,d}) = \mathbf{46.4 \text{ kN/m}}$$

Resistance to sliding

$$F_{\text{rest}} = F_{\text{exc}_h} + F_{\text{friction}} = \mathbf{61.4 \text{ kN/m}}$$

Factor of safety

$$FoS_{\text{Sl}} = F_{\text{rest}} / F_{\text{total}_h} = \mathbf{1.125}$$

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = \gamma_{\text{Gf}} \times A_{\text{stem}} \times \gamma_{\text{stem}} = \mathbf{49.2 \text{ kN/m}}$$

Wall base

$$F_{\text{base}} = \gamma_{\text{Gf}} \times A_{\text{base}} \times \gamma_{\text{base}} = \mathbf{12.6 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_v} = \gamma_{\text{Gf}} \times A_{\text{moist}} \times \gamma_{\text{mr}'} = \mathbf{36.6 \text{ kN/m}}$$

Base soil

$$F_{\text{exc}_v} = \gamma_{\text{Gf}} \times A_{\text{exc}} \times \gamma_{b'} = \mathbf{2.2 \text{ kN/m}}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{moist}_v} + F_{\text{exc}_v} = \mathbf{100.6 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{\text{eff}} = \mathbf{16 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_h} = \gamma_G \times K_A \times \gamma_{\text{mr}'} \times h_{\text{eff}}^2 / 2 = \mathbf{38.7 \text{ kN/m}}$$

Base soil

$$F_{\text{exc}_h} = -\gamma_{\text{Gf}} \times K_P \times \cos(\delta_{b,d}) \times \gamma_{b'} \times (h_{\text{pass}} + h_{\text{base}})^2 / 2 = \mathbf{-15 \text{ kN/m}}$$

Total

$$F_{\text{total}_h} = F_{\text{moist}_h} + F_{\text{exc}_h} + F_{\text{sur}_h} = \mathbf{39.6 \text{ kN/m}}$$

Overturning moments on wall

Surcharge load

$$M_{\text{sur}_\text{OT}} = F_{\text{sur}_h} \times X_{\text{sur}_h} = \mathbf{23.9 \text{ kNm/m}}$$

Moist retained soil

$$M_{\text{moist}_\text{OT}} = F_{\text{moist}_h} \times X_{\text{moist}_h} = \mathbf{38.7 \text{ kNm/m}}$$



Cwm Planning & Design Ltd.
(Civil, Structural & Architectural)

Project Mr. S. Rees, Alltwen Hill, Alltwen				Job no.	
Calcs for Garden Retaining wall (Supporting Car Parking Space)				Start page no./Revision 7	
Calcs by CM	Calcs date 08/04/2019	Checked by	Checked date	Approved by	Approved date

Total

$$M_{total_OT} = M_{moist_OT} + M_{sur_OT} = \mathbf{62.6 \text{ kNm/m}}$$

Restoring moments on wall

Wall stem

$$M_{stem_R} = F_{stem} \times X_{stem} = \mathbf{36.2 \text{ kNm/m}}$$

Wall base

$$M_{base_R} = F_{base} \times X_{base} = \mathbf{10.5 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist_R} = F_{moist_v} \times X_{moist_v} = \mathbf{46.5 \text{ kNm/m}}$$

Base soil

$$M_{exc_R} = F_{exc_v} \times X_{exc_v} - F_{exc_h} \times X_{exc_h} = \mathbf{3.8 \text{ kNm/m}}$$

Total

$$M_{total_R} = M_{stem_R} + M_{base_R} + M_{moist_R} + M_{exc_R} = \mathbf{97.1 \text{ kNm/m}}$$

Check stability against overturning

Factor of safety

$$FoS_{ot} = M_{total_R} / M_{total_OT} = \mathbf{1.552}$$

PASS - Maximum restoring moment is greater than overturning moment