



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

STRUCTURAL CALCULATIONS
- PROPOSED GARDEN RETAINING WALL -

at:

**129 Cilmaengwyn
Pontardawe**

Date: 4th December 2023

BRIEF:

- 1) The design of a masonry retaining wall to support an elevated lawned rear garden

REFERENCES:

Architectural Drawings
SCALE structural design package (for unit loads)
TEDDS structural design computer package.

DESIGN LOADINGS:

Refer to structural calculations attached.

Surcharge = **1.5kN (garden loading)**

Vertical Load on Wall: Garden Fence

Dead = **0.45 kN/m**

Live = **0 kN/m**

Ground Bearing Capacity presumed to be **150kN/m²**

SUMMARY

Retained height taken as **2400mm**

350mm deep mass concrete foundation

1100mm wide – 450mm wide stepped rear face with weepholes at 2m c/c's



 Cwm Planning & Design Ltd. (architectural and Draughting Services)	Client:	Project Title:	General Notes:	Drawing Title:	
	129 Cilmaengwyn Road Pontardawe	PROPOSED GARDEN RETAINING WALL	1. Do not scale from this drawing, take figured dimensions only. 2. Dimensions are in millimeters unless otherwise stated.	GARDEN RETAINING WALL	
			Drawing Issue:	Drawing No: RW001	Revision:
			CONSTRUCTION	Date: 04-12-2023	Revised:
				Scale(s): 1:25	Paper Size: A4

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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 2.9.17

Analysis summary

Design summary

Overall design utilisation 0.989
Overall design status Pass

Description	Unit	Capacity	Applied	F o S	Result
Sliding stability	kN/m	35.7	35.3	1.011	PASS
Overturning stability	kNm/m	88.3	40	2.208	PASS
Bearing pressure	kN/m ²	150	110.4	1.359	PASS

Retaining wall details

Stem type Cantilever with stepped rear face
Stem height $h_{\text{stem}} = 2700$ mm
Number of steps $N_{\text{steps}} = 3$
Height of step 1 $h_{s1} = 900$ mm
Thickness of step 1 $t_{s1} = 1100$ mm
Height of step 2 $h_{s2} = 900$ mm
Thickness of step 2 $t_{s2} = 900$ mm
Height of step 3 $h_{s3} = 900$ mm
Thickness of step 3 $t_{s3} = 450$ mm
Angle to rear face of stem $\alpha = 90$ deg
Stem density $\gamma_{\text{stem}} = 25$ kN/m³
Toe length $l_{\text{toe}} = 250$ mm
Heel length $l_{\text{heel}} = 250$ mm
Base thickness $t_{\text{base}} = 350$ mm
Base density $\gamma_{\text{base}} = 25$ kN/m³
Height of retained soil $h_{\text{ret}} = 2400$ mm
Angle of soil surface $\beta = 0$ deg
Depth of cover $d_{\text{cover}} = 300$ mm

Retained soil properties

Soil type Medium dense well graded sand
Moist density $\gamma_{\text{mr}} = 19.5$ kN/m³
Saturated density $\gamma_{\text{sr}} = 21.5$ kN/m³
Characteristic effective shear resistance angle $\phi'_{r,k} = 30$ deg
Characteristic wall friction angle $\delta_{r,k} = 15$ deg

Base soil properties

Soil type Stiff or hard glacial clay
Soil density $\gamma_b = 23$ 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 $\delta_{bb,k} = 18$ deg
Presumed bearing capacity $P_{\text{bearing}} = 150$ kN/m²



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Loading details

Permanent surcharge load

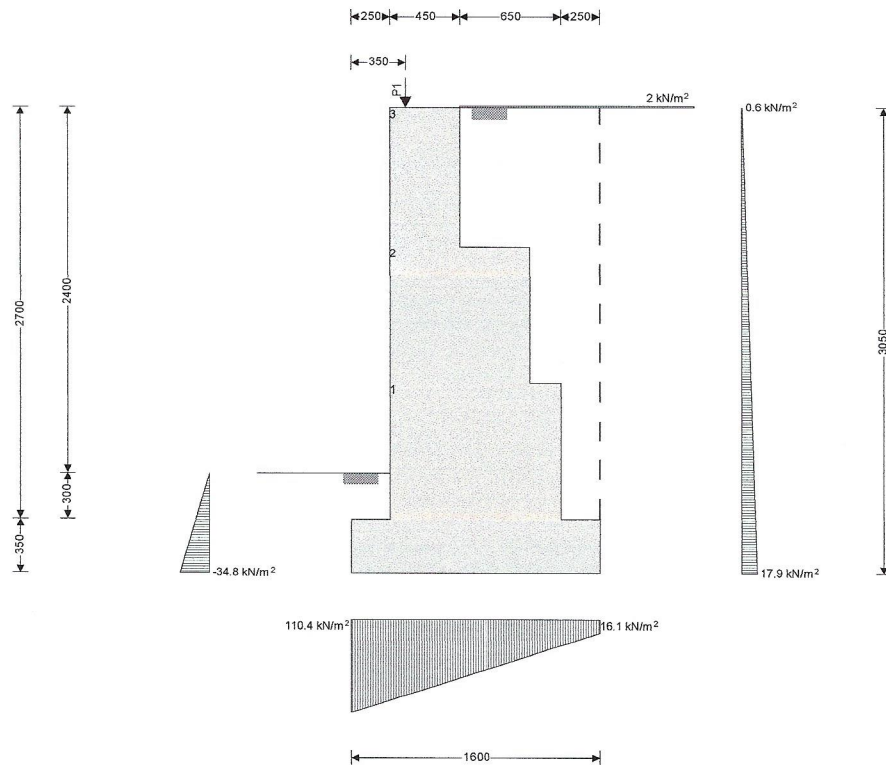
$$\text{Surcharge}_G = 1.5 \text{ kN/m}^2$$

Variable surcharge load

$$\text{Surcharge}_Q = 0.5 \text{ kN/m}^2$$

Vertical line load at 350 mm

$$P_{G1} = 0.5 \text{ kN/m}$$



General arrangement - sketch pressures relate to bearing check

Calculate retaining wall geometry

Base length

$$l_{\text{base}} = l_{\text{toe}} + t_{s1} + l_{\text{heel}} = 1600 \text{ mm}$$

Moist soil height

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

Length of surcharge load

$$l_{\text{sur}} = (l_{\text{heel}} + t_{s1} - t_{s3}) = 900 \text{ mm}$$

- Distance to vertical component

$$x_{\text{sur}_v} = l_{\text{base}} - (l_{\text{heel}} + t_{s1} - t_{s3}) / 2 = 1150 \text{ mm}$$

Effective height of wall

$$h_{\text{eff}} = h_{\text{base}} + d_{\text{cover}} + h_{\text{ret}} = 3050 \text{ mm}$$

- Distance to horizontal component

$$x_{\text{sur}_h} = h_{\text{eff}} / 2 = 1525 \text{ mm}$$

Area of wall stem

$$A_{\text{stem}} = h_{s1} \times t_{s1} + h_{s2} \times t_{s2} + h_{s3} \times t_{s3} = 2.205 \text{ m}^2$$

- Distance to vertical component

$$x_{\text{stem}} = l_{\text{base}} - (h_{s1} \times t_{s1} \times (l_{\text{heel}} + t_{s1} - t_{s1} / 2) + h_{s2} \times t_{s2} \times (l_{\text{heel}} + t_{s1} - t_{s2} / 2) + h_{s3} \times t_{s3} \times (l_{\text{heel}} + t_{s1} - t_{s3} / 2)) / A_{\text{stem}} = 704 \text{ mm}$$

Area of wall base

$$A_{\text{base}} = l_{\text{base}} \times t_{\text{base}} = 0.56 \text{ m}^2$$

- Distance to vertical component

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

Area of moist soil

$$A_{\text{moist}} = l_{\text{heel}} \times h_{s1} + (l_{\text{heel}} + t_{s1} - t_{s2}) \times h_{s2} + (l_{\text{heel}} + t_{s1} - t_{s3}) \times h_{s3} = 1.44 \text{ m}^2$$

- Distance to vertical component

$$x_{\text{moist}_v} = l_{\text{base}} - (l_{\text{heel}} \times h_{s1} \times l_{\text{heel}} / 2 + (l_{\text{heel}} + t_{s1} - t_{s2}) \times h_{s2} \times (l_{\text{heel}} + t_{s1} - t_{s2} / 2) + (l_{\text{heel}} + t_{s1} - t_{s3}) \times h_{s3} \times (l_{\text{heel}} + t_{s1} - t_{s3} / 2)) / A_{\text{moist}} = 1264 \text{ mm}$$

- Distance to horizontal component

$$x_{\text{moist}_h} = h_{\text{eff}} / 3 = 1017 \text{ mm}$$

Area of base soil

$$A_{\text{pass}} = d_{\text{cover}} \times l_{\text{toe}} = 0.075 \text{ m}^2$$

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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

$$x_{pass_v} = l_{base} - (d_{cover} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{pass} = 125 \text{ mm}$$

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

$$A_{exc} = h_{pass} \times l_{toe} = 0.075 \text{ m}^2$$

$$x_{exc_v} = l_{base} - (h_{pass} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{exc} = 125 \text{ mm}$$

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

$$K_A = \sin(\alpha + \phi'_{r,k})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,k}) \times [1 + \sqrt{[\sin(\phi'_{r,k} + \delta_{r,k}) \times \sin(\phi'_{r,k} - \beta) / (\sin(\alpha - \delta_{r,k}) \times \sin(\alpha + \beta))]}]) = 0.301$$

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

Bearing pressure check

Vertical forces on wall

Wall stem

$$F_{stem} = A_{stem} \times \gamma_{stem} = 55.1 \text{ kN/m}$$

Wall base

$$F_{base} = A_{base} \times \gamma_{base} = 14 \text{ kN/m}$$

Surcharge load

$$F_{sur_v} = (Surcharge_G + Surcharge_Q) \times (l_{heel} + t_{s1} - t_{s3}) = 1.8 \text{ kN/m}$$

Line loads

$$F_{P_v} = P_{G1} = 0.5 \text{ kN/m}$$

Moist retained soil

$$F_{moist_v} = A_{moist} \times \gamma_{mr} = 28.1 \text{ kN/m}$$

Base soil

$$F_{pass_v} = A_{pass} \times \gamma_b = 1.7 \text{ kN/m}$$

Total

$$F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{P_v} + F_{moist_v} + F_{pass_v} = 101.2 \text{ kN/m}$$

Horizontal forces on wall

Surcharge load

$$F_{sur_h} = K_A \times \cos(\delta_{r,k}) \times (Surcharge_G + Surcharge_Q) \times h_{eff} = 1.8 \text{ kN/m}$$

Moist retained soil

$$F_{moist_h} = K_A \times \cos(\delta_{r,k}) \times \gamma_{mr} \times h_{eff}^2 / 2 = 26.4 \text{ kN/m}$$

Base soil

$$F_{pass_h} = -K_P \times \cos(\delta_{b,k}) \times \gamma_b \times (d_{cover} + h_{base})^2 / 2 = -11.3 \text{ kN/m}$$

Total

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

Moments on wall

Wall stem

$$M_{stem} = F_{stem} \times x_{stem} = 38.8 \text{ kNm/m}$$

Wall base

$$M_{base} = F_{base} \times x_{base} = 11.2 \text{ kNm/m}$$

Surcharge load

$$M_{sur} = F_{sur_v} \times x_{sur_v} - F_{sur_h} \times x_{sur_h} = -0.6 \text{ kNm/m}$$

Line loads

$$M_P = P_{G1} \times p_1 = 0.2 \text{ kNm/m}$$

Moist retained soil

$$M_{moist} = F_{moist_v} \times x_{moist_v} - F_{moist_h} \times x_{moist_h} = 8.6 \text{ kNm/m}$$

Base soil

$$M_{pass} = F_{pass_v} \times x_{pass_v} - F_{pass_h} \times x_{pass_h} = 2.7 \text{ kNm/m}$$

Total

$$M_{total} = M_{stem} + M_{base} + M_{sur} + M_P + M_{moist} + M_{pass} = 60.8 \text{ kNm/m}$$

Check bearing pressure

Distance to reaction

$$\bar{x} = M_{total} / F_{total_v} = 601 \text{ mm}$$

Eccentricity of reaction

$$e = \bar{x} - l_{base} / 2 = -199 \text{ mm}$$

Loaded length of base

$$l_{load} = l_{base} = 1600 \text{ mm}$$

Bearing pressure at toe

$$q_{toe} = F_{total_v} / l_{base} \times (1 - 6 \times e / l_{base}) = 110.4 \text{ kN/m}^2$$

Bearing pressure at heel

$$q_{heel} = F_{total_v} / l_{base} \times (1 + 6 \times e / l_{base}) = 16.1 \text{ kN/m}^2$$

Factor of safety

$$FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel}) = 1.359$$

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	$\gamma_{mr}' = \gamma_{mr} / \gamma_\gamma = 19.5 \text{ kN/m}^3$
Design saturated density	$\gamma_{sr}' = \gamma_{sr} / \gamma_\gamma = 21.5 \text{ kN/m}^3$
Design effective shear resistance angle	$\phi'_{r,d} = \text{atan}(\tan(\phi'_{r,k}) / \gamma_{\phi'}) = 30 \text{ deg}$
Design wall friction angle	$\delta_{r,d} = \text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}) = 15 \text{ deg}$

Base soil properties

Design soil density	$\gamma_b' = \gamma_b / \gamma_\gamma = 23 \text{ kN/m}^3$
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	$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_{\phi'}) = 18 \text{ deg}$
Design effective cohesion	$c'_{b,d} = c'_{b,k} / \gamma_{c'} = 0 \text{ kN/m}^2$

Using Coulomb theory

Active pressure coefficient	$K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times [1 + \sqrt{[\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))]}]^2) = 0.301$
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	$F_{\text{stem}} = \gamma_{Gf} \times A_{\text{stem}} \times \gamma_{\text{stem}} = 55.1 \text{ kN/m}$
Wall base	$F_{\text{base}} = \gamma_{Gf} \times A_{\text{base}} \times \gamma_{\text{base}} = 14 \text{ kN/m}$
Surcharge load	$F_{\text{sur}_v} = (\gamma_{Gf} \times \text{Surcharge}_G + \gamma_{Qf} \times \text{Surcharge}_Q) \times (l_{\text{heel}} + t_{s1} - t_{s3}) = 1.4 \text{ kN/m}$
Line loads	$F_{P_v} = \gamma_{Gf} \times P_{G1} = 0.5 \text{ kN/m}$
Moist retained soil	$F_{\text{moist}_v} = \gamma_{Gf} \times A_{\text{moist}} \times \gamma_{mr}' = 28.1 \text{ kN/m}$
Base soil	$F_{\text{exc}_v} = \gamma_{Gf} \times A_{\text{exc}} \times \gamma_b' = 1.7 \text{ kN/m}$
Total	$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{sur}_v} + F_{P_v} + F_{\text{moist}_v} + F_{\text{exc}_v} = 100.7 \text{ kN/m}$

Horizontal forces on wall

Surcharge load	$F_{\text{sur}_h} = K_A \times \cos(\delta_{r,d}) \times (\gamma_G \times \text{Surcharge}_G + \gamma_Q \times \text{Surcharge}_Q) \times h_{\text{eff}} = 2.5 \text{ kN/m}$
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Moist retained soil

$$F_{\text{moist}_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{mr}' \times h_{\text{eff}}^2 / 2 = 35.6 \text{ kN/m}$$

Total

$$F_{\text{total}_h} = F_{\text{sur}_h} + F_{\text{moist}_h} = 38.1 \text{ kN/m}$$

Check stability against sliding

Base soil resistance

$$F_{\text{exc}_h} = \gamma_{Gf} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (h_{\text{pass}} + h_{\text{base}})^2 / 2 = 11.3 \text{ kN/m}$$

Base friction

$$F_{\text{friction}} = F_{\text{total}_v} \times \tan(\delta_{bb,d}) = 32.7 \text{ kN/m}$$

Resistance to sliding

$$F_{\text{rest}} = F_{\text{exc}_h} + F_{\text{friction}} = 44 \text{ kN/m}$$

Factor of safety

$$F_{\text{OSl}} = F_{\text{rest}} / F_{\text{total}_h} = 1.156$$

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = \gamma_{Gf} \times A_{\text{stem}} \times \gamma_{\text{stem}} = 55.1 \text{ kN/m}$$

Wall base

$$F_{\text{base}} = \gamma_{Gf} \times A_{\text{base}} \times \gamma_{\text{base}} = 14 \text{ kN/m}$$

Surcharge load

$$F_{\text{sur}_v} = (\gamma_{Gf} \times \text{Surcharge}_G + \gamma_{Qf} \times \text{Surcharge}_Q) \times (l_{\text{heel}} + t_{s1} - t_{s3}) = 1.4 \text{ kN/m}$$

Line loads

$$F_{P_v} = \gamma_{Gf} \times P_{G1} = 0.5 \text{ kN/m}$$

Moist retained soil

$$F_{\text{moist}_v} = \gamma_{Gf} \times A_{\text{moist}} \times \gamma_{mr}' = 28.1 \text{ kN/m}$$

Base soil

$$F_{\text{exc}_v} = \gamma_{Gf} \times A_{\text{exc}} \times \gamma_b' = 1.7 \text{ kN/m}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{sur}_v} + F_{P_v} + F_{\text{moist}_v} + F_{\text{exc}_v} = 100.7 \text{ kN/m}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_A \times \cos(\delta_{r,d}) \times (\gamma_G \times \text{Surcharge}_G + \gamma_Q \times \text{Surcharge}_Q) \times h_{\text{eff}} = 2.5 \text{ kN/m}$$

Moist retained soil

$$F_{\text{moist}_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{mr}' \times h_{\text{eff}}^2 / 2 = 35.6 \text{ kN/m}$$

Base soil

$$F_{\text{exc}_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (h_{\text{pass}} + h_{\text{base}})^2 / 2 = -11.3 \text{ kN/m}$$

Total

$$F_{\text{total}_h} = F_{\text{sur}_h} + F_{\text{moist}_h} + F_{\text{exc}_h} = 26.8 \text{ kN/m}$$

Overturning moments on wall

Surcharge load

$$M_{\text{sur}_OT} = F_{\text{sur}_h} \times x_{\text{sur}_h} = 3.8 \text{ kNm/m}$$

Moist retained soil

$$M_{\text{moist}_OT} = F_{\text{moist}_h} \times x_{\text{moist}_h} = 36.2 \text{ kNm/m}$$

Total

$$M_{\text{total}_OT} = M_{\text{sur}_OT} + M_{\text{moist}_OT} = 40 \text{ kNm/m}$$

Restoring moments on wall

Wall stem

$$M_{\text{stem}_R} = F_{\text{stem}} \times x_{\text{stem}} = 38.8 \text{ kNm/m}$$

Wall base

$$M_{\text{base}_R} = F_{\text{base}} \times x_{\text{base}} = 11.2 \text{ kNm/m}$$

Line loads

$$M_{P_R} = \text{abs}(\gamma_{Gf} \times P_{G1}) \times p_1 = 0.2 \text{ kNm/m}$$

Moist retained soil

$$M_{\text{moist}_R} = F_{\text{moist}_v} \times x_{\text{moist}_v} = 35.5 \text{ kNm/m}$$

Base soil

$$M_{\text{exc}_R} = F_{\text{exc}_v} \times x_{\text{exc}_v} - F_{\text{exc}_h} \times x_{\text{exc}_h} = 2.7 \text{ kNm/m}$$

Total

$$M_{\text{total}_R} = M_{\text{stem}_R} + M_{\text{base}_R} + M_{P_R} + M_{\text{moist}_R} + M_{\text{exc}_R} = 88.3 \text{ kNm/m}$$

Check stability against overturning

Factor of safety

$$F_{\text{OSot}} = M_{\text{total}_R} / M_{\text{total}_OT} = 2.208$$

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

$\gamma_G = 1.000$

Permanent favourable action

$\gamma_{Gf} = 1.000$

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Variable unfavourable action $\gamma_Q = 1.300$

Variable favourable action $\gamma_{Qf} = 0.000$

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 $\gamma_Y = 1.00$

Retained soil properties

Design moist density $\gamma_{mr}' = \gamma_{mr} / \gamma_Y = 19.5 \text{ kN/m}^3$

Design saturated density $\gamma_{sr}' = \gamma_{sr} / \gamma_Y = 21.5 \text{ kN/m}^3$

Design effective shear resistance angle $\phi'_{r,d} = \text{atan}(\tan(\phi'_{r,k}) / \gamma_{\phi'}) = 24.8 \text{ deg}$

Design wall friction angle $\delta_{r,d} = \text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}) = 12.1 \text{ deg}$

Base soil properties

Design soil density $\gamma_b' = \gamma_b / \gamma_Y = 23 \text{ kN/m}^3$

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 $\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_{\phi'}) = 14.6 \text{ deg}$

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

Using Coulomb theory

Active pressure coefficient $K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times [1 + \sqrt{[\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))]}])^2 = 0.371$

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 $F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = 55.1 \text{ kN/m}$

Wall base $F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = 14 \text{ kN/m}$

Surcharge load $F_{sur_v} = (\gamma_{Gf} \times \text{Surcharge}_G + \gamma_{Qf} \times \text{Surcharge}_Q) \times (l_{heel} + t_{s1} - t_{s3}) = 1.4 \text{ kN/m}$

Line loads $F_{P_v} = \gamma_{Gf} \times P_{G1} = 0.5 \text{ kN/m}$

Moist retained soil $F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' = 28.1 \text{ kN/m}$

Base soil $F_{exc_v} = \gamma_{Gf} \times A_{exc} \times \gamma_b' = 1.7 \text{ kN/m}$

Total $F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{P_v} + F_{moist_v} + F_{exc_v} = 100.7 \text{ kN/m}$

Horizontal forces on wall

Surcharge load $F_{sur_h} = K_A \times \cos(\delta_{r,d}) \times (\gamma_G \times \text{Surcharge}_G + \gamma_Q \times \text{Surcharge}_Q) \times h_{eff} = 2.4 \text{ kN/m}$

Moist retained soil $F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 = 32.9 \text{ kN/m}$

Total $F_{total_h} = F_{sur_h} + F_{moist_h} = 35.3 \text{ kN/m}$

Check stability against sliding

Base soil resistance $F_{exc_h} = \gamma_{Gf} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = 9.5 \text{ kN/m}$

Base friction $F_{friction} = F_{total_v} \times \tan(\delta_{bb,d}) = 26.2 \text{ kN/m}$

Resistance to sliding $F_{rest} = F_{exc_h} + F_{friction} = 35.7 \text{ kN/m}$

Project 129 Cilmaengwyn, Pontardawe			Job no.		
Calcs for GARDEN RETAINING WALL			Start page no./Revision 7		
Calcs by CM	Calcs date 04/12/2023	Checked by	Checked date	Approved by	Approved date

Factor of safety

$$FoS_{sl} = F_{rest} / F_{total_h} = 1.011$$

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem

$$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = 55.1 \text{ kN/m}$$

Wall base

$$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = 14 \text{ kN/m}$$

Surcharge load

$$F_{sur_v} = (\gamma_{Gf} \times \text{Surcharge}_G + \gamma_{Qf} \times \text{Surcharge}_Q) \times (l_{heel} + t_{s1} - t_{s3}) = 1.4 \text{ kN/m}$$

Line loads

$$F_{P_v} = \gamma_{Gf} \times P_{G1} = 0.5 \text{ kN/m}$$

Moist retained soil

$$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' = 28.1 \text{ kN/m}$$

Base soil

$$F_{exc_v} = \gamma_{Gf} \times A_{exc} \times \gamma_b' = 1.7 \text{ kN/m}$$

Total

$$F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{P_v} + F_{moist_v} + F_{exc_v} = 100.7 \text{ kN/m}$$

Horizontal forces on wall

Surcharge load

$$F_{sur_h} = K_A \times \cos(\delta_{r,d}) \times (\gamma_G \times \text{Surcharge}_G + \gamma_Q \times \text{Surcharge}_Q) \times h_{eff} = 2.4 \text{ kN/m}$$

Moist retained soil

$$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 = 32.9 \text{ kN/m}$$

Base soil

$$F_{exc_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = -9.5 \text{ kN/m}$$

Total

$$F_{total_h} = F_{sur_h} + F_{moist_h} + F_{exc_h} = 25.8 \text{ kN/m}$$

Overturning moments on wall

Surcharge load

$$M_{sur_OT} = F_{sur_h} \times x_{sur_h} = 3.6 \text{ kNm/m}$$

Moist retained soil

$$M_{moist_OT} = F_{moist_h} \times x_{moist_h} = 33.4 \text{ kNm/m}$$

Total

$$M_{total_OT} = M_{sur_OT} + M_{moist_OT} = 37.1 \text{ kNm/m}$$

Restoring moments on wall

Wall stem

$$M_{stem_R} = F_{stem} \times x_{stem} = 38.8 \text{ kNm/m}$$

Wall base

$$M_{base_R} = F_{base} \times x_{base} = 11.2 \text{ kNm/m}$$

Line loads

$$M_{P_R} = \text{abs}(\gamma_{Gf} \times P_{G1}) \times p_1 = 0.2 \text{ kNm/m}$$

Moist retained soil

$$M_{moist_R} = F_{moist_v} \times x_{moist_v} = 35.5 \text{ kNm/m}$$

Base soil

$$M_{exc_R} = F_{exc_v} \times x_{exc_v} - F_{exc_h} \times x_{exc_h} = 2.3 \text{ kNm/m}$$

Total

$$M_{total_R} = M_{stem_R} + M_{base_R} + M_{P_R} + M_{moist_R} + M_{exc_R} = 87.9 \text{ kNm/m}$$

Check stability against overturning

Factor of safety

$$FoS_{ot} = M_{total_R} / M_{total_OT} = 2.371$$

PASS - Maximum restoring moment is greater than overturning moment