



Marsh Design Limited
18 Howard Avenue
Lindley

Project 121 Wakefield Road, Fenay Bridge		Job no. MDL - 9549	
Calcs for Garden Parking Area Retaining Wall - EN1997		Start page no./Revision RW 1	
Calcs by DSH	Calcs date 05/12/2023	Checked by	Checked date
Approved by		Approved date	

MASS BLOCKWORK RETAINING WALL SUPPORTING GARDENS ADJACENT TO THE HIGHWAY

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 0.983

Overall design status Pass

Description	Unit	Capacity	Applied	F o S	Result
Sliding stability	kN/m	16.5	16.3	1.017	PASS
Overturning stability	kNm/m	48	14.8	3.237	PASS
Bearing pressure	kN/m ²	100	55.7	1.796	PASS

Retaining wall details

Stem type	Cantilever
Stem height	$h_{stem} = 1950$ mm
Stem thickness	$t_{stem} = 600$ mm
Angle to rear face of stem	$\alpha = 90$ deg
Stem density	$\gamma_{stem} = 22$ kN/m ³
Toe length	$l_{toe} = 300$ mm
Heel length	$l_{heel} = 600$ mm
Base thickness	$t_{base} = 300$ mm
Base density	$\gamma_{base} = 23.6$ kN/m ³
Height of retained soil	$h_{ret} = 1500$ mm
Angle of soil surface	$\beta = 0$ deg
Depth of cover	$d_{cover} = 450$ mm
Depth of excavation	$d_{exc} = 450$ mm

Retained soil properties

Soil type	Dense rock fill
Moist density	$\gamma_{mr} = 17.5$ kN/m ³
Saturated density	$\gamma_{sr} = 21$ kN/m ³
Characteristic effective shear resistance angle	$\phi'_{r,k} = 38$ deg
Characteristic wall friction angle	$\delta_{r,k} = 19$ deg

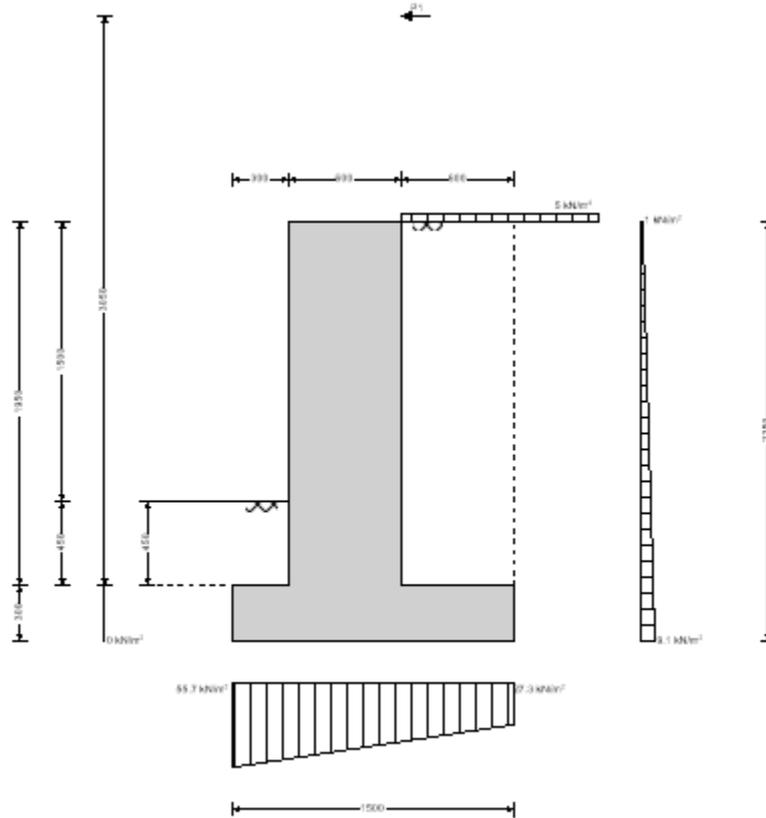
Base soil properties

Soil density	$\gamma_b = 18$ kN/m ³
Characteristic effective shear resistance angle	$\phi'_{b,k} = 30$ deg
Characteristic wall friction angle	$\delta_{b,k} = 15$ deg
Characteristic base friction angle	$\delta_{bb,k} = 20$ deg
Presumed bearing capacity	$P_{bearing} = 100$ kN/m ²

Loading details

Variable surcharge load	Surcharge _Q = 5 kN/m ²
Horizontal line load at 3050 mm	$P_{Q1} = 0.3$ kN/m

Project		121 Wakefield Road, Fenay Bridge		Job no.		MDL - 9549	
Calcs for		Garden Parking Area Retaining Wall - EN1997		Start page no./Revision		RW 2	
Calcs by	Calcs date	Checked by	Checked date	Approved by	Approved date		
DSH	05/12/2023						



General arrangement - sketch pressures relate to bearing check

Calculate retaining wall geometry

Base length	$l_{base} = l_{toe} + t_{stem} + l_{heel} = 1500 \text{ mm}$
Moist soil height	$h_{moist} = h_{soil} = 1950 \text{ mm}$
Length of surcharge load	$l_{sur} = l_{heel} = 600 \text{ mm}$
- Distance to vertical component	$x_{sur_v} = l_{base} - l_{heel} / 2 = 1200 \text{ mm}$
Effective height of wall	$h_{eff} = h_{base} + d_{cover} + h_{ret} = 2250 \text{ mm}$
- Distance to horizontal component	$x_{sur_h} = h_{eff} / 2 = 1125 \text{ mm}$
Area of wall stem	$A_{stem} = h_{stem} \times t_{stem} = 1.17 \text{ m}^2$
- Distance to vertical component	$x_{stem} = l_{toe} + t_{stem} / 2 = 600 \text{ mm}$
Area of wall base	$A_{base} = l_{base} \times t_{base} = 0.45 \text{ m}^2$
- Distance to vertical component	$x_{base} = l_{base} / 2 = 750 \text{ mm}$
Area of moist soil	$A_{moist} = h_{moist} \times l_{heel} = 1.17 \text{ m}^2$
- Distance to vertical component	$x_{moist_v} = l_{base} - (h_{moist} \times l_{heel}^2 / 2) / A_{moist} = 1200 \text{ mm}$
- Distance to horizontal component	$x_{moist_h} = h_{eff} / 3 = 750 \text{ mm}$
Area of base soil	$A_{pass} = d_{cover} \times l_{toe} = 0.135 \text{ m}^2$
- Distance to vertical component	$x_{pass_v} = l_{base} - (d_{cover} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{pass} = 150 \text{ mm}$
- Distance to horizontal component	$x_{pass_h} = (d_{cover} + h_{base}) / 3 = 250 \text{ mm}$

Using Coulomb theory

Active pressure coefficient	$K_A = \frac{\sin(\alpha + \phi'_{r,k})^2}{(\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,k}) \times [1 + \sqrt{(\sin(\phi'_{r,k} + \delta_{r,k}) \times \sin(\phi'_{r,k} - \beta) / (\sin(\alpha - \delta_{r,k}) \times \sin(\alpha + \beta))}]^2)} = 0.217$
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Project 121 Wakefield Road, Fenay Bridge				Job no. MDL - 9549	
Calcs for Garden Parking Area Retaining Wall - EN1997				Start page no./Revision RW 3	
Calcs by DSH	Calcs date 05/12/2023	Checked by	Checked date	Approved by	Approved date

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

Bearing pressure check

Vertical forces on wall

Wall stem $F_{stem} = A_{stem} \times \gamma_{stem} = 25.7$ kN/m
 Wall base $F_{base} = A_{base} \times \gamma_{base} = 10.6$ kN/m
 Surcharge load $F_{sur_v} = \text{Surcharge}_Q \times l_{heel} = 3$ kN/m
 Moist retained soil $F_{moist_v} = A_{moist} \times \gamma_{mr} = 20.5$ kN/m
 Base soil $F_{pass_v} = A_{pass} \times \gamma_b = 2.4$ kN/m
 Total $F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{moist_v} + F_{pass_v} = 62.3$ kN/m

Horizontal forces on wall

Surcharge load $F_{sur_h} = K_A \times \cos(\delta_{r,k}) \times \text{Surcharge}_Q \times h_{eff} = 2.3$ kN/m
 Line loads $F_{P_h} = P_{Q1} = 0.3$ kN/m
 Moist retained soil $F_{moist_h} = K_A \times \cos(\delta_{r,k}) \times \gamma_{mr} \times h_{eff}^2 / 2 = 9.1$ kN/m
 Total $F_{total_h} = \max(F_{sur_h} + F_{P_h} + F_{moist_h} - F_{total_v} \times \tan(\delta_{bb,k}), 0 \text{ kN/m}) = 0$ kN/m

Moments on wall

Wall stem $M_{stem} = F_{stem} \times X_{stem} = 15.4$ kNm/m
 Wall base $M_{base} = F_{base} \times X_{base} = 8$ kNm/m
 Surcharge load $M_{sur} = F_{sur_v} \times X_{sur_v} - F_{sur_h} \times X_{sur_h} = 1$ kNm/m
 Line loads $M_P = -(P_{Q1} \times (p_1 + t_{base})) = -1.1$ kNm/m
 Moist retained soil $M_{moist} = F_{moist_v} \times X_{moist_v} - F_{moist_h} \times X_{moist_h} = 17.7$ kNm/m
 Base soil $M_{pass} = F_{pass_v} \times X_{pass_v} = 0.4$ kNm/m
 Total $M_{total} = M_{stem} + M_{base} + M_{sur} + M_P + M_{moist} + M_{pass} = 41.4$ kNm/m

Check bearing pressure

Distance to reaction $\bar{x} = M_{total} / F_{total_v} = 665$ mm
 Eccentricity of reaction $e = \bar{x} - l_{base} / 2 = -85$ mm
 Loaded length of base $l_{load} = l_{base} = 1500$ mm
 Bearing pressure at toe $q_{toe} = F_{total_v} / l_{base} \times (1 - 6 \times e / l_{base}) = 55.7$ kN/m²
 Bearing pressure at heel $q_{heel} = F_{total_v} / l_{base} \times (1 + 6 \times e / l_{base}) = 27.3$ kN/m²
 Factor of safety $FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel}) = 1.796$

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 $\gamma_G = 1.350$
 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 $\gamma_{c'} = 1.00$



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Project 121 Wakefield Road, Fenay Bridge				Job no. MDL - 9549	
Calcs for Garden Parking Area Retaining Wall - EN1997				Start page no./Revision RW 4	
Calcs by DSH	Calcs date 05/12/2023	Checked by	Checked date	Approved by	Approved date

Weight density

$$\gamma_r = 1.00$$

Retained soil properties

Design moist density

$$\gamma_{mr}' = \gamma_{mr} / \gamma_r = 17.5 \text{ kN/m}^3$$

Design saturated density

$$\gamma_{sr}' = \gamma_{sr} / \gamma_r = 21 \text{ kN/m}^3$$

Design effective shear resistance angle

$$\phi'_{r,d} = \text{atan}(\tan(\phi'_{r,k}) / \gamma_\psi) = 38 \text{ deg}$$

Design wall friction angle

$$\delta_{r,d} = \text{atan}(\tan(\delta_{r,k}) / \gamma_\psi) = 19 \text{ deg}$$

Base soil properties

Design soil density

$$\gamma_b' = \gamma_b / \gamma_r = 18 \text{ kN/m}^3$$

Design effective shear resistance angle

$$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_\psi) = 30 \text{ deg}$$

Design wall friction angle

$$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_\psi) = 15 \text{ deg}$$

Design base friction angle

$$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_\psi) = 20 \text{ deg}$$

Design effective cohesion

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

Using Coulomb theory

Active pressure coefficient

$$K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times [1 + \sqrt{[\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))]}])^2 = 0.217$$

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

$$F_{stem} = \gamma G_f \times A_{stem} \times \gamma_{stem} = 25.7 \text{ kN/m}$$

Wall base

$$F_{base} = \gamma G_f \times A_{base} \times \gamma_{base} = 10.6 \text{ kN/m}$$

Moist retained soil

$$F_{moist_v} = \gamma G_f \times A_{moist} \times \gamma_{mr}' = 20.5 \text{ kN/m}$$

Total

$$F_{total_v} = F_{stem} + F_{base} + F_{moist_v} = 56.8 \text{ kN/m}$$

Horizontal forces on wall

Surcharge load

$$F_{sur_h} = K_A \times \cos(\delta_{r,d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} = 3.5 \text{ kN/m}$$

Line loads

$$F_{P_h} = \gamma_Q \times P_{Q1} = 0.5 \text{ kN/m}$$

Moist retained soil

$$F_{moist_h} = \gamma G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 = 12.3 \text{ kN/m}$$

Total

$$F_{total_h} = F_{sur_h} + F_{P_h} + F_{moist_h} = 16.3 \text{ kN/m}$$

Check stability against sliding

Base soil resistance

$$F_{exc_h} = 0 \text{ kN/m}$$

Base friction

$$F_{friction} = F_{total_v} \times \tan(\delta_{bb,d}) = 20.7 \text{ kN/m}$$

Resistance to sliding

$$F_{rest} = F_{exc_h} + F_{friction} = 20.7 \text{ kN/m}$$

Factor of safety

$$FoS_{sl} = F_{rest} / F_{total_h} = 1.273$$

PASS - Resistance to sliding is greater than sliding force

Overtipping check

Vertical forces on wall

Wall stem

$$F_{stem} = \gamma G_f \times A_{stem} \times \gamma_{stem} = 25.7 \text{ kN/m}$$

Wall base

$$F_{base} = \gamma G_f \times A_{base} \times \gamma_{base} = 10.6 \text{ kN/m}$$

Moist retained soil

$$F_{moist_v} = \gamma G_f \times A_{moist} \times \gamma_{mr}' = 20.5 \text{ kN/m}$$

Total

$$F_{total_v} = F_{stem} + F_{base} + F_{moist_v} = 56.8 \text{ kN/m}$$

Horizontal forces on wall

Surcharge load

$$F_{sur_h} = K_A \times \cos(\delta_{r,d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} = 3.5 \text{ kN/m}$$

Line loads

$$F_{P_h} = \gamma_Q \times P_{Q1} = 0.5 \text{ kN/m}$$



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Project 121 Wakefield Road, Fenay Bridge		Job no. MDL - 9549	
Calcs for Garden Parking Area Retaining Wall - EN1997		Start page no./Revision RW 5	
Calcs by DSH	Calcs date 05/12/2023	Checked by	Checked date
Approved by		Approved date	

Moist retained soil $F_{\text{moist}_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{mr} \times h_{\text{eff}}^2 / 2 = \mathbf{12.3 \text{ kN/m}}$
 Total $F_{\text{total}_h} = F_{\text{sur}_h} + F_{P_h} + F_{\text{moist}_h} = \mathbf{16.3 \text{ kN/m}}$

Overturning moments on wall

Surcharge load $M_{\text{sur}_{OT}} = F_{\text{sur}_h} \times X_{\text{sur}_h} = \mathbf{3.9 \text{ kNm/m}}$
 Line loads $M_{P_{OT}} = \text{abs}(\gamma_Q \times P_{Q1}) \times (p_1 + t_{\text{base}}) = \mathbf{1.7 \text{ kNm/m}}$
 Moist retained soil $M_{\text{moist}_{OT}} = F_{\text{moist}_h} \times X_{\text{moist}_h} = \mathbf{9.2 \text{ kNm/m}}$
 Total $M_{\text{total}_{OT}} = M_{\text{sur}_{OT}} + M_{P_{OT}} + M_{\text{moist}_{OT}} = \mathbf{14.8 \text{ kNm/m}}$

Restoring moments on wall

Wall stem $M_{\text{stem}_R} = F_{\text{stem}} \times X_{\text{stem}} = \mathbf{15.4 \text{ kNm/m}}$
 Wall base $M_{\text{base}_R} = F_{\text{base}} \times X_{\text{base}} = \mathbf{8 \text{ kNm/m}}$
 Moist retained soil $M_{\text{moist}_R} = F_{\text{moist}_v} \times X_{\text{moist}_v} = \mathbf{24.6 \text{ kNm/m}}$
 Total $M_{\text{total}_R} = M_{\text{stem}_R} + M_{\text{base}_R} + M_{\text{moist}_R} = \mathbf{48 \text{ kNm/m}}$

Check stability against overturning

Factor of safety $FoS_{ot} = M_{\text{total}_R} / M_{\text{total}_{OT}} = \mathbf{3.238}$
 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 $\gamma_{Qf} = \mathbf{0.000}$

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

Retained soil properties

Design moist density $\gamma_{mr} = \gamma_{mr} / \gamma_{\gamma} = \mathbf{17.5 \text{ kN/m}^3}$
 Design saturated density $\gamma_{sr} = \gamma_{sr} / \gamma_{\gamma} = \mathbf{21 \text{ kN/m}^3}$
 Design effective shear resistance angle $\phi'_{r,d} = \text{atan}(\tan(\phi'_{r,k}) / \gamma_{\phi}) = \mathbf{32 \text{ deg}}$
 Design wall friction angle $\delta_{r,d} = \text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi}) = \mathbf{15.4 \text{ deg}}$

Base soil properties

Design soil density $\gamma_b = \gamma_b / \gamma_{\gamma} = \mathbf{18 \text{ kN/m}^3}$
 Design effective shear resistance angle $\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_{\phi}) = \mathbf{24.8 \text{ deg}}$
 Design wall friction angle $\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_{\phi}) = \mathbf{12.1 \text{ deg}}$
 Design base friction angle $\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_{\phi}) = \mathbf{16.2 \text{ deg}}$
 Design effective cohesion $c'_{b,d} = c'_{b,k} / \gamma_{c'} = \mathbf{0 \text{ kN/m}^2}$

Using Coulomb theory

Active pressure coefficient $K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times [1 + \sqrt{[\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))]}])^2 = \mathbf{0.279}$



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Project 121 Wakefield Road, Fenay Bridge		Job no. MDL - 9549	
Calcs for Garden Parking Area Retaining Wall - EN1997		Start page no./Revision RW 6	
Calcs by DSH	Calcs date 05/12/2023	Checked by	Checked date
Approved by		Approved date	

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

$$F_{stem} = \gamma G_f \times A_{stem} \times \gamma_{stem} = \mathbf{25.7 \text{ kN/m}}$$

Wall base

$$F_{base} = \gamma G_f \times A_{base} \times \gamma_{base} = \mathbf{10.6 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_v} = \gamma G_f \times A_{moist} \times \gamma_{mr'} = \mathbf{20.5 \text{ kN/m}}$$

Total

$$F_{total_v} = F_{stem} + F_{base} + F_{moist_v} = \mathbf{56.8 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{sur_h} = K_A \times \cos(\delta_{r,d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} = \mathbf{3.9 \text{ kN/m}}$$

Line loads

$$F_{P_h} = \gamma_Q \times P_{Q1} = \mathbf{0.4 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_h} = \gamma G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{mr'} \times h_{eff}^2 / 2 = \mathbf{11.9 \text{ kN/m}}$$

Total

$$F_{total_h} = F_{sur_h} + F_{P_h} + F_{moist_h} = \mathbf{16.3 \text{ kN/m}}$$

Check stability against sliding

Base soil resistance

$$F_{exc_h} = \mathbf{0 \text{ kN/m}}$$

Base friction

$$F_{friction} = F_{total_v} \times \tan(\delta_{bb,d}) = \mathbf{16.5 \text{ kN/m}}$$

Resistance to sliding

$$F_{rest} = F_{exc_h} + F_{friction} = \mathbf{16.5 \text{ kN/m}}$$

Factor of safety

$$FoS_{sl} = F_{rest} / F_{total_h} = \mathbf{1.017}$$

PASS - Resistance to sliding is greater than sliding force

Overtuning check

Vertical forces on wall

Wall stem

$$F_{stem} = \gamma G_f \times A_{stem} \times \gamma_{stem} = \mathbf{25.7 \text{ kN/m}}$$

Wall base

$$F_{base} = \gamma G_f \times A_{base} \times \gamma_{base} = \mathbf{10.6 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_v} = \gamma G_f \times A_{moist} \times \gamma_{mr'} = \mathbf{20.5 \text{ kN/m}}$$

Total

$$F_{total_v} = F_{stem} + F_{base} + F_{moist_v} = \mathbf{56.8 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{sur_h} = K_A \times \cos(\delta_{r,d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} = \mathbf{3.9 \text{ kN/m}}$$

Line loads

$$F_{P_h} = \gamma_Q \times P_{Q1} = \mathbf{0.4 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_h} = \gamma G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{mr'} \times h_{eff}^2 / 2 = \mathbf{11.9 \text{ kN/m}}$$

Total

$$F_{total_h} = F_{sur_h} + F_{P_h} + F_{moist_h} = \mathbf{16.3 \text{ kN/m}}$$

Overtuning moments on wall

Surcharge load

$$M_{sur_OT} = F_{sur_h} \times X_{sur_h} = \mathbf{4.4 \text{ kNm/m}}$$

Line loads

$$M_{P_OT} = \text{abs}(\gamma_Q \times P_{Q1}) \times (p_1 + t_{base}) = \mathbf{1.5 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist_OT} = F_{moist_h} \times X_{moist_h} = \mathbf{8.9 \text{ kNm/m}}$$

Total

$$M_{total_OT} = M_{sur_OT} + M_{P_OT} + M_{moist_OT} = \mathbf{14.8 \text{ kNm/m}}$$

Restoring moments on wall

Wall stem

$$M_{stem_R} = F_{stem} \times X_{stem} = \mathbf{15.4 \text{ kNm/m}}$$

Wall base

$$M_{base_R} = F_{base} \times X_{base} = \mathbf{8 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist_R} = F_{moist_v} \times X_{moist_v} = \mathbf{24.6 \text{ kNm/m}}$$

Total

$$M_{total_R} = M_{stem_R} + M_{base_R} + M_{moist_R} = \mathbf{48 \text{ kNm/m}}$$

Check stability against overturning

Factor of safety

$$FoS_{ot} = M_{total_R} / M_{total_OT} = \mathbf{3.237}$$

PASS - Maximum restoring moment is greater than overturning moment



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Project 121 Wakefield Road, Fenay Bridge		Job no. MDL - 9549			
Calcs for Garden Parking Area Retaining Wall - EN1997		Start page no./Revision RW 7			
Calcs by DSH	Calcs date 05/12/2023	Checked by	Checked date	Approved by	Approved date

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