



Haigh Huddleston & Associates
Civil Structural Engineering Consultants

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Project				Job Ref.	
SB Homes - Lingards Road, Slaithwaite				7567	
Section				Sheet no./rev.	
Mass concrete retaining wall to Road 2A				1	
Calc. by	Date	Chk'd by	Date	App'd by	Date
IM	10/11/2023	PW	10/11/2023		

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 with stepped rear face
Stem height	$h_{\text{stem}} = 3600$ mm
Number of steps	$N_{\text{steps}} = 4$
Height of step 1	$h_{s1} = 1900$ mm
Thickness of step 1	$t_{s1} = 2700$ mm
Height of step 2	$h_{s2} = 700$ mm
Thickness of step 2	$t_{s2} = 2000$ mm
Height of step 3	$h_{s3} = 700$ mm
Thickness of step 3	$t_{s3} = 1300$ mm
Height of step 4	$h_{s4} = 300$ mm
Thickness of step 4	$t_{s4} = 500$ mm
Angle to rear face of stem	$\alpha = 90$ deg
Stem density	$\gamma_{\text{stem}} = 25$ kN/m ³
Base thickness	$t_{\text{base}} = 0$ mm
Base density	$\gamma_{\text{base}} = 25$ kN/m ³
Height of retained soil	$h_{\text{ret}} = 2750$ mm
Angle of soil surface	$\beta = 0$ deg
Depth of cover	$d_{\text{cover}} = 850$ mm

Retained soil properties

Soil type	Medium dense gravel
Moist density	$\gamma_{\text{mr}} = 17$ kN/m ³
Saturated density	$\gamma_{\text{sr}} = 20.5$ kN/m ³
Characteristic effective shear resistance angle	$\phi'_{r,k} = 30$ deg
Characteristic wall friction angle	$\delta_{r,k} = 15$ deg

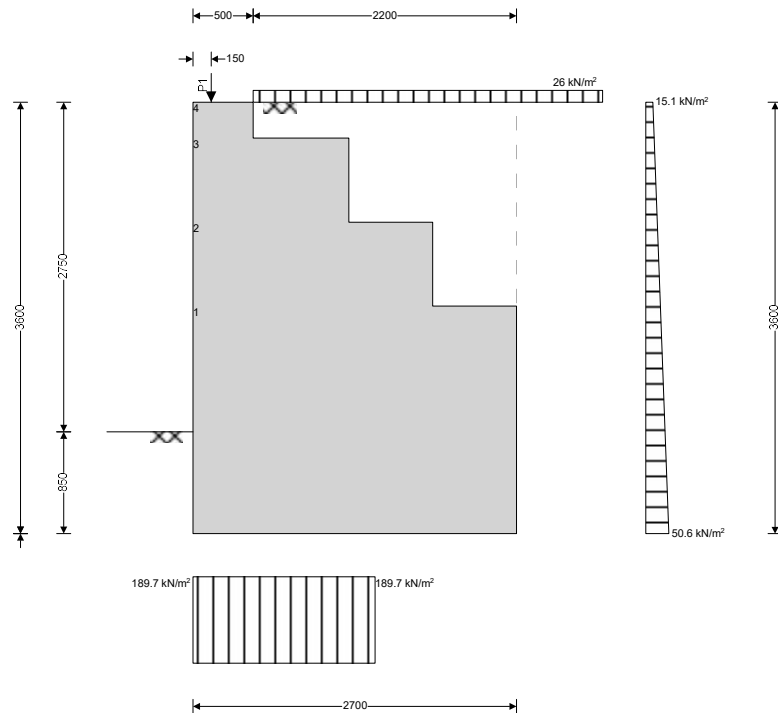
Base soil properties

Soil type	Dense rock fill
Soil density	$\gamma_b = 18$ kN/m ³
Characteristic cohesion	$c'_{b,k} = 0$ kN/m ²
Characteristic effective shear resistance angle	$\phi'_{b,k} = 40$ deg
Characteristic wall friction angle	$\delta_{b,k} = 20$ deg
Characteristic base friction angle	$\delta_{bb,k} = 30$ deg

Loading details

Variable surcharge load	Surcharge _Q = 20 kN/m ²
Vertical line load at 150 mm	$P_{G1} = 5$ kN/m

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General arrangement

Calculate retaining wall geometry

Base length

$$l_{base} = t_{s1} = 2700 \text{ mm}$$

Moist soil height

$$h_{moist} = h_{soil} = 3600 \text{ mm}$$

Length of surcharge load

$$l_{sur} = (l_{heel} + t_{s1} - t_{s4}) = 2200 \text{ mm}$$

- Distance to vertical component

$$x_{sur_v} = l_{base} - (l_{heel} + t_{s1} - t_{s4}) / 2 = 1600 \text{ mm}$$

Effective height of wall

$$h_{eff} = h_{base} + d_{cover} + h_{ret} = 3600 \text{ mm}$$

- Distance to horizontal component

$$x_{sur_h} = h_{eff} / 2 = 1800 \text{ mm}$$

Area of wall stem

$$A_{stem} = h_{s1} \times t_{s1} + h_{s2} \times t_{s2} + h_{s3} \times t_{s3} + h_{s4} \times t_{s4} = 7.59 \text{ m}^2$$

- Distance to vertical component

$$x_{stem} = l_{base} - (h_{s1} \times t_{s1} \times (l_{heel} + t_{s1} - t_{s1} / 2) + h_{s2} \times t_{s2} \times (l_{heel} + t_{s1} - t_{s2} / 2) + h_{s3} \times t_{s3} \times (l_{heel} + t_{s1} - t_{s3} / 2) + h_{s4} \times t_{s4} \times (l_{heel} + t_{s1} - t_{s4} / 2)) / A_{stem} = 1180 \text{ mm}$$

Area of wall base

$$A_{base} = l_{base} \times t_{base} = 0 \text{ m}^2$$

- Distance to vertical component

$$x_{base} = l_{base} / 2 = 1350 \text{ mm}$$

Area of moist soil

$$A_{moist} = l_{heel} \times h_{s1} + (l_{heel} + t_{s1} - t_{s2}) \times h_{s2} + (l_{heel} + t_{s1} - t_{s3}) \times h_{s3} + (l_{heel} + t_{s1} - t_{s4}) \times h_{s4} = 2.13 \text{ m}^2$$

- Distance to vertical component

$$x_{moist_v} = l_{base} - (l_{heel} \times h_{s1} \times l_{heel} / 2 + (l_{heel} + t_{s1} - t_{s2}) \times h_{s2} \times (l_{heel} + t_{s1} - t_{s2} / 2) + (l_{heel} + t_{s1} - t_{s3}) \times h_{s3} \times (l_{heel} + t_{s1} - t_{s3} / 2) + (l_{heel} + t_{s1} - t_{s4}) \times h_{s4} \times (l_{heel} + t_{s1} - t_{s4} / 2)) / A_{moist} = 1957 \text{ mm}$$

- Distance to horizontal component

$$x_{moist_h} = h_{eff} / 3 = 1200 \text{ mm}$$

Design approach 1

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

Partial factor set

A1

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Permanent unfavourable action $\gamma_G = 1.35$
Permanent favourable action $\gamma_{Gf} = 1.00$
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 $\gamma_{mr}' = \gamma_{mr} / \gamma_\gamma = 17 \text{ kN/m}^3$
Design saturated density $\gamma_{sr}' = \gamma_{sr} / \gamma_\gamma = 20.5 \text{ kN/m}^3$
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 $\gamma_b' = \gamma_b / \gamma_\gamma = 18 \text{ kN/m}^3$
Design effective shear resistance angle $\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_{\phi'}) = 40 \text{ deg}$
Design wall friction angle $\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_{\phi'}) = 20 \text{ deg}$
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 Rankine theory

At rest pressure coefficient $K_0 = 1 - \sin(\phi'_{r,d}) = 0.500$
Passive pressure coefficient $K_P = (1 + \sin(\phi'_{b,d})) / (1 - \sin(\phi'_{b,d})) = 4.599$

Sliding check

Vertical forces on wall

Wall stem $F_{\text{stem}} = \gamma_{Gf} \times A_{\text{stem}} \times \gamma_{\text{stem}} = 189.8 \text{ kN/m}$
Wall base $F_{\text{base}} = \gamma_{Gf} \times A_{\text{base}} \times \gamma_{\text{base}} = 0 \text{ kN/m}$
Line loads $F_{P_v} = \gamma_{Gf} \times P_{G1} = 5 \text{ kN/m}$
Moist retained soil $F_{\text{moist}_v} = \gamma_{Gf} \times A_{\text{moist}} \times \gamma_{mr}' = 36.2 \text{ kN/m}$
Total $F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{P_v} + F_{\text{moist}_v} = 231 \text{ kN/m}$

Horizontal forces on wall

Surcharge load $F_{\text{sur}_h} = K_0 \times \gamma_Q \times \text{Surcharge}_Q \times h_{\text{eff}} = 54 \text{ kN/m}$
Moist retained soil $F_{\text{moist}_h} = \gamma_G \times K_0 \times \gamma_{mr}' \times h_{\text{eff}}^2 / 2 = 74.4 \text{ kN/m}$
Total $F_{\text{total}_h} = F_{\text{sur}_h} + F_{\text{moist}_h} = 128.4 \text{ kN/m}$

Check stability against sliding

Base soil resistance $F_{\text{exc}_h} = \gamma_{Gf} \times K_P \times \gamma_b' \times (h_{\text{pass}} + h_{\text{base}})^2 / 2 = 29.9 \text{ kN/m}$
Base friction $F_{\text{friction}} = F_{\text{total}_v} \times \tan(\delta_{bb,d}) = 133.3 \text{ kN/m}$
Resistance to sliding $F_{\text{rest}} = F_{\text{exc}_h} + F_{\text{friction}} = 163.3 \text{ kN/m}$
Factor of safety $\text{FoS}_{\text{sl}} = F_{\text{rest}} / F_{\text{total}_h} = 1.272$

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem $F_{\text{stem}} = \gamma_{Gf} \times A_{\text{stem}} \times \gamma_{\text{stem}} = 189.8 \text{ kN/m}$

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Wall base

$$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = \mathbf{0 \text{ kN/m}}$$

Line loads

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

Moist retained soil

$$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' = \mathbf{36.2 \text{ kN/m}}$$

Total

$$F_{total_v} = F_{stem} + F_{base} + F_{P_v} + F_{moist_v} = \mathbf{231 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{sur_h} = K_0 \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} = \mathbf{54 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_h} = \gamma_G \times K_0 \times \gamma_{mr}' \times h_{eff}^2 / 2 = \mathbf{74.4 \text{ kN/m}}$$

Base soil

$$F_{exc_h} = -\gamma_{Gf} \times K_P \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = \mathbf{-29.9 \text{ kN/m}}$$

Total

$$F_{total_h} = F_{sur_h} + F_{moist_h} + F_{exc_h} = \mathbf{98.5 \text{ kN/m}}$$

Overturning moments on wall

Surcharge load

$$M_{sur_OT} = F_{sur_h} \times X_{sur_h} = \mathbf{97.2 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist_OT} = F_{moist_h} \times X_{moist_h} = \mathbf{89.2 \text{ kNm/m}}$$

Total

$$M_{total_OT} = M_{sur_OT} + M_{moist_OT} = \mathbf{186.4 \text{ kNm/m}}$$

Restoring moments on wall

Wall stem

$$M_{stem_R} = F_{stem} \times X_{stem} = \mathbf{223.9 \text{ kNm/m}}$$

Wall base

$$M_{base_R} = F_{base} \times X_{base} = \mathbf{0 \text{ kNm/m}}$$

Line loads

$$M_{P_R} = \text{abs}(\gamma_{Gf} \times P_{G1}) \times p_1 = \mathbf{0.8 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist_R} = F_{moist_v} \times X_{moist_v} = \mathbf{70.8 \text{ kNm/m}}$$

Base soil

$$M_{exc_R} = -F_{exc_h} \times X_{exc_h} = \mathbf{8.5 \text{ kNm/m}}$$

Total

$$M_{total_R} = M_{stem_R} + M_{base_R} + M_{P_R} + M_{moist_R} + M_{exc_R} = \mathbf{303.9 \text{ kNm/m}}$$

Check stability against overturning

Factor of safety

$$FoS_{ot} = M_{total_R} / M_{total_OT} = \mathbf{1.63}$$

PASS - Maximum restoring moment is greater than overturning moment

Bearing pressure check

Vertical forces on wall

Wall stem

$$F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem} = \mathbf{256.2 \text{ kN/m}}$$

Wall base

$$F_{base} = \gamma_G \times A_{base} \times \gamma_{base} = \mathbf{0 \text{ kN/m}}$$

Surcharge load

$$F_{sur_v} = \gamma_Q \times \text{Surcharge}_Q \times (l_{heel} + t_{s1} - t_{s4}) = \mathbf{66 \text{ kN/m}}$$

Line loads

$$F_{P_v} = \gamma_G \times P_{G1} = \mathbf{6.8 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_v} = \gamma_G \times A_{moist} \times \gamma_{mr}' = \mathbf{48.9 \text{ kN/m}}$$

Total

$$F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{P_v} + F_{moist_v} = \mathbf{377.8 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{sur_h} = K_0 \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} = \mathbf{54 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_h} = \gamma_G \times K_0 \times \gamma_{mr}' \times h_{eff}^2 / 2 = \mathbf{74.4 \text{ kN/m}}$$

Base soil

$$F_{pass_h} = -\gamma_{Gf} \times K_P \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2 = \mathbf{-29.9 \text{ kN/m}}$$

Total

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

Moments on wall

Wall stem

$$M_{stem} = F_{stem} \times X_{stem} = \mathbf{302.2 \text{ kNm/m}}$$

Wall base

$$M_{base} = F_{base} \times X_{base} = \mathbf{0 \text{ kNm/m}}$$

Surcharge load

$$M_{sur} = F_{sur_v} \times X_{sur_v} - F_{sur_h} \times X_{sur_h} = \mathbf{8.4 \text{ kNm/m}}$$

Line loads

$$M_P = \gamma_G \times P_{G1} \times p_1 = \mathbf{1 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist} = F_{moist_v} \times X_{moist_v} - F_{moist_h} \times X_{moist_h} = \mathbf{6.4 \text{ kNm/m}}$$

Base soil

$$M_{pass} = -F_{pass_h} \times X_{pass_h} = \mathbf{8.5 \text{ kNm/m}}$$

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Total $M_{total} = M_{stem} + M_{base} + M_{sur} + M_P + M_{moist} + M_{pass} = 326.5 \text{ kNm/m}$

Check bearing pressure

Distance to reaction $\bar{x} = M_{total} / F_{total_v} = 864 \text{ mm}$
 Eccentricity of reaction $e = \bar{x} - l_{base} / 2 = -486 \text{ mm}$
 Loaded length of base $l_{load} = 2 \times \bar{x} = 1728 \text{ mm}$
 Bearing pressure at toe $q_{toe} = F_{total_v} / l_{load} = 218.6 \text{ kN/m}^2$
 Bearing pressure at heel $q_{heel} = 0 \text{ kN/m}^2$
 Effective overburden pressure $q = (t_{base} + d_{cover}) \times \gamma'_b = 15.3 \text{ kN/m}^2$
 Design effective overburden pressure $q' = q / \gamma_\gamma = 15.3 \text{ kN/m}^2$
 Bearing resistance factors $N_q = \text{Exp}(\pi \times \tan(\phi'_{b,d})) \times (\tan(45 \text{ deg} + \phi'_{b,d} / 2))^2 = 64.195$
 $N_c = (N_q - 1) \times \cot(\phi'_{b,d}) = 75.313$
 $N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b,d}) = 106.054$

Foundation shape factors

$s_q = 1$
 $s_\gamma = 1$
 $s_c = 1$

Load inclination factors

$H = F_{sur_h} + F_{moist_h} + F_{pass_h} = 98.5 \text{ kN/m}$
 $V = F_{total_v} = 377.8 \text{ kN/m}$
 $m = 2$
 $i_q = [1 - H / (V + l_{load} \times c'_{b,d} \times \cot(\phi'_{b,d}))]^m = 0.547$
 $i_\gamma = [1 - H / (V + l_{load} \times c'_{b,d} \times \cot(\phi'_{b,d}))]^{(m+1)} = 0.404$
 $i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b,d})) = 0.54$

Net ultimate bearing capacity

$n_f = c'_{b,d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma'_b \times l_{load} \times N_\gamma \times s_\gamma \times i_\gamma = 1204 \text{ kN/m}^2$

Factor of safety

$FoS_{bp} = n_f / \max(q_{toe}, q_{heel}) = 5.508$

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 $\gamma_{Qf} = 0.00$

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 $\gamma_{mr}' = \gamma_{mr} / \gamma_\gamma = 17 \text{ kN/m}^3$
 Design saturated density $\gamma_{sr}' = \gamma_{sr} / \gamma_\gamma = 20.5 \text{ kN/m}^3$
 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 $\gamma'_b = \gamma_b / \gamma_\gamma = 18 \text{ kN/m}^3$

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Design effective shear resistance angle

$$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_{\phi'}) = \mathbf{33.9 \text{ deg}}$$

Design wall friction angle

$$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_{\phi'}) = \mathbf{16.2 \text{ deg}}$$

Design base friction angle

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

Design effective cohesion

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

Using Rankine theory

At rest pressure coefficient

$$K_0 = 1 - \sin(\phi'_{r,d}) = \mathbf{0.581}$$

Passive pressure coefficient

$$K_P = (1 + \sin(\phi'_{b,d})) / (1 - \sin(\phi'_{b,d})) = \mathbf{3.518}$$

Sliding check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = \gamma G_f \times A_{\text{stem}} \times \gamma_{\text{stem}} = \mathbf{189.8 \text{ kN/m}}$$

Wall base

$$F_{\text{base}} = \gamma G_f \times A_{\text{base}} \times \gamma_{\text{base}} = \mathbf{0 \text{ kN/m}}$$

Line loads

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

Moist retained soil

$$F_{\text{moist}_v} = \gamma G_f \times A_{\text{moist}} \times \gamma_{mr}' = \mathbf{36.2 \text{ kN/m}}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{P_v} + F_{\text{moist}_v} = \mathbf{231 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_0 \times \gamma_Q \times \text{Surcharge}_Q \times h_{\text{eff}} = \mathbf{54.4 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_h} = \gamma_G \times K_0 \times \gamma_{mr}' \times h_{\text{eff}}^2 / 2 = \mathbf{64 \text{ kN/m}}$$

Total

$$F_{\text{total}_h} = F_{\text{sur}_h} + F_{\text{moist}_h} = \mathbf{118.3 \text{ kN/m}}$$

Check stability against sliding

Base soil resistance

$$F_{\text{exc}_h} = \gamma G_f \times K_P \times \gamma_b' \times (h_{\text{pass}} + h_{\text{base}})^2 / 2 = \mathbf{22.9 \text{ kN/m}}$$

Base friction

$$F_{\text{friction}} = F_{\text{total}_v} \times \tan(\delta_{bb,d}) = \mathbf{106.7 \text{ kN/m}}$$

Resistance to sliding

$$F_{\text{rest}} = F_{\text{exc}_h} + F_{\text{friction}} = \mathbf{129.6 \text{ kN/m}}$$

Factor of safety

$$FoS_{sl} = F_{\text{rest}} / F_{\text{total}_h} = \mathbf{1.095}$$

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = \gamma G_f \times A_{\text{stem}} \times \gamma_{\text{stem}} = \mathbf{189.8 \text{ kN/m}}$$

Wall base

$$F_{\text{base}} = \gamma G_f \times A_{\text{base}} \times \gamma_{\text{base}} = \mathbf{0 \text{ kN/m}}$$

Line loads

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

Moist retained soil

$$F_{\text{moist}_v} = \gamma G_f \times A_{\text{moist}} \times \gamma_{mr}' = \mathbf{36.2 \text{ kN/m}}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{P_v} + F_{\text{moist}_v} = \mathbf{231 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_0 \times \gamma_Q \times \text{Surcharge}_Q \times h_{\text{eff}} = \mathbf{54.4 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_h} = \gamma_G \times K_0 \times \gamma_{mr}' \times h_{\text{eff}}^2 / 2 = \mathbf{64 \text{ kN/m}}$$

Base soil

$$F_{\text{exc}_h} = -\gamma G_f \times K_P \times \gamma_b' \times (h_{\text{pass}} + h_{\text{base}})^2 / 2 = \mathbf{-22.9 \text{ kN/m}}$$

Total

$$F_{\text{total}_h} = F_{\text{sur}_h} + F_{\text{moist}_h} + F_{\text{exc}_h} = \mathbf{95.4 \text{ kN/m}}$$

Overturning moments on wall

Surcharge load

$$M_{\text{sur}_OT} = F_{\text{sur}_h} \times X_{\text{sur}_h} = \mathbf{97.8 \text{ kNm/m}}$$

Moist retained soil

$$M_{\text{moist}_OT} = F_{\text{moist}_h} \times X_{\text{moist}_h} = \mathbf{76.8 \text{ kNm/m}}$$

Total

$$M_{\text{total}_OT} = M_{\text{sur}_OT} + M_{\text{moist}_OT} = \mathbf{174.6 \text{ kNm/m}}$$

Restoring moments on wall

Wall stem

$$M_{\text{stem}_R} = F_{\text{stem}} \times X_{\text{stem}} = \mathbf{223.9 \text{ kNm/m}}$$

Wall base

$$M_{\text{base}_R} = F_{\text{base}} \times X_{\text{base}} = \mathbf{0 \text{ kNm/m}}$$

Line loads

$$M_{P_R} = \text{abs}(\gamma G_f \times P_{G1}) \times p_1 = \mathbf{0.8 \text{ kNm/m}}$$

 Haigh Huddleston & Associates Civil Structural Engineering Consultants Haigh Huddleston & Associates 99-101 Leeds Road Dewsbury 01924 464342	Project				Job Ref.	
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Moist retained soil

$$M_{\text{moist}_R} = F_{\text{moist}_v} \times X_{\text{moist}_v} = \mathbf{70.8 \text{ kNm/m}}$$

Base soil

$$M_{\text{exc}_R} = -F_{\text{exc}_h} \times X_{\text{exc}_h} = \mathbf{6.5 \text{ kNm/m}}$$

Total

$$M_{\text{total}_R} = M_{\text{stem}_R} + M_{\text{base}_R} + M_{P_R} + M_{\text{moist}_R} + M_{\text{exc}_R} = \mathbf{302 \text{ kNm/m}}$$

Check stability against overturning

Factor of safety

$$FoS_{ot} = M_{\text{total}_R} / M_{\text{total}_{OT}} = \mathbf{1.729}$$

PASS - Maximum restoring moment is greater than overturning moment

Bearing pressure check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = \gamma_G \times A_{\text{stem}} \times \gamma_{\text{stem}} = \mathbf{189.8 \text{ kN/m}}$$

Wall base

$$F_{\text{base}} = \gamma_G \times A_{\text{base}} \times \gamma_{\text{base}} = \mathbf{0 \text{ kN/m}}$$

Surcharge load

$$F_{\text{sur}_v} = \gamma_Q \times \text{Surcharge}_Q \times (l_{\text{heel}} + t_{s1} - t_{s4}) = \mathbf{57.2 \text{ kN/m}}$$

Line loads

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

Moist retained soil

$$F_{\text{moist}_v} = \gamma_G \times A_{\text{moist}} \times \gamma_{mr}' = \mathbf{36.2 \text{ kN/m}}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{sur}_v} + F_{P_v} + F_{\text{moist}_v} = \mathbf{288.2 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_0 \times \gamma_Q \times \text{Surcharge}_Q \times h_{\text{eff}} = \mathbf{54.4 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_h} = \gamma_G \times K_0 \times \gamma_{mr}' \times h_{\text{eff}}^2 / 2 = \mathbf{64 \text{ kN/m}}$$

Base soil

$$F_{\text{pass}_h} = -\gamma_{Gf} \times K_P \times \gamma_b' \times (d_{\text{cover}} + h_{\text{base}})^2 / 2 = \mathbf{-22.9 \text{ kN/m}}$$

Total

$$F_{\text{total}_h} = \max(F_{\text{sur}_h} + F_{\text{moist}_h} + F_{\text{pass}_h} - F_{\text{total}_v} \times \tan(\delta_{bb,d}), 0 \text{ kN/m}) = \mathbf{0 \text{ kN/m}}$$

Moments on wall

Wall stem

$$M_{\text{stem}} = F_{\text{stem}} \times X_{\text{stem}} = \mathbf{223.9 \text{ kNm/m}}$$

Wall base

$$M_{\text{base}} = F_{\text{base}} \times X_{\text{base}} = \mathbf{0 \text{ kNm/m}}$$

Surcharge load

$$M_{\text{sur}} = F_{\text{sur}_v} \times X_{\text{sur}_v} - F_{\text{sur}_h} \times X_{\text{sur}_h} = \mathbf{-6.3 \text{ kNm/m}}$$

Line loads

$$M_P = \gamma_G \times P_{G1} \times p_1 = \mathbf{0.8 \text{ kNm/m}}$$

Moist retained soil

$$M_{\text{moist}} = F_{\text{moist}_v} \times X_{\text{moist}_v} - F_{\text{moist}_h} \times X_{\text{moist}_h} = \mathbf{-5.9 \text{ kNm/m}}$$

Base soil

$$M_{\text{pass}} = -F_{\text{pass}_h} \times X_{\text{pass}_h} = \mathbf{6.5 \text{ kNm/m}}$$

Total

$$M_{\text{total}} = M_{\text{stem}} + M_{\text{base}} + M_{\text{sur}} + M_P + M_{\text{moist}} + M_{\text{pass}} = \mathbf{218.9 \text{ kNm/m}}$$

Check bearing pressure

Distance to reaction

$$\bar{x} = M_{\text{total}} / F_{\text{total}_v} = \mathbf{760 \text{ mm}}$$

Eccentricity of reaction

$$e = \bar{x} - l_{\text{base}} / 2 = \mathbf{-590 \text{ mm}}$$

Loaded length of base

$$l_{\text{load}} = 2 \times \bar{x} = \mathbf{1519 \text{ mm}}$$

Bearing pressure at toe

$$q_{\text{toe}} = F_{\text{total}_v} / l_{\text{load}} = \mathbf{189.7 \text{ kN/m}^2}$$

Bearing pressure at heel

$$q_{\text{heel}} = \mathbf{0 \text{ kN/m}^2}$$

Effective overburden pressure

$$q = (t_{\text{base}} + d_{\text{cover}}) \times \gamma_b' = \mathbf{15.3 \text{ kN/m}^2}$$

Design effective overburden pressure

$$q' = q / \gamma_r = \mathbf{15.3 \text{ kN/m}^2}$$

Bearing resistance factors

$$N_q = \text{Exp}(\pi \times \tan(\phi'_{b,d})) \times (\tan(45 \text{ deg} + \phi'_{b,d} / 2))^2 = \mathbf{28.987}$$

$$N_c = (N_q - 1) \times \cot(\phi'_{b,d}) = \mathbf{41.692}$$

$$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b,d}) = \mathbf{37.574}$$

Foundation shape factors

$$S_q = 1$$

$$S_\gamma = 1$$

$$S_c = 1$$

Load inclination factors

$$H = F_{\text{sur}_h} + F_{\text{moist}_h} + F_{\text{pass}_h} = \mathbf{95.4 \text{ kN/m}}$$

$$V = F_{\text{total}_v} = \mathbf{288.2 \text{ kN/m}}$$

$$m = 2$$

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$$i_q = [1 - H / (V + l_{load} \times c'_{b,d} \times \cot(\phi'_{b,d}))]^m = \mathbf{0.447}$$

$$i_\gamma = [1 - H / (V + l_{load} \times c'_{b,d} \times \cot(\phi'_{b,d}))]^{(m+1)} = \mathbf{0.299}$$

$$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b,d})) = \mathbf{0.428}$$

Net ultimate bearing capacity

$$n_f = c'_{b,d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_b' \times l_{load} \times N_\gamma \times s_\gamma \times i_\gamma = \mathbf{352.1 \text{ kN/m}^2}$$

Factor of safety

$$FoS_{bp} = n_f / \max(q_{toe}, q_{heel}) = \mathbf{1.856}$$

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure