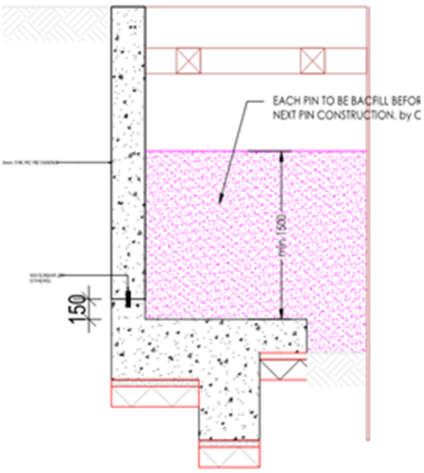
AIM:

Provide calculation for permanent RC retaining wall construction in temporary condition. All set out on DWG: 4070-09-1 & 4070-10-1.

Design Standards used:

- BS EN 1990:2002- Eurocode 0: Basis of structural design
-BS EN 1991-1-1:2002 - Eurocode 1: Actions on structures. General Actions- Densities, self-weight and imposed loads for buildings
-BS EN 5975:2019 Code of Practice for temporary works procedures and permissible stress design of falsework
-BS EN 1997-1 Geotechnical design.
-EN1997-1:2004

Phase 2- step 2:



STEP 2

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 2.9.10

Analysis summary

Description	Unit	Capacity	Applied	F o S	Result
Sliding stability	kN/m	228.8	59.6	3.837	PASS
Overturning stability	kNm/m	72.8	51.2	1.421	PASS
Bearing pressure	kN/m^2	461.3	115	4.011	PASS

Retaining wall details

Stem type; Cantilever

Stem height; h_{stem} = **2323** mm

Stem thickness; t_{stem} = **250** mm

Angle to rear face of stem; α = **90** deg

Stem density; γ_{stem} = **25** kN/m^3
Toe length; l_{toe} = **1200** mm
Base thickness; t_{base} = **450** mm
Key position; p_{key} = **400** mm
Key depth; d_{key} = **450** mm
Key thickness; t_{key} = **450** mm
Base density; γ_{base} = **25** kN/m^3
Height of retained soil; h_{ret} = **823** mm
Angle of soil surface; β = **0** deg
Depth of cover; d_{cover} = **1500** mm

Retained soil properties

Soil type; Medium dense well graded sand
Moist density; γ_{mr} = **20** kN/m^3
Saturated density; γ_{sr} = **22** kN/m^3
Characteristic effective shear resistance angle; $\phi'_{r.k}$ = **30** deg
Characteristic wall friction angle; $\delta_{r.k}$ = **0** deg

Base soil properties

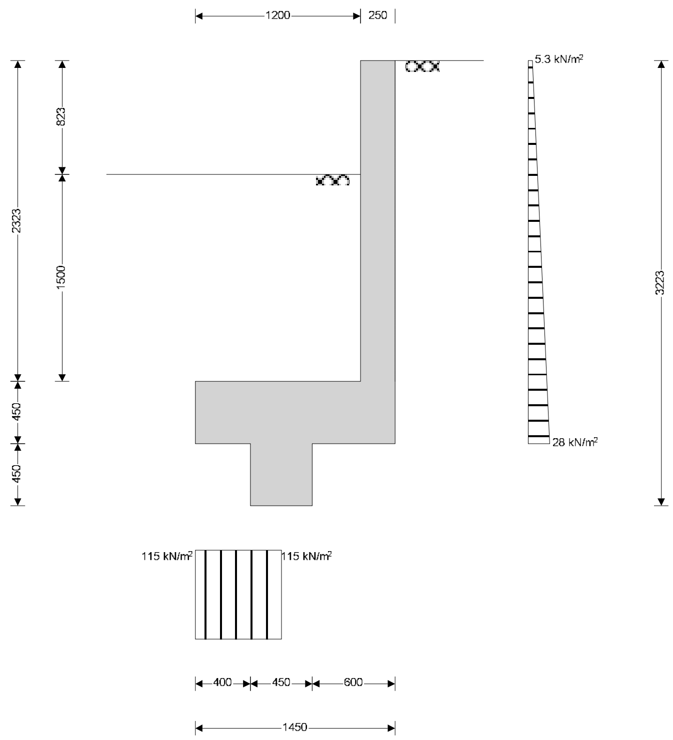
Soil type; Medium dense well graded sand
Soil density; γ_b = **20** kN/m^3
Characteristic cohesion; $c'_{b.k}$ = **0** kN/m^2
Characteristic effective shear resistance angle; $\phi'_{b.k}$ = **30** deg
Characteristic wall friction angle; $\delta_{b.k}$ = **15** deg
Characteristic base friction angle; $\delta_{bb.k}$ = **30** deg

Loading details

Variable surcharge load; $Surcharge_Q$ = **10** kN/m^2

Project: 12 PILGRIM'S LANE, HAMPSTEAD, LONDON		Job Ref.: 4070-01-C0
Section:		Sheet no./rev.: 3

Calc. by	Date	Chk'd by	Date	App'd by	Date
MH	25.01.2024	S	25.01.24		



General arrangement

Calculate retaining wall geometry

Base length;	$l_{base} = l_{toe} + t_{stem} = \mathbf{1450}$ mm
Base height;	$h_{base} = t_{base} + d_{key} = \mathbf{900}$ mm
Moist soil height;	$h_{moist} = h_{soil} = \mathbf{2323}$ mm
Length of surcharge load;	$l_{sur} = l_{heel} = \mathbf{0}$ mm
- Distance to vertical component;	$x_{sur\_v} = l_{base} - l_{heel} / 2 = \mathbf{1450}$ mm
Effective height of wall;	$h_{eff} = h_{base} + d_{cover} + h_{ret} = \mathbf{3223}$ mm
- Distance to horizontal component;	$x_{sur\_h} = h_{eff} / 2 - d_{key} = \mathbf{1162}$ mm
- Distance to horizontal component above key;	$x_{sur\_h\_a} = (h_{eff} - d_{key}) / 2 = \mathbf{1387}$ mm
Area of wall stem;	$A_{stem} = h_{stem} \times t_{stem} = \mathbf{0.581}$ m^2
- Distance to vertical component;	$x_{stem} = l_{toe} + t_{stem} / 2 = \mathbf{1325}$ mm
Area of wall base;	$A_{base} = l_{base} \times t_{base} + d_{key} \times t_{key} = \mathbf{0.855}$ m^2
- Distance to vertical component;	$x_{base} = (l_{base}^2 \times t_{base} / 2 + d_{key} \times t_{key} \times (p_{key} + t_{key} / 2)) / A_{base} = \mathbf{701}$ mm
Area of base soil;	$A_{pass} = d_{cover} \times l_{toe} = \mathbf{1.8}$ m^2
- Distance to vertical component;	$x_{pass\_v} = l_{base} - (d_{cover} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{pass} = \mathbf{600}$ mm
- Distance to horizontal component;	$x_{pass\_h} = (d_{cover} + h_{base}) / 3 - d_{key} = \mathbf{350}$ mm
Area of excavated base soil;	$A_{exc} = h_{pass} \times l_{toe} = \mathbf{1.8}$ m^2
- Distance to vertical component;	$x_{exc\_v} = l_{base} - (h_{pass} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{exc} = \mathbf{600}$ mm
- Distance to horizontal component;	$x_{exc\_h} = (h_{pass} + h_{base}) / 3 - d_{key} = \mathbf{350}$ mm

Design approach 1

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

Partial factor set; A1

Permanent unfavourable action; γ_G = **1.35**

Permanent favourable action; γ_{Gf} = **1.00**

Variable unfavourable action; γ_Q = **1.50**

Variable favourable action; γ_{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; γ_γ = **1.00**

Library item; Partial factors output

Retained soil properties

Design moist density; $\gamma_{mr}' = \gamma_{mr} / \gamma_\gamma$ = **20** kN/m^3

Design saturated density; $\gamma_{sr}' = \gamma_{sr} / \gamma_\gamma$ = **22** kN/m^3

Design effective shear resistance angle; $\phi'_{r.d} = \text{atan}(\tan(\phi'_{r.k}) / \gamma_{\phi'})$ = **30** deg

Design wall friction angle; $\delta_{r.d} = \text{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'})$ = **0** deg

Base soil properties

Design soil density; $\gamma_b' = \gamma_b / \gamma_\gamma$ = **20** kN/m^3

Design effective shear resistance angle; $\phi'_{b.d} = \text{atan}(\tan(\phi'_{b.k}) / \gamma_{\phi'})$ = **30** deg

Design wall friction angle; $\delta_{b.d} = \text{atan}(\tan(\delta_{b.k}) / \gamma_{\phi'})$ = **15** deg

Design base friction angle; $\delta_{bb.d} = \text{atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'})$ = **30** deg

Design effective cohesion; $c'_{b.d} = c'_{b.k} / \gamma_{c'}$ = **0** 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; $F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem}$ = **14.5** kN/m

Wall base; $F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base}$ = **21.4** kN/m

Base soil; $F_{exc\_v} = \gamma_{Gf} \times A_{exc} \times \gamma_b'$ = **36** kN/m

Total; $F_{total\_v} = F_{stem} + F_{base} + F_{exc\_v}$ = **71.9** kN/m

Horizontal forces on wall

Surcharge load; $F_{sur\_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff}$ = **16.1** kN/m

Moist retained soil; $F_{moist\_h} = \gamma_G \times K_A \times \gamma_{mr}' \times h_{eff}^2 / 2$ = **46.7** kN/m

Total; $F_{total\_h} = F_{sur\_h} + F_{moist\_h}$ = **62.9** kN/m

Check stability against sliding

Base soil resistance; $F_{exc\_h} = \gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2$ = **276.9** kN/m

Base friction; $F_{friction} = F_{total\_v} \times \tan(\delta_{bb.d})$ = **41.5** kN/m

Resistance to sliding; $F_{rest} = F_{exc\_h} + F_{friction}$ = **318.4** kN/m

Factor of safety; $FoS_{sl} = F_{rest} / F_{total\_h}$ = **5.065**

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem; $F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem}$ = **14.5** kN/m

Wall base; $F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base}$ = **21.4** kN/m

Base soil; $F_{exc\_v} = \gamma_{Gf} \times A_{exc} \times \gamma_b'$ = **36** kN/m

Total; $F_{total\_v} = F_{stem} + F_{base} + F_{exc\_v}$ = **71.9** kN/m

Horizontal forces on wall

Surcharge load; $F_{sur\_h} = K_A \times \gamma_Q \times Surcharge_Q \times (h_{eff} - d_{key})$ = **13.9** kN/m

Moist retained soil; $F_{moist\_h} = \gamma_G \times K_A \times \gamma_{mr}' \times (h_{eff} - d_{key})^2 / 2$ = **34.6** kN/m

Base soil; $F_{exc\_h} = \max(-\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2, -(F_{moist\_h} + F_{sur\_h}))$ = **-48.5** kN/m

Total; $F_{total\_h} = F_{sur\_h} + F_{moist\_h} + F_{exc\_h}$ = **0** kN/m

Overturning moments on wall

Surcharge load; $M_{sur\_OT} = F_{sur\_h} \times x_{sur\_h\_a}$ = **19.2** kNm/m

Moist retained soil; $M_{moist\_OT} = F_{moist\_h} \times x_{moist\_h\_a}$ = **32** kNm/m

Total; $M_{total\_OT} = M_{sur\_OT} + M_{moist\_OT}$ = **51.2** kNm/m

Restoring moments on wall

Wall stem; $M_{stem\_R} = F_{stem} \times x_{stem}$ = **19.2** kNm/m

Wall base; $M_{base\_R} = F_{base} \times x_{base}$ = **15** kNm/m

Base soil; $M_{exc\_R} = F_{exc\_v} \times x_{exc\_v} - F_{exc\_h} \times x_{exc\_h}$ = **38.6** kNm/m

Total; $M_{total\_R} = M_{stem\_R} + M_{base\_R} + M_{exc\_R}$ = **72.8** kNm/m

Check stability against overturning

Factor of safety; $FoS_{ot} = M_{total\_R} / M_{total\_OT}$ = **1.421**

PASS - Maximum restoring moment is greater than overturning moment

Bearing pressure check

Vertical forces on wall

Wall stem; $F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem}$ = **19.6** kN/m

Wall base; $F_{base} = \gamma_G \times A_{base} \times \gamma_{base}$ = **28.9** kN/m

Base soil; $F_{pass\_v} = \gamma_G \times A_{pass} \times \gamma_b'$ = **48.6** kN/m

Total; $F_{total\_v} = F_{stem} + F_{base} + F_{pass\_v}$ = **97.1** kN/m

Horizontal forces on wall

Surcharge load; $F_{sur\_h} = K_A \times \gamma_Q \times Surcharge_Q \times (h_{eff} - d_{key})$ = **13.9** kN/m

Moist retained soil; $F_{moist\_h} = \gamma_G \times K_A \times \gamma_{mr}' \times (h_{eff} - d_{key})^2 / 2$ = **34.6** kN/m

Base soil; $F_{pass\_h} = \max(-\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2, -(F_{moist\_h} + F_{sur\_h}))$ = **-48.5** kN/m

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

Moments on wall

Wall stem; $M_{stem} = F_{stem} \times x_{stem}$ = **26** kNm/m

Wall base; $M_{base} = F_{base} \times x_{base}$ = **20.2** kNm/m

Surcharge load; $M_{sur} = -F_{sur\_h} \times x_{sur\_h\_a}$ = **-19.2** kNm/m

Moist retained soil; $M_{moist} = -F_{moist\_h} \times x_{moist\_h\_a}$ = **-32** kNm/m

Base soil; $M_{pass} = F_{pass\_v} \times x_{pass\_v} - F_{pass\_h} \times x_{pass\_h}$ = **46.1** kNm/m

Total; $M_{total} = M_{stem} + M_{base} + M_{sur} + M_{moist} + M_{pass}$ = **41.1** kNm/m

Check bearing pressure

Distance to reaction; $\bar{x} = M_{total} / F_{total\_v}$ = **424** mm

Eccentricity of reaction; $e = \bar{x} - l_{base} / 2$ = **-301** mm

Loaded length of base; $l_{load} = 2 \times \bar{x}$ = **847** mm

Bearing pressure at toe; $q_{toe} = F_{total\_v} / l_{load}$ = **114.5** kN/m^2

Bearing pressure at heel; q_{heel} = **0** kN/m^2

Effective overburden pressure; $q = (t_{base} + d_{cover}) \times \gamma_b'$ = **39** kN/m^2

Design effective overburden pressure; $q' = q / \gamma_\gamma$ = **39** kN/m^2

Bearing resistance factors; $N_q = Exp(\pi \times tan(\phi'_{b.d})) \times (tan(45 deg + \phi'_{b.d} / 2))^2$ = **18.401**

$N_c = (N_q - 1) \times cot(\phi'_{b.d})$ = **30.14**

$N_\gamma = 2 \times (N_q - 1) \times tan(\phi'_{b.d})$ = **20.093**

Foundation shape factors; $s_q = 1$

$s_\gamma = 1$

$s_c = 1$

Load inclination factors; $H = F_{sur\_h} + F_{moist\_h} + F_{pass\_h}$ = **0** kN/m

$V = F_{total\_v}$ = **97.1** kN/m

$m = 2$

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

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

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

Net ultimate bearing capacity

$n_f = c'_{b.d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_b' \times l_{load} \times N_\gamma \times s_\gamma \times i_\gamma$ = **887.9** kN/m^2

Factor of safety; $FoS_{bp} = n_f / max(q_{toe}, q_{heel})$ = **7.752**

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; γ_G = **1.00**

Permanent favourable action; γ_{Gf} = **1.00**

Variable unfavourable action; γ_Q = **1.30**

Variable favourable action; γ_{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; γ_γ = **1.00**

Library item; Partial factors output

Retained soil properties

Design moist density; $\gamma_{mr}' = \gamma_{mr} / \gamma_\gamma$ = **20** kN/m^3

Design saturated density; $\gamma_{sr}' = \gamma_{sr} / \gamma_\gamma$ = **22** kN/m^3

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

Design wall friction angle; $\delta_{r.d} = atan(tan(\delta_{r.k}) / \gamma_{\phi'})$ = **0** deg

Base soil properties

Design soil density; $\gamma_b' = \gamma_b / \gamma_\gamma = \mathbf{20}$ kN/m^3

Design effective shear resistance angle; $\phi'_{b.d} = atan(tan(\phi'_{b.k}) / \gamma_{\phi'}) = \mathbf{24.8}$ deg

Design wall friction angle; $\delta_{b.d} = atan(tan(\delta_{b.k}) / \gamma_{\phi'}) = \mathbf{12.1}$ deg

Design base friction angle; $\delta_{bb.d} = atan(tan(\delta_{bb.k}) / \gamma_{\phi'}) = \mathbf{24.8}$ deg

Design effective cohesion; $c'_{b.d} = c'_{b.k} / \gamma_{c'} = \mathbf{0}$ 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; $F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = \mathbf{14.5}$ kN/m

Wall base; $F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = \mathbf{21.4}$ kN/m

Base soil; $F_{exc\_v} = \gamma_{Gf} \times A_{exc} \times \gamma_b' = \mathbf{36}$ kN/m

Total; $F_{total\_v} = F_{stem} + F_{base} + F_{exc\_v} = \mathbf{71.9}$ kN/m

Horizontal forces on wall

Surcharge load; $F_{sur\_h} = K_A \times \gamma_Q \times Surcharge_Q \times h_{eff} = \mathbf{17.1}$ kN/m

Moist retained soil; $F_{moist\_h} = \gamma_G \times K_A \times \gamma_{mr}' \times h_{eff}^2 / 2 = \mathbf{42.5}$ kN/m

Total; $F_{total\_h} = F_{sur\_h} + F_{moist\_h} = \mathbf{59.6}$ kN/m

Check stability against sliding

Base soil resistance; $F_{exc\_h} = \gamma_{Gf} \times K_P \times cos(\delta_{b.d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = \mathbf{195.6}$ kN/m

Base friction; $F_{friction} = F_{total\_v} \times tan(\delta_{bb.d}) = \mathbf{33.2}$ kN/m

Resistance to sliding; $F_{rest} = F_{exc\_h} + F_{friction} = \mathbf{228.8}$ kN/m

Factor of safety; $FoS_{sl} = F_{rest} / F_{total\_h} = \mathbf{3.837}$

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem; $F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = \mathbf{14.5}$ kN/m

Wall base; $F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = \mathbf{21.4}$ kN/m

Base soil; $F_{exc\_v} = \gamma_{Gf} \times A_{exc} \times \gamma_b' = \mathbf{36}$ kN/m

Total; $F_{total\_v} = F_{stem} + F_{base} + F_{exc\_v} = \mathbf{71.9}$ kN/m

Horizontal forces on wall

Surcharge load; $F_{sur\_h} = K_A \times \gamma_Q \times Surcharge_Q \times (h_{eff} - d_{key}) = \mathbf{14.7}$ kN/m

Moist retained soil; $F_{moist\_h} = \gamma_G \times K_A \times \gamma_{mr}' \times (h_{eff} - d_{key})^2 / 2 = \mathbf{31.5}$ kN/m

Base soil; $F_{exc\_h} = max(-\gamma_{Gf} \times K_P \times cos(\delta_{b.d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2, -(F_{moist\_h} + F_{sur\_h})) = \mathbf{-46.2}$ kN/m

Total; $F_{total\_h} = F_{sur\_h} + F_{moist\_h} + F_{exc\_h} = \mathbf{0}$ kN/m

Overturning moments on wall

Surcharge load; $M_{sur\_OT} = F_{sur\_h} \times x_{sur\_h\_a} = \mathbf{20.4}$ kNm/m

Moist retained soil; $M_{moist\_OT} = F_{moist\_h} \times x_{moist\_h\_a} = \mathbf{29.1}$ kNm/m

Total; $M_{total\_OT} = M_{sur\_OT} + M_{moist\_OT} = \mathbf{49.5}$ kNm/m

Restoring moments on wall

Wall stem; $M_{stem\_R} = F_{stem} \times x_{stem}$ = **19.2** kNm/m

Wall base; $M_{base\_R} = F_{base} \times x_{base}$ = **15** kNm/m

Base soil; $M_{exc\_R} = F_{exc\_v} \times x_{exc\_v} - F_{exc\_h} \times x_{exc\_h}$ = **37.8** kNm/m

Total; $M_{total\_R} = M_{stem\_R} + M_{base\_R} + M_{exc\_R}$ = **72** kNm/m

Check stability against overturning

Factor of safety; $FoS_{ot} = M_{total\_R} / M_{total\_OT}$ = **1.454**

PASS - Maximum restoring moment is greater than overturning moment

Bearing pressure check

Vertical forces on wall

Wall stem; $F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem}$ = **14.5** kN/m

Wall base; $F_{base} = \gamma_G \times A_{base} \times \gamma_{base}$ = **21.4** kN/m

Base soil; $F_{pass\_v} = \gamma_G \times A_{pass} \times \gamma_b'$ = **36** kN/m

Total; $F_{total\_v} = F_{stem} + F_{base} + F_{pass\_v}$ = **71.9** kN/m

Horizontal forces on wall

Surcharge load; $F_{sur\_h} = K_A \times \gamma_Q \times Surcharge_Q \times (h_{eff} - d_{key})$ = **14.7** kN/m

Moist retained soil; $F_{moist\_h} = \gamma_G \times K_A \times \gamma_{mr}' \times (h_{eff} - d_{key})^2 / 2$ = **31.5** kN/m

Base soil; $F_{pass\_h} = \max(-\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2, -(F_{moist\_h} + F_{sur\_h}))$ = **-46.2** kN/m

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

Moments on wall

Wall stem; $M_{stem} = F_{stem} \times x_{stem}$ = **19.2** kNm/m

Wall base; $M_{base} = F_{base} \times x_{base}$ = **15** kNm/m

Surcharge load; $M_{sur} = -F_{sur\_h} \times x_{sur\_h\_a}$ = **-20.4** kNm/m

Moist retained soil; $M_{moist} = -F_{moist\_h} \times x_{moist\_h\_a}$ = **-29.1** kNm/m

Base soil; $M_{pass} = F_{pass\_v} \times x_{pass\_v} - F_{pass\_h} \times x_{pass\_h}$ = **37.8** kNm/m

Total; $M_{total} = M_{stem} + M_{base} + M_{sur} + M_{moist} + M_{pass}$ = **22.5** kNm/m

Check bearing pressure

Distance to reaction; $\bar{x} = M_{total} / F_{total\_v}$ = **313** mm

Eccentricity of reaction; $e = \bar{x} - l_{base} / 2$ = **-412** mm

Loaded length of base; $l_{load} = 2 \times \bar{x}$ = **625** mm

Bearing pressure at toe; $q_{toe} = F_{total\_v} / l_{load}$ = **115** kN/m^2

Bearing pressure at heel; q_{heel} = **0** kN/m^2

Effective overburden pressure; $q = (t_{base} + d_{cover}) \times \gamma_b'$ = **39** kN/m^2

Design effective overburden pressure; $q' = q / \gamma_\gamma$ = **39** kN/m^2

Bearing resistance factors; $N_q = Exp(\pi \times \tan(\phi'_{b.d})) \times (\tan(45\ deg + \phi'_{b.d} / 2))^2$ = **10.431**

$N_c = (N_q - 1) \times \cot(\phi'_{b.d})$ = **20.418**

$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b.d})$ = **8.712**

Foundation shape factors; $s_q = 1$

$s_\gamma = 1$

$s_c = 1$

Load inclination factors; $H = F_{sur\_h} + F_{moist\_h} + F_{pass\_h}$ = **0** kN/m

$V = F_{total\_v}$ = **71.9** kN/m

$m = 2$

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

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

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

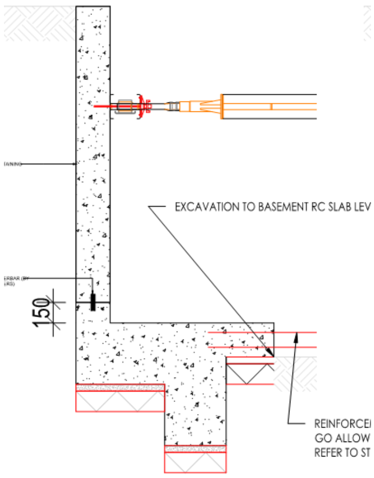
Net ultimate bearing capacity

$n_f = c'_{b.d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_b' \times l_{load} \times N_\gamma \times s_\gamma \times i_\gamma = \mathbf{461.3}$ kN/m^2

Factor of safety; $FoS_{bp} = n_f / \max(q_{toe}, q_{heel}) = \mathbf{4.011}$

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

Phase 3- step 4:



STEP 4

<u>RETAINING WALL ANALYSIS</u>

In accordance with EN1997-1:2004 incorporating Corrigendum dated February 2009 and the UK National Annex incorporating Corrigendum No.1

Tedds calculation version 2.9.10

<u>Analysis summary</u>

Description	Unit	Capacity	Applied	F o S	Result
Bearing pressure	kN/m^2	217.8	24.8	8.800	PASS

Retaining wall details

Stem type; Propped cantilever

Stem height; h_{stem} = **2323** mm

Prop height; h_{prop} = **2000** mm

Stem thickness; t_{stem} = **250** mm

Angle to rear face of stem; α = **90** deg

Stem density; γ_{stem} = **25** kN/m^3

Toe length; l_{toe} = **1200** mm

Base thickness; t_{base} = **450** mm

Key position; p_{key} = **400** mm

Key depth; d_{key} = **450** mm

Key thickness; t_{key} = **450** mm

Base density; γ_{base} = **25** kN/m^3

Height of retained soil; h_{ret} = **2323** mm

Angle of soil surface; β = **0** deg

Depth of cover; d_{cover} = **0** mm

Retained soil properties

Soil type; Medium dense well graded sand

Moist density; γ_{mr} = **20** kN/m^3

Saturated density; γ_{sr} = **22** kN/m^3

Characteristic effective shear resistance angle; $\phi'_{r.k}$ = **30** deg

Characteristic wall friction angle; $\delta_{r.k}$ = **0** deg

Base soil properties

Soil type; Medium dense well graded sand

Soil density; γ_b = **20** kN/m^3

Characteristic cohesion; $c'_{b.k}$ = **0** kN/m^2

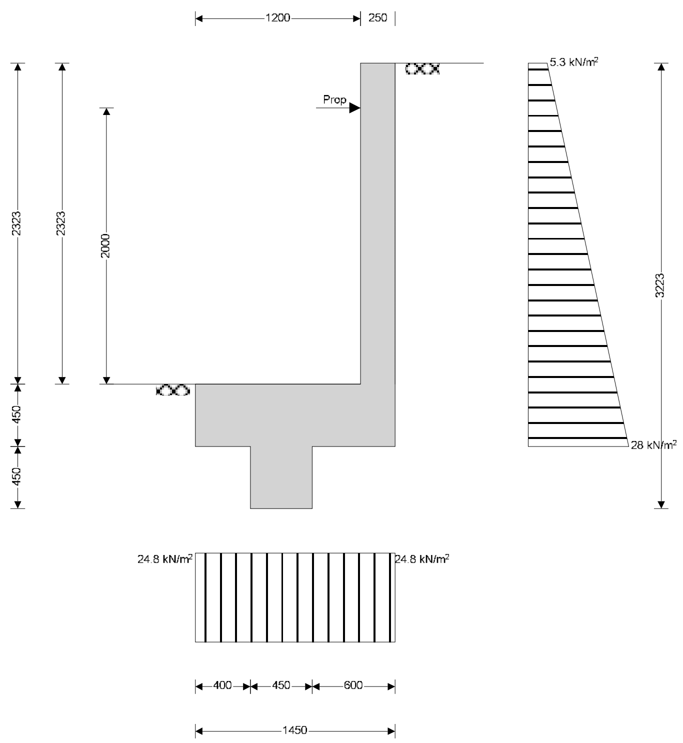
Characteristic effective shear resistance angle; $\phi'_{b.k}$ = **30** deg

Characteristic wall friction angle; $\delta_{b.k}$ = **15** deg

Characteristic base friction angle; $\delta_{bb.k}$ = **30** deg

Loading details

Variable surcharge load; $Surcharge_Q$ = **10** kN/m^2



General arrangement

Calculate retaining wall geometry

Base length; $l_{base} = l_{toe} + t_{stem}$ = **1450** mm

Base height; $h_{base} = t_{base} + d_{key} = \mathbf{900}$ mm

Moist soil height; $h_{moist} = h_{soil} = \mathbf{2323}$ mm

Length of surcharge load; $l_{sur} = l_{heel} = \mathbf{0}$ mm

- Distance to vertical component; $x_{sur\_v} = l_{base} - l_{heel} / 2 = \mathbf{1450}$ mm

Effective height of wall; $h_{eff} = h_{base} + d_{cover} + h_{ret} = \mathbf{3223}$ mm

- Distance to horizontal component; $x_{sur\_h} = h_{eff} / 2 - d_{key} = \mathbf{1162}$ mm

- Distance to horizontal component above key; $x_{sur\_h\_a} = (h_{eff} - d_{key}) / 2 = \mathbf{1387}$ mm

Area of wall stem; $A_{stem} = h_{stem} \times t_{stem} = \mathbf{0.581}$ m^2

- Distance to vertical component; $x_{stem} = l_{toe} + t_{stem} / 2 = \mathbf{1325}$ mm

Area of wall base; $A_{base} = l_{base} \times t_{base} + d_{key} \times t_{key} = \mathbf{0.855}$ m^2

- Distance to vertical component; $x_{base} = (l_{base}^2 \times t_{base} / 2 + d_{key} \times t_{key} \times (p_{key} + t_{key} / 2)) / A_{base} = \mathbf{701}$ mm

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

Variable unfavourable action; $\gamma_Q = \mathbf{1.50}$

Variable favourable action; $\gamma_{Qf} = \mathbf{0.00}$

;**Partial factors for soil parameters – Table A.4 - Combination 1**

Soil parameter set; M1

Angle of shearing resistance; $\gamma_{\phi'} = \mathbf{1.00}$

Effective cohesion; $\gamma_{c'} = \mathbf{1.00}$

Weight density; $\gamma_\gamma = \mathbf{1.00}$

Library item; Partial factors output

Retained soil properties

Design moist density; $\gamma_{mr}' = \gamma_{mr} / \gamma_\gamma = \mathbf{20}$ kN/m^3

Design saturated density; $\gamma_{sr}' = \gamma_{sr} / \gamma_\gamma = \mathbf{22}$ kN/m^3

Design effective shear resistance angle; $\phi'_{r.d} = \text{atan}(\tan(\phi'_{r.k}) / \gamma_{\phi'}) = \mathbf{30}$ deg

Design wall friction angle; $\delta_{r.d} = \text{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'}) = \mathbf{0}$ deg

Base soil properties

Design soil density; $\gamma_b' = \gamma_b / \gamma_\gamma = \mathbf{20}$ kN/m^3

Design effective shear resistance angle; $\phi'_{b.d} = \text{atan}(\tan(\phi'_{b.k}) / \gamma_{\phi'}) = \mathbf{30}$ deg

Design wall friction angle; $\delta_{b.d} = \text{atan}(\tan(\delta_{b.k}) / \gamma_{\phi'}) = \mathbf{15}$ deg

Design base friction angle; $\delta_{bb.d} = \text{atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'}) = \mathbf{30}$ deg

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

Using Coulomb theory

Active pressure coefficient; $K_A = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times [1 + \sqrt{[\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))]}]^2) = \mathbf{0.333}$

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

Bearing pressure check

Vertical forces on wall

Wall stem; $F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem} = \mathbf{19.6}$ kN/m

Wall base; $F_{base} = \gamma_G \times A_{base} \times \gamma_{base} = \mathbf{28.9}$ kN/m

Total; $F_{total\_v} = F_{stem} + F_{base} = \mathbf{48.5}$ kN/m

Horizontal forces on wall

Surcharge load; $F_{sur\_h} = K_A \times \gamma_Q \times Surcharge_Q \times (h_{eff} - d_{key}) = \mathbf{13.9}$ kN/m

Moist retained soil; $F_{moist\_h} = \gamma_G \times K_A \times \gamma_{mr}' \times (h_{eff} - d_{key})^2 / 2 = \mathbf{34.6}$ kN/m

Base soil; $F_{pass\_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2 = \mathbf{-38.9}$ kN/m

Total; $F_{total\_h} = F_{sur\_h} + F_{moist\_h} + F_{pass\_h} = \mathbf{9.5}$ kN/m

Moments on wall

Wall stem; $M_{stem} = F_{stem} \times x_{stem} = \mathbf{26}$ kNm/m

Wall base; $M_{base} = F_{base} \times x_{base} = \mathbf{20.2}$ kNm/m

Surcharge load; $M_{sur} = -F_{sur\_h} \times x_{sur\_h\_a} = \mathbf{-19.2}$ kNm/m

Moist retained soil; $M_{moist} = -F_{moist\_h} \times x_{moist\_h\_a} = \mathbf{-32}$ kNm/m

Base soil; $M_{pass} = -F_{pass\_h} \times x_{pass\_h} = \mathbf{-5.8}$ kNm/m

Total; $M_{total} = M_{stem} + M_{base} + M_{sur} + M_{moist} + M_{pass} = \mathbf{-10.8}$ kNm/m

Check bearing pressure

Maximum friction force; $F_{friction\_max} = F_{total\_v} \times \tan(\delta_{bb.d}) = \mathbf{28}$ kN/m

Propping force; $F_{prop\_stem} = \max((F_{total\_v} \times l_{base} / 2 - M_{total}) / (h_{prop} + t_{base}), F_{total\_h} - F_{friction\_max}) = \mathbf{18.8}$ kN/m

Moment from propping force; $M_{prop} = F_{prop\_stem} \times (h_{prop} + t_{base}) = \mathbf{46}$ kNm/m

Distance to reaction; $\bar{x} = (M_{total} + M_{prop}) / F_{total\_v} = \mathbf{725}$ mm

Eccentricity of reaction; $e = \bar{x} - l_{base} / 2 = \mathbf{0}$ mm

Loaded length of base; $l_{load} = l_{base} = \mathbf{1450}$ mm

Bearing pressure at toe; $q_{toe} = F_{total\_v} / l_{base} = \mathbf{33.4}$ kN/m^2

Bearing pressure at heel; $q_{heel} = F_{total\_v} / l_{base} = \mathbf{33.4}$ kN/m^2

Effective overburden pressure; $q = (t_{base} + d_{cover}) \times \gamma_b' = \mathbf{9}$ kN/m^2

Design effective overburden pressure; $q' = q / \gamma_\gamma = \mathbf{9}$ kN/m^2

Bearing resistance factors; $N_q = Exp(\pi \times \tan(\phi'_{b.d})) \times (\tan(45\ deg + \phi'_{b.d} / 2))^2 = \mathbf{18.401}$

$N_c = (N_q - 1) \times \cot(\phi'_{b.d}) = \mathbf{30.14}$

$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b.d}) = \mathbf{20.093}$

Foundation shape factors; $s_q = 1$

$s_\gamma = 1$

$s_c = 1$

Load inclination factors; $H = F_{sur\_h} + F_{moist\_h} + F_{pass\_h} - F_{prop\_stem} = \mathbf{-9.2}$ kN/m

$V = F_{total\_v} = \mathbf{48.5}$ kN/m

$m = 2$

$i_q = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^m = \mathbf{1.417}$

$i_\gamma = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^{(m + 1)} = \mathbf{1.687}$

$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b.d})) = \mathbf{1.441}$

Net ultimate bearing capacity

$n_f = c'_{b.d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_b' \times l_{load} \times N_\gamma \times s_\gamma \times i_\gamma = \mathbf{726.4}$ kN/m^2

Factor of safety; $FoS_{bp} = n_f / \max(q_{toe}, q_{heel}) = \mathbf{21.735}$

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; $\gamma_G = \mathbf{1.00}$

Permanent favourable action; γ_{Gf} = **1.00**

Variable unfavourable action; γ_Q = **1.30**

Variable favourable action; γ_{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; γ_γ = **1.00**

Library item; Partial factors output

Retained soil properties

Design moist density; $\gamma_{mr}' = \gamma_{mr} / \gamma_\gamma$ = **20** kN/m^3

Design saturated density; $\gamma_{sr}' = \gamma_{sr} / \gamma_\gamma$ = **22** kN/m^3

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

Design wall friction angle; $\delta_{r.d} = \text{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'})$ = **0** deg

Base soil properties

Design soil density; $\gamma_b' = \gamma_b / \gamma_\gamma$ = **20** kN/m^3

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

Design wall friction angle; $\delta_{b.d} = \text{atan}(\tan(\delta_{b.k}) / \gamma_{\phi'})$ = **12.1** deg

Design base friction angle; $\delta_{bb.d} = \text{atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'})$ = **24.8** deg

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

Using Coulomb theory

Active pressure coefficient; $K_A = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times [1 + \sqrt{[\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))]}]^2)$ = **0.409**

Passive pressure coefficient; $K_P = \sin(90 - \phi'_{b.d})^2 / (\sin(90 + \delta_{b.d}) \times [1 - \sqrt{[\sin(\phi'_{b.d} + \delta_{b.d}) \times \sin(\phi'_{b.d}) / (\sin(90 + \delta_{b.d}))]}]^2)$ = **3.473**

Bearing pressure check

Vertical forces on wall

Wall stem; $F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem}$ = **14.5** kN/m

Wall base; $F_{base} = \gamma_G \times A_{base} \times \gamma_{base}$ = **21.4** kN/m

Total; $F_{total\_v} = F_{stem} + F_{base}$ = **35.9** kN/m

Horizontal forces on wall

Surcharge load; $F_{sur\_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times (h_{eff} - d_{key})$ = **14.7** kN/m

Moist retained soil; $F_{moist\_h} = \gamma_G \times K_A \times \gamma_{mr}' \times (h_{eff} - d_{key})^2 / 2$ = **31.5** kN/m

Base soil; $F_{pass\_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2$ = **-27.5** kN/m

Total; $F_{total\_h} = F_{sur\_h} + F_{moist\_h} + F_{pass\_h}$ = **18.7** kN/m

Moments on wall

Wall stem; $M_{stem} = F_{stem} \times x_{stem}$ = **19.2** kNm/m

Wall base; $M_{base} = F_{base} \times x_{base}$ = **15** kNm/m

Surcharge load; $M_{sur} = -F_{sur\_h} \times x_{sur\_h\_a}$ = **-20.4** kNm/m

Moist retained soil; $M_{moist} = -F_{moist\_h} \times x_{moist\_h\_a}$ = **-29.1** kNm/m

Base soil; $M_{pass} = -F_{pass\_h} \times x_{pass\_h}$ = **-4.1** kNm/m

Total; $M_{total} = M_{stem} + M_{base} + M_{sur} + M_{moist} + M_{pass}$ = **-19.4** kNm/m

Check bearing pressure

Maximum friction force; $F_{friction\_max} = F_{total\_v} \times \tan(\delta_{bb.d})$ = **16.6** kN/m

Propping force; $F_{prop\_stem} = \max((F_{total\_v} \times l_{base} / 2 - M_{total}) / (h_{prop} + t_{base}), F_{total\_h} - F_{friction\_max}) = \mathbf{18.6}$ kN/m

Moment from propping force; $M_{prop} = F_{prop\_stem} \times (h_{prop} + t_{base}) = \mathbf{45.5}$ kNm/m

Distance to reaction; $\bar{x} = (M_{total} + M_{prop}) / F_{total\_v} = \mathbf{725}$ mm

Eccentricity of reaction; $e = \bar{x} - l_{base} / 2 = \mathbf{0}$ mm

Loaded length of base; $l_{load} = l_{base} = \mathbf{1450}$ mm

Bearing pressure at toe; $q_{toe} = F_{total\_v} / l_{base} = \mathbf{24.8}$ kN/m^2

Bearing pressure at heel; $q_{heel} = F_{total\_v} / l_{base} = \mathbf{24.8}$ kN/m^2

Effective overburden pressure; $q = (t_{base} + d_{cover}) \times \gamma_b' = \mathbf{9}$ kN/m^2

Design effective overburden pressure; $q' = q / \gamma_\gamma = \mathbf{9}$ kN/m^2

Bearing resistance factors; $N_q = Exp(\pi \times \tan(\phi'_{b.d})) \times (\tan(45 \text{ deg} + \phi'_{b.d} / 2))^2 = \mathbf{10.431}$

$N_c = (N_q - 1) \times \cot(\phi'_{b.d}) = \mathbf{20.418}$

$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b.d}) = \mathbf{8.712}$

Foundation shape factors; $s_q = 1$

$s_\gamma = 1$

$s_c = 1$

Load inclination factors; $H = F_{sur\_h} + F_{moist\_h} + F_{pass\_h} - F_{prop\_stem} = \mathbf{0.1}$ kN/m

$V = F_{total\_v} = \mathbf{35.9}$ kN/m

$m = 2$

$i_q = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^m = \mathbf{0.992}$

$i_\gamma = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^{(m+1)} = \mathbf{0.988}$

$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b.d})) = \mathbf{0.991}$

Net ultimate bearing capacity

$n_f = c'_{b.d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_b' \times l_{load} \times N_\gamma \times s_\gamma \times i_\gamma = \mathbf{217.8}$ kN/m^2

Factor of safety; $FoS_{bp} = n_f / \max(q_{toe}, q_{heel}) = \mathbf{8.8}$

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure