

Afan Boat Club

Widening of Slipway

31/3/2021

Solutions to Structures Ltd.

J.M. Davies

 Solutions to Structures Ltd 44 Depot Road Port Talbot SA12 9BA	Project				Job Ref.	
	Afan Boat Club				21-789	
	Section				Sheet no./rev.	
	Slipway Widening				2	
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INTRODUCTION

Solutions to Structures Ltd. have been instructed to carry out the structural design for the proposed widening of the slipway to the estuary of the River Afan.

It is proposed to excavate behind the existing raised platform to cast a concrete section of uniform thickness to a depth exceeding that of the platform, allow this to set, then excavate the platform and extend the slipway slab to the face of the wall to provide a prop to the wall section.

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 2.9.11

Retaining wall details

Stem type;	Propped cantilever
Stem height;	$h_{\text{stem}} = 1500 \text{ mm}$
Prop height;	$h_{\text{prop}} = 200 \text{ mm}$
Stem thickness;	$t_{\text{stem}} = 600 \text{ mm}$
Angle to rear face of stem;	$\alpha = 90 \text{ deg}$
Stem density;	$\gamma_{\text{stem}} = 25 \text{ kN/m}^3$
Base thickness;	$t_{\text{base}} = 300 \text{ mm}$
Base density;	$\gamma_{\text{base}} = 25 \text{ kN/m}^3$
Height of retained soil;	$h_{\text{ret}} = 1250 \text{ mm}$
Angle of soil surface;	$\beta = 25 \text{ deg}$
Depth of cover;	$d_{\text{cover}} = 200 \text{ mm}$
Height of water;	$h_{\text{water}} = 1250 \text{ mm}$
Water density;	$\gamma_w = 9.8 \text{ kN/m}^3$

Retained soil properties

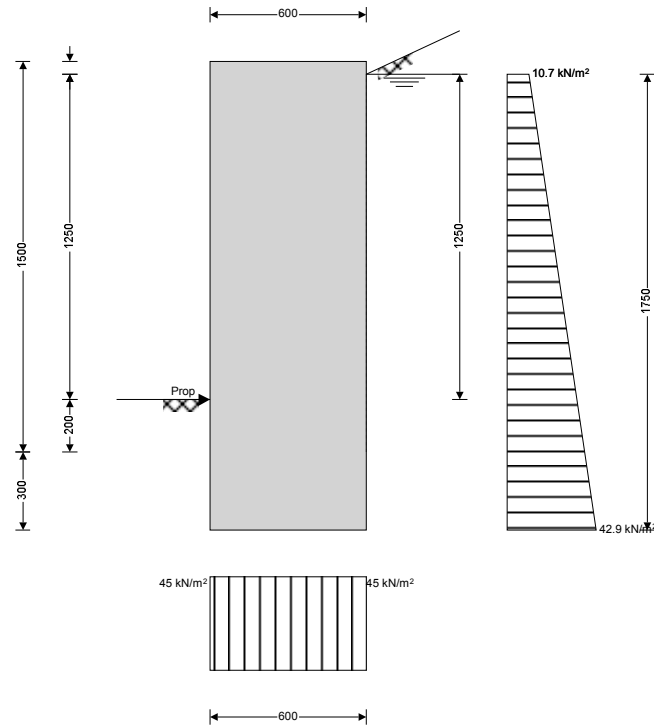
Soil type;	Medium dense rock fill
Moist density;	$\gamma_{\text{mr}} = 18 \text{ kN/m}^3$
Saturated density;	$\gamma_{\text{sr}} = 20.3 \text{ kN/m}^3$
Characteristic effective shear resistance angle;	$\phi'_{r,k} = 30 \text{ deg}$
Characteristic wall friction angle;	$\delta_{r,k} = 15 \text{ deg}$

Base soil properties

Soil type;	Medium dense rock fill
Soil density;	$\gamma_b = 18 \text{ kN/m}^3$
Characteristic cohesion;	$c'_{b,k} = 0 \text{ kN/m}^2$
Characteristic effective shear resistance angle;	$\phi'_{b,k} = 30 \text{ deg}$
Characteristic wall friction angle;	$\delta_{b,k} = 15 \text{ deg}$
Characteristic base friction angle;	$\delta_{bb,k} = 20 \text{ deg}$

Loading details

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

Calculate retaining wall geometry

Base length;

$$l_{\text{base}} = t_{\text{stem}} = 600 \text{ mm}$$

Saturated soil height;

$$h_{\text{sat}} = h_{\text{water}} + d_{\text{cover}} = 1450 \text{ mm}$$

Moist soil height;

$$h_{\text{moist}} = h_{\text{ret}} - h_{\text{water}} = 0 \text{ mm}$$

Length of surcharge load;

$$l_{\text{sur}} = l_{\text{heel}} = 0 \text{ mm}$$

- Distance to vertical component;

$$x_{\text{sur}_v} = l_{\text{base}} - l_{\text{heel}} / 2 = 600 \text{ mm}$$

Effective height of wall;

$$h_{\text{eff}} = h_{\text{base}} + d_{\text{cover}} + h_{\text{ret}} + l_{\text{sur}} \times \tan(\beta) = 1750 \text{ mm}$$

- Distance to horizontal component;

$$x_{\text{sur}_h} = h_{\text{eff}} / 2 = 875 \text{ mm}$$

Area of wall stem;

$$A_{\text{stem}} = h_{\text{stem}} \times t_{\text{stem}} = 0.9 \text{ m}^2$$

- Distance to vertical component;

$$x_{\text{stem}} = l_{\text{toe}} + t_{\text{stem}} / 2 = 300 \text{ mm}$$

Area of wall base;

$$A_{\text{base}} = l_{\text{base}} \times t_{\text{base}} = 0.18 \text{ m}^2$$

- Distance to vertical component;

$$x_{\text{base}} = l_{\text{base}} / 2 = 300 \text{ mm}$$

Design approach 1

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

Partial factor set;

$$A1$$

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;

$$\gamma_{\phi'} = 1.00$$

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Effective cohesion;

$$\gamma_c' = 1.00$$

Weight density;

$$\gamma_\gamma = 1.00$$

Library item; Partial factors output

Water properties

Design water density;

$$\gamma_w' = \gamma_w / \gamma_\gamma = 9.8 \text{ kN/m}^3$$

Retained soil properties

Design moist density;

$$\gamma_{mr}' = \gamma_{mr} / \gamma_\gamma = 18 \text{ kN/m}^3$$

Design saturated density;

$$\gamma_{sr}' = \gamma_{sr} / \gamma_\gamma = 20.3 \text{ kN/m}^3$$

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;

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

Design wall friction angle;

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

Design base friction angle;

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

Design effective cohesion;

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

Using Coulomb theory

Active pressure coefficient;

$$K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times [1 + \sqrt{[\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))]}])^2 = 0.485$$

Passive pressure coefficient;

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

Bearing pressure check

Vertical forces on wall

Wall stem;

$$F_{\text{stem}} = \gamma_G \times A_{\text{stem}} \times \gamma_{\text{stem}} = 30.4 \text{ kN/m}$$

Wall base;

$$F_{\text{base}} = \gamma_G \times A_{\text{base}} \times \gamma_{\text{base}} = 6.1 \text{ kN/m}$$

Total;

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{water}_v} = 36.5 \text{ kN/m}$$

Horizontal forces on wall

Surcharge load;

$$F_{\text{sur}_h} = K_A \times \cos(\delta_{r,d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{\text{eff}} = 12.3 \text{ kN/m}$$

Saturated retained soil;

$$F_{\text{sat}_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times (\gamma_{sr}' - \gamma_w') \times (h_{\text{sat}} + h_{\text{base}})^2 / 2 = 10.1 \text{ kN/m}$$

Water;

$$F_{\text{water}_h} = \gamma_G \times \gamma_w' \times (h_{\text{water}} + d_{\text{cover}} + h_{\text{base}})^2 / 2 = 20.3 \text{ kN/m}$$

Moist retained soil;

$$F_{\text{moist}_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{mr}' \times ((h_{\text{eff}} - h_{\text{sat}} - h_{\text{base}})^2 / 2 + (h_{\text{eff}} - h_{\text{sat}} - h_{\text{base}}) \times (h_{\text{sat}} + h_{\text{base}})) = 0 \text{ kN/m}$$

Base soil;

$$F_{\text{pass}_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (d_{\text{cover}} + h_{\text{base}})^2 / 2 = -10.8 \text{ kN/m}$$

Total;

$$F_{\text{total}_h} = F_{\text{sur}_h} + F_{\text{sat}_h} + F_{\text{water}_h} + F_{\text{moist}_h} + F_{\text{pass}_h} = 31.9 \text{ kN/m}$$

Moments on wall

Wall stem;

$$M_{\text{stem}} = F_{\text{stem}} \times x_{\text{stem}} = 9.1 \text{ kNm/m}$$

Wall base;

$$M_{\text{base}} = F_{\text{base}} \times x_{\text{base}} = 1.8 \text{ kNm/m}$$

Surcharge load;

$$M_{\text{sur}} = -F_{\text{sur}_h} \times x_{\text{sur}_h} = -10.8 \text{ kNm/m}$$

Saturated retained soil;

$$M_{\text{sat}} = -F_{\text{sat}_h} \times x_{\text{sat}_h} = -5.9 \text{ kNm/m}$$

Water;

$$M_{\text{water}} = -F_{\text{water}_h} \times x_{\text{water}_h} = -11.8 \text{ kNm/m}$$

Base soil;

$$M_{\text{pass}} = -F_{\text{pass}_h} \times x_{\text{pass}_h} = 1.8 \text{ kNm/m}$$

Total;

$$M_{\text{total}} = M_{\text{stem}} + M_{\text{base}} + M_{\text{sur}} + M_{\text{sat}} + M_{\text{water}} + M_{\text{moist}} + M_{\text{pass}} = -15.7 \text{ kNm/m}$$

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Check bearing pressure

Maximum friction force;	$F_{\text{friction_max}} = F_{\text{total_v}} \times \tan(\delta_{\text{bb,d}}) = 13.3 \text{ kN/m}$
Propping force;	$F_{\text{prop_stem}} = \max((F_{\text{total_v}} \times l_{\text{base}} / 2 - M_{\text{total}}) / (h_{\text{prop}} + t_{\text{base}}), F_{\text{total_h}} - F_{\text{friction_max}}) = 53.4 \text{ kN/m}$
Moment from propping force;	$M_{\text{prop}} = F_{\text{prop_stem}} \times (h_{\text{prop}} + t_{\text{base}}) = 26.7 \text{ kNm/m}$
Distance to reaction;	$\bar{x} = (M_{\text{total}} + M_{\text{prop}}) / F_{\text{total_v}} = 300 \text{ mm}$
Eccentricity of reaction;	$e = \bar{x} - l_{\text{base}} / 2 = 0 \text{ mm}$
Loaded length of base;	$l_{\text{load}} = l_{\text{base}} = 600 \text{ mm}$
Bearing pressure at toe;	$q_{\text{toe}} = F_{\text{total_v}} / l_{\text{base}} = 60.8 \text{ kN/m}^2$
Bearing pressure at heel;	$q_{\text{heel}} = F_{\text{total_v}} / l_{\text{base}} = 60.8 \text{ kN/m}^2$
Effective overburden pressure;	$q = \max((t_{\text{base}} + d_{\text{cover}}) \times \gamma'_b - (t_{\text{base}} + d_{\text{cover}} + h_{\text{water}}) \times \gamma'_w, 0 \text{ kN/m}^2) = 0 \text{ kN/m}^2$
Design effective overburden pressure;	$q' = q / \gamma_\gamma = 0 \text{ kN/m}^2$
Bearing resistance factors;	$N_q = \text{Exp}(\pi \times \tan(\phi'_{\text{b,d}})) \times (\tan(45 \text{ deg} + \phi'_{\text{b,d}} / 2))^2 = 18.401$ $N_c = (N_q - 1) \times \cot(\phi'_{\text{b,d}}) = 30.14$ $N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{\text{b,d}}) = 20.093$
Foundation shape factors;	$s_q = 1$ $s_\gamma = 1$ $s_c = 1$
Load inclination factors;	$H = F_{\text{sur_h}} + F_{\text{sat_h}} + F_{\text{water_h}} + F_{\text{moist_h}} + F_{\text{pass_h}} - F_{\text{prop_stem}} = -21.5 \text{ kN/m}$ $V = F_{\text{total_v}} = 36.5 \text{ kN/m}$ $m = 2$ $i_q = [1 - H / (V + l_{\text{load}} \times c'_{\text{b,d}} \times \cot(\phi'_{\text{b,d}}))]^m = 2.527$ $i_\gamma = [1 - H / (V + l_{\text{load}} \times c'_{\text{b,d}} \times \cot(\phi'_{\text{b,d}}))]^{(m+1)} = 4.018$ $i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{\text{b,d}})) = 2.615$
Net ultimate bearing capacity	$n_f = c'_{\text{b,d}} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times (\gamma'_b - \gamma'_w) \times l_{\text{load}} \times N_\gamma \times s_\gamma \times i_\gamma = 198.4 \text{ kN/m}^2$
Factor of safety;	$\text{FoS}_{\text{bp}} = n_f / \max(q_{\text{toe}}, q_{\text{heel}}) = 3.265$ 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;	$\gamma_{\text{Gf}} = 1.00$
Variable unfavourable action;	$\gamma_Q = 1.30$
Variable favourable action;	$\gamma_{\text{Qf}} = 0.00$

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

Water properties

Design water density;	$\gamma_w' = \gamma_w / \gamma_\gamma = 9.8 \text{ kN/m}^3$
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Retained soil properties

Design moist density;	$\gamma_{\text{mr}}' = \gamma_{\text{mr}} / \gamma_\gamma = 18 \text{ kN/m}^3$
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Design saturated density;

$$\gamma_{sr}' = \gamma_{sr} / \gamma_f = \mathbf{20.3 \text{ kN/m}^3}$$

Design effective shear resistance angle;

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

Design wall friction angle;

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

Base soil properties

Design soil density;

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

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;

$$K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d})) = \mathbf{0.843}$$

Passive pressure coefficient;

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

Bearing pressure check

Vertical forces on wall

Wall stem;

$$F_{\text{stem}} = \gamma_G \times A_{\text{stem}} \times \gamma_{\text{stem}} = \mathbf{22.5 \text{ kN/m}}$$

Wall base;

$$F_{\text{base}} = \gamma_G \times A_{\text{base}} \times \gamma_{\text{base}} = \mathbf{4.5 \text{ kN/m}}$$

Total;

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{water}_v} = \mathbf{27 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load;

$$F_{\text{sur}_h} = K_A \times \cos(\delta_{r,d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{\text{eff}} = \mathbf{18.8 \text{ kN/m}}$$

Saturated retained soil;

$$F_{\text{sat}_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times (\gamma_{sr}' - \gamma_w') \times (h_{\text{sat}} + h_{\text{base}})^2 / 2 = \mathbf{13.2 \text{ kN/m}}$$

Water;

$$F_{\text{water}_h} = \gamma_G \times \gamma_w' \times (h_{\text{water}} + d_{\text{cover}} + h_{\text{base}})^2 / 2 = \mathbf{15 \text{ kN/m}}$$

Moist retained soil;

$$F_{\text{moist}_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{mr}' \times ((h_{\text{eff}} - h_{\text{sat}} - h_{\text{base}})^2 / 2 + (h_{\text{eff}} - h_{\text{sat}} - h_{\text{base}}) \times (h_{\text{sat}} + h_{\text{base}})) = \mathbf{0 \text{ kN/m}}$$

Base soil;

$$F_{\text{pass}_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (d_{\text{cover}} + h_{\text{base}})^2 / 2 = \mathbf{-7.6 \text{ kN/m}}$$

Total;

$$F_{\text{total}_h} = F_{\text{sur}_h} + F_{\text{sat}_h} + F_{\text{water}_h} + F_{\text{moist}_h} + F_{\text{pass}_h} = \mathbf{39.3 \text{ kN/m}}$$

Moments on wall

Wall stem;

$$M_{\text{stem}} = F_{\text{stem}} \times x_{\text{stem}} = \mathbf{6.7 \text{ kNm/m}}$$

Wall base;

$$M_{\text{base}} = F_{\text{base}} \times x_{\text{base}} = \mathbf{1.4 \text{ kNm/m}}$$

Surcharge load;

$$M_{\text{sur}} = -F_{\text{sur}_h} \times x_{\text{sur}_h} = \mathbf{-16.4 \text{ kNm/m}}$$

Saturated retained soil;

$$M_{\text{sat}} = -F_{\text{sat}_h} \times x_{\text{sat}_h} = \mathbf{-7.7 \text{ kNm/m}}$$

Water;

$$M_{\text{water}} = -F_{\text{water}_h} \times x_{\text{water}_h} = \mathbf{-8.8 \text{ kNm/m}}$$

Moist retained soil;

$$M_{\text{moist}} = -F_{\text{moist}_h} \times x_{\text{moist}_h} = \mathbf{0 \text{ kNm/m}}$$

Base soil;

$$M_{\text{pass}} = -F_{\text{pass}_h} \times x_{\text{pass}_h} = \mathbf{1.3 \text{ kNm/m}}$$

Total;

$$M_{\text{total}} = M_{\text{stem}} + M_{\text{base}} + M_{\text{sur}} + M_{\text{sat}} + M_{\text{water}} + M_{\text{moist}} + M_{\text{pass}} = \mathbf{-23.5 \text{ kNm/m}}$$

Check bearing pressure

Maximum friction force;

$$F_{\text{friction}_\text{max}} = F_{\text{total}_v} \times \tan(\delta_{bb,d}) = \mathbf{7.9 \text{ kN/m}}$$

Propping force;

$$F_{\text{prop}_\text{stem}} = \max((F_{\text{total}_v} \times l_{\text{base}} / 2 - M_{\text{total}}) / (h_{\text{prop}} + t_{\text{base}}), F_{\text{total}_h} - F_{\text{friction}_\text{max}}) = \mathbf{63.2 \text{ kN/m}}$$

Moment from propping force;

$$M_{\text{prop}} = F_{\text{prop}_\text{stem}} \times (h_{\text{prop}} + t_{\text{base}}) = \mathbf{31.6 \text{ kNm/m}}$$

Distance to reaction;

$$\bar{x} = (M_{\text{total}} + M_{\text{prop}}) / F_{\text{total}_v} = \mathbf{300 \text{ mm}}$$

Eccentricity of reaction;

$$e = \bar{x} - l_{\text{base}} / 2 = \mathbf{0 \text{ mm}}$$

Loaded length of base;

$$l_{\text{load}} = l_{\text{base}} = \mathbf{600 \text{ mm}}$$

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Bearing pressure at toe;	$q_{toe} = F_{total_v} / l_{base} = 45 \text{ kN/m}^2$
Bearing pressure at heel;	$q_{heel} = F_{total_v} / l_{base} = 45 \text{ kN/m}^2$
Effective overburden pressure;	$q = \max((t_{base} + d_{cover}) \times \gamma'_b - (t_{base} + d_{cover} + h_{water}) \times \gamma'_w, 0 \text{ kN/m}^2) = 0 \text{ kN/m}^2$
Design effective overburden pressure;	$q' = q / \gamma_\gamma = 0 \text{ kN/m}^2$
Bearing resistance factors;	$N_q = \text{Exp}(\pi \times \tan(\phi'_{b,d})) \times (\tan(45 \text{ deg} + \phi'_{b,d} / 2))^2 = 10.431$ $N_c = (N_q - 1) \times \cot(\phi'_{b,d}) = 20.418$ $N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b,d}) = 8.712$
Foundation shape factors;	$s_q = 1$ $s_\gamma = 1$ $s_c = 1$
Load inclination factors;	$H = F_{sur_h} + F_{sat_h} + F_{water_h} + F_{moist_h} + F_{pass_h} - F_{prop_stem} = -23.9 \text{ kN/m}$ $V = F_{total_v} = 27 \text{ kN/m}$ $m = 2$ $i_q = [1 - H / (V + l_{load} \times c'_{b,d} \times \cot(\phi'_{b,d}))]^m = 3.548$ $i_\gamma = [1 - H / (V + l_{load} \times c'_{b,d} \times \cot(\phi'_{b,d}))]^{(m+1)} = 6.682$ $i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b,d})) = 3.818$
Net ultimate bearing capacity	$n_f = c'_{b,d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times (\gamma'_b - \gamma'_w) \times l_{load} \times N_\gamma \times s_\gamma \times i_\gamma = 143 \text{ kN/m}^2$
Factor of safety;	$FoS_{bp} = n_f / \max(q_{toe}, q_{heel}) = 3.179$ PASS - Allowable bearing pressure exceeds maximum applied bearing pressure