

Title: Structural Calculations

Project: 6 Brynseion Street

Client: Andrew Nolan

Document No: 001
Project No: B1265
Prepared By: AS
Checked By: CN

Revision: C
Date: 23/07/2024

DESIGN STATEMENT

The design has been done in accordance with British Standards BS6399, BS8110-1:1997 (Foundations).

Information provided by the client.

The design is for 1No. Block on Flat Retaining Wall supporting garden applied loading, 1No. Reinforced Concrete Retaining Wall supporting exterior house structure and loading applied from the driveway, and 1No. Raft Foundation supporting new structure.

Ground bearing pressure assumed to be 100kN/m², to be confirmed on site by contractor prior to works.

Refer to our sketches B1265 for references.

Existing & proposed blockwork assumed to have minimum 7.3N/mm² compressive strength.

All dimensions, weights, member lengths, member tables, and any other relevant design information contained within this package is for analysis, and design purposes only, for submission to building control, and must not be used for pricing or fabrication purposes. All queries are to be directed to the engineer prior to tendering, pricing or fabrication. All structural members dimensions need to be taken accurately on site by the contractor prior to fabrication.

(Note that all specialist design items (waterproofing, temporary works) are to be provided by others/specialist as required).

During any initial site visits performed by our Engineer, assumptions have to be made where structural elements may have been obscured by finishes. Opening up works should be undertaken prior to fabrication or construction of any structural members to confirm that the structural layout as indicated in our proposed sketches/detailed drawings is correct.

If there are any discrepancies, the Engineer MUST be informed immediately, and prior to proceeding with construction works on site.

CDM Comments:

- All temporary propping/support is to correspond to contractor's specification and details.

 Vale Consultancy CONSULTING CIVIL & STRUCTURAL ENGINEERS 29 Bocam Park Old Field Road, Pencoed CF35 5LJ	Project				Job Ref.	
	6 Brynseion Street				B1265	
	Section				Sheet no./rev.	
	Design loadings				03	
	Calc. by	Date	Chk'd by	Date	App'd by	Date
	AS	23/07/2024	CN	23/07/2024	CN	23/07/2024

6 Brynseion Street

Foundations design calculations have been completed in accordance with (BS8110-1:1997).

All dimensions stated in the following calculations are for design purposes only and not for use for fabrication or construction purposes. All dimensions must be checked by a competent contractor prior to fabrication or construction and any discrepancies found are to be reported to the design engineer.

Design Loadings

1. Roof 35° Pitch (Max)

Dead Loading:	
Tiles	= 0.45 kN/m²
Insulation, Felt & Battens	= 0.10 kN/m²
Truss or Purlins/Rafters	= 0.20 kN/m²
Plasterboard & skim	= 0.15 kN/m²
	<u>0.90 kN/m² /cos(35) = 1.10kN/m² Total Dead Loading</u>

Imposed Loading:	
Snow	= <u>0.60 kN/m² Total Live Loading</u>

2. Walls

Dead Loading:	
Render	= 0.15 kN/m²
200mm masonry	= 4.30kN/m²
Plaster	= 0.15 kN/m²
	<u>4.60 kN/m² Total Dead Loading</u>

3. Residential Floor

Dead Loading:	
Boarding	= 0.15 kN/m²
Insulation	= 0.05 kN/m²
Joists	= 0.15 kN/m²
Plaster and skim Ceiling	= 0.15 kN/m²

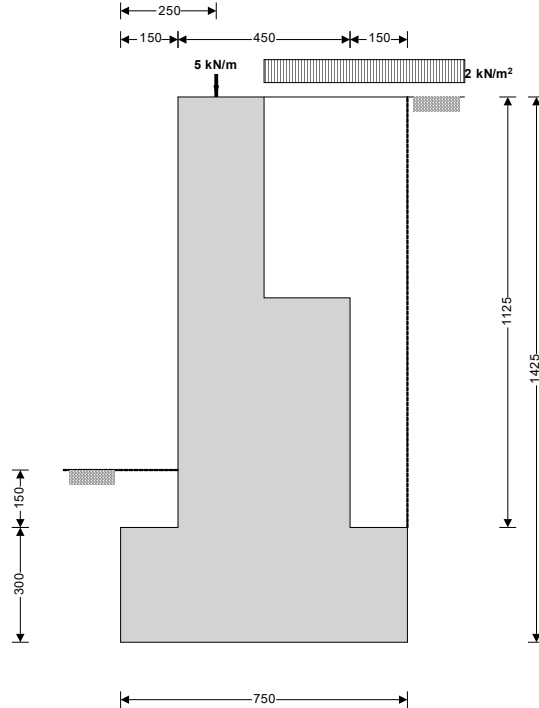
	<u>0.5 kN/m² Total Dead Loading</u>

Imposed Loading:	
Residential	= <u>1.50 kN/m2 Total Live Loading</u>

Project 6 Brynseion Street, Troedyrhiw				Job no. B1265	
Calcs for Block on flat retaining wall - garden wall				Start page no./Revision 1	
Calcs by AS	Calcs date 02/08/2024	Checked by CN	Checked date 02/08/2024	Approved by CN	Approved date 02/08/2024

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.08



Wall details

Retaining wall type
Number of steps
Height of retaining wall stem
Length of toe
Length of heel
Overall length of base
Thickness of base
Depth of downstand
Position of downstand
Thickness of downstand
Height of retaining wall
Depth of cover in front of wall
Depth of unplanned excavation
Height of ground water behind wall
Height of saturated fill above base
Density of wall construction
Density of base construction
Angle of rear face of wall
Angle of soil surface behind wall
Effective height at virtual back of wall

Unpropped cantilever with stepped rear face

2

$h_{\text{stem}} = 1125 \text{ mm}$
 $l_{\text{toe}} = 150 \text{ mm}$
 $l_{\text{heel}} = 150 \text{ mm}$
 $l_{\text{base}} = l_{\text{toe}} + l_{\text{heel}} + t_{s1} = 750 \text{ mm}$
 $t_{\text{base}} = 300 \text{ mm}$
 $d_{\text{ds}} = 0 \text{ mm}$
 $l_{\text{ds}} = 148 \text{ mm}$
 $t_{\text{ds}} = 300 \text{ mm}$
 $h_{\text{wall}} = h_{\text{stem}} + t_{\text{base}} + d_{\text{ds}} = 1425 \text{ mm}$
 $d_{\text{cover}} = 150 \text{ mm}$
 $d_{\text{exc}} = 0 \text{ mm}$
 $h_{\text{water}} = 0 \text{ mm}$
 $h_{\text{sat}} = \max(h_{\text{water}} - t_{\text{base}} - d_{\text{ds}}, 0 \text{ mm}) = 0 \text{ mm}$
 $\gamma_{\text{wall}} = 23.6 \text{ kN/m}^3$
 $\gamma_{\text{base}} = 23.6 \text{ kN/m}^3$
 $\alpha = 90.0 \text{ deg}$
 $\beta = 0.0 \text{ deg}$
 $h_{\text{eff}} = h_{\text{wall}} + (l_{\text{heel}} + t_{s1} - t_{s2}) \times \tan(\beta) = 1425 \text{ mm}$

Retained material details

Mobilisation factor
Moist density of retained material

$M = 1.5$
 $\gamma_m = 18.0 \text{ kN/m}^3$

Project 6 Brynseion Street, Troedryhiw				Job no. B1265	
Calcs for Block on flat retaining wall - garden wall				Start page no./Revision 3	
Calcs by AS	Calcs date 02/08/2024	Checked by CN	Checked date 02/08/2024	Approved by CN	Approved date 02/08/2024

Vertical forces on wall

Wall step no. 2

$$W_{step2} = h_{s2} \times t_{s2} \times \gamma_{wall} = \mathbf{2.8 \text{ kN/m}}$$

Wall step no. 1

$$W_{step1} = h_{s1} \times t_{s1} \times \gamma_{wall} = \mathbf{6.4 \text{ kN/m}}$$

Wall base

$$W_{base} = l_{base} \times t_{base} \times \gamma_{base} = \mathbf{5.3 \text{ kN/m}}$$

Surcharge

$$W_{sur} = \text{Surcharge} \times [l_{heel} + (t_{s1} - t_{s2})] = \mathbf{0.6 \text{ kN/m}}$$

Moist backfill to step no. 2

$$W_{m_w2} = (l_{heel} + t_{s1} - t_{s2}) \times h_{s2} \times \gamma_m = \mathbf{3.5 \text{ kN/m}}$$

Moist backfill to step no. 1

$$W_{m_w1} = (l_{heel} + t_{s1} - t_{s1}) \times h_{s1} \times \gamma_m = \mathbf{1.6 \text{ kN/m}}$$

Soil in front of wall

$$W_p = l_{toe} \times d_{cover} \times \gamma_m = \mathbf{0.4 \text{ kN/m}}$$

Applied vertical load

$$W_v = W_{dead} + W_{live} = \mathbf{5 \text{ kN/m}}$$

Total vertical load

$$W_{total} = W_{step2} + W_{step1} + W_{base} + W_{sur} + W_{m_w2} + W_{m_w1} + W_p + W_v = \mathbf{25.6 \text{ kN/m}}$$

kN/m

Horizontal forces on wall

Surcharge

$$F_{sur} = K_a \times \cos(90 - \alpha + \delta) \times \text{Surcharge} \times h_{eff} = \mathbf{0.7 \text{ kN/m}}$$

Moist backfill above water table

$$F_{m_a} = 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water})^2 = \mathbf{6.4 \text{ kN/m}}$$

Total horizontal load

$$F_{total} = F_{sur} + F_{m_a} = \mathbf{7.1 \text{ kN/m}}$$

Calculate stability against sliding

Passive resistance of soil in front of wall

$$F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb} = \mathbf{7.2 \text{ kN/m}}$$

Resistance to sliding

$$F_{res} = F_p + W_{total} \times \tan(\delta_b) = \mathbf{15.8 \text{ kN/m}}$$

PASS - Resistance force is greater than sliding force

Overturning moments

Surcharge

$$M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2 = \mathbf{0.5 \text{ kNm/m}}$$

Moist backfill above water table

$$M_{m_a} = F_{m_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3 = \mathbf{3 \text{ kNm/m}}$$

Total overturning moment

$$M_{ot} = M_{sur} + M_{m_a} = \mathbf{3.6 \text{ kNm/m}}$$

Restoring moments

Wall step no. 2

$$M_{step2} = W_{step2} \times (l_{toe} + t_{s2} / 2) = \mathbf{0.7 \text{ kNm/m}}$$

Wall step no. 1

$$M_{step1} = W_{step1} \times (l_{toe} + t_{s1} / 2) = \mathbf{2.4 \text{ kNm/m}}$$

Wall base

$$M_{base} = W_{base} \times l_{base} / 2 = \mathbf{2 \text{ kNm/m}}$$

Surcharge

$$M_{sur_r} = W_{sur} \times (l_{base} - (l_{heel} + t_{s1} - t_{s2}) / 2) = \mathbf{0.3 \text{ kNm/m}}$$

Moist backfill to step no. 2

$$M_{m_w2} = W_{m_w2} \times (l_{base} - (l_{heel} + t_{s1} - t_{s2}) / 2) = \mathbf{2 \text{ kNm/m}}$$

Moist backfill to step no. 1

$$M_{m_w1} = W_{m_w1} \times (l_{base} - (l_{heel} + t_{s1} - t_{s1}) / 2) = \mathbf{1.1 \text{ kNm/m}}$$

Soil in front of wall

$$M_{p_r} = W_p \times l_{toe} / 2 = \mathbf{0 \text{ kNm/m}}$$

Design vertical load

$$M_v = W_v \times l_{load} = \mathbf{1.3 \text{ kNm/m}}$$

Total restoring moment

$$M_{rest} = M_{step2} + M_{step1} + M_{base} + M_{sur_r} + M_{m_w2} + M_{m_w1} + M_{p_r} + M_v = \mathbf{9.8 \text{ kNm/m}}$$

kNm/m

Check stability against overturning

Total overturning moment

$$M_{ot} = \mathbf{3.6 \text{ kNm/m}}$$

Total restoring moment

$$M_{rest} = \mathbf{9.8 \text{ kNm/m}}$$

PASS - Restoring moment is greater than overturning moment

Check bearing pressure

Total moment for bearing

$$M_{total} = M_{rest} - M_{ot} = \mathbf{6.2 \text{ kNm/m}}$$

Total vertical reaction

$$R = W_{total} = \mathbf{25.6 \text{ kN/m}}$$

Distance to reaction

$$x_{bar} = M_{total} / R = \mathbf{243 \text{ mm}}$$

Eccentricity of reaction

$$e = \text{abs}((l_{base} / 2) - x_{bar}) = \mathbf{132 \text{ mm}}$$

Reaction acts outside middle third of base



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Project 6 Brynseion Street, Troedyrhiw				Job no. B1265	
Calcs for Block on flat retaining wall - garden wall				Start page no./Revision 4	
Calcs by AS	Calcs date 02/08/2024	Checked by CN	Checked date 02/08/2024	Approved by CN	Approved date 02/08/2024

Bearing pressure at toe

$$p_{toe} = R / (1.5 \times x_{bar}) = \mathbf{70.2 \text{ kN/m}^2}$$

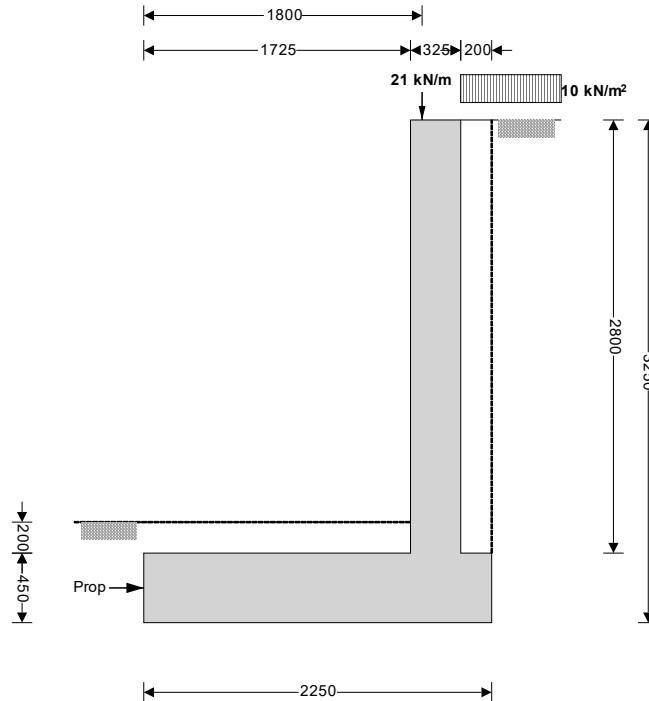
Bearing pressure at heel

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

PASS - Maximum bearing pressure is less than allowable bearing pressure

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.09



Wall details

Retaining wall type

Height of retaining wall stem

Thickness of wall stem

Length of toe

Length of heel

Overall length of base

Thickness of base

Depth of downstand

Position of downstand

Thickness of downstand

Height of retaining wall

Depth of cover in front of wall

Depth of unplanned excavation

Height of ground water behind wall

Height of saturated fill above base

Density of wall construction

Density of base construction

Angle of rear face of wall

Angle of soil surface behind wall

Effective height at virtual back of wall

Cantilever propped at base

 $h_{\text{stem}} = 2800 \text{ mm}$
 $t_{\text{wall}} = 325 \text{ mm}$
 $l_{\text{toe}} = 1725 \text{ mm}$
 $l_{\text{heel}} = 200 \text{ mm}$
 $l_{\text{base}} = l_{\text{toe}} + l_{\text{heel}} + t_{\text{wall}} = 2250 \text{ mm}$
 $t_{\text{base}} = 450 \text{ mm}$
 $d_{\text{ds}} = 0 \text{ mm}$
 $l_{\text{ds}} = 40 \text{ mm}$
 $t_{\text{ds}} = 450 \text{ mm}$
 $h_{\text{wall}} = h_{\text{stem}} + t_{\text{base}} + d_{\text{ds}} = 3250 \text{ mm}$
 $d_{\text{cover}} = 200 \text{ mm}$
 $d_{\text{exc}} = 0 \text{ mm}$
 $h_{\text{water}} = 0 \text{ mm}$
 $h_{\text{sat}} = \max(h_{\text{water}} - t_{\text{base}} - d_{\text{ds}}, 0 \text{ mm}) = 0 \text{ mm}$
 $\gamma_{\text{wall}} = 23.6 \text{ kN/m}^3$
 $\gamma_{\text{base}} = 23.6 \text{ kN/m}^3$
 $\alpha = 90.0 \text{ deg}$
 $\beta = 0.0 \text{ deg}$
 $h_{\text{eff}} = h_{\text{wall}} + l_{\text{heel}} \times \tan(\beta) = 3250 \text{ mm}$

Retained material details

Mobilisation factor

 $M = 1.5$

Moist density of retained material

 $\gamma_m = 18.0 \text{ kN/m}^3$

Project 6 Brynseion Street, Troedyrhiw				Job no. B1265	
Calcs for Reinforced concrete retaining wall				Start page no./Revision 6 A	
Calcs by AS	Calcs date 02/08/2024	Checked by MJ	Checked date 02/08/2024	Approved by CN	Approved date 02/08/2024

Saturated density of retained material $\gamma_s = 21.0 \text{ kN/m}^3$

Design shear strength $\phi' = 24.2 \text{ deg}$

Angle of wall friction $\delta = 18.0 \text{ deg}$

Base material details

Moist density $\gamma_{mb} = 18.0 \text{ kN/m}^3$

Design shear strength $\phi'_b = 24.2 \text{ deg}$

Design base friction $\delta_b = 18.6 \text{ deg}$

Allowable bearing pressure $P_{\text{bearing}} = 100 \text{ kN/m}^2$

Using Coulomb theory

Active pressure coefficient for retained material

$$K_a = \sin(\alpha + \phi')^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta) \times [1 + \sqrt{(\sin(\phi' + \delta) \times \sin(\phi' - \beta) / (\sin(\alpha - \delta) \times \sin(\alpha + \beta)))})^2) = 0.370$$

Passive pressure coefficient for base material

$$K_p = \sin(90 - \phi'_b)^2 / (\sin(90 - \delta_b) \times [1 - \sqrt{(\sin(\phi'_b + \delta_b) \times \sin(\phi'_b) / (\sin(90 + \delta_b)))})^2) = 4.187$$

At-rest pressure

At-rest pressure for retained material $K_0 = 1 - \sin(\phi') = 0.590$

Loading details

Surcharge load on plan Surcharge = **10.0 kN/m²**

Applied vertical dead load on wall $W_{\text{dead}} = 21.0 \text{ kN/m}$

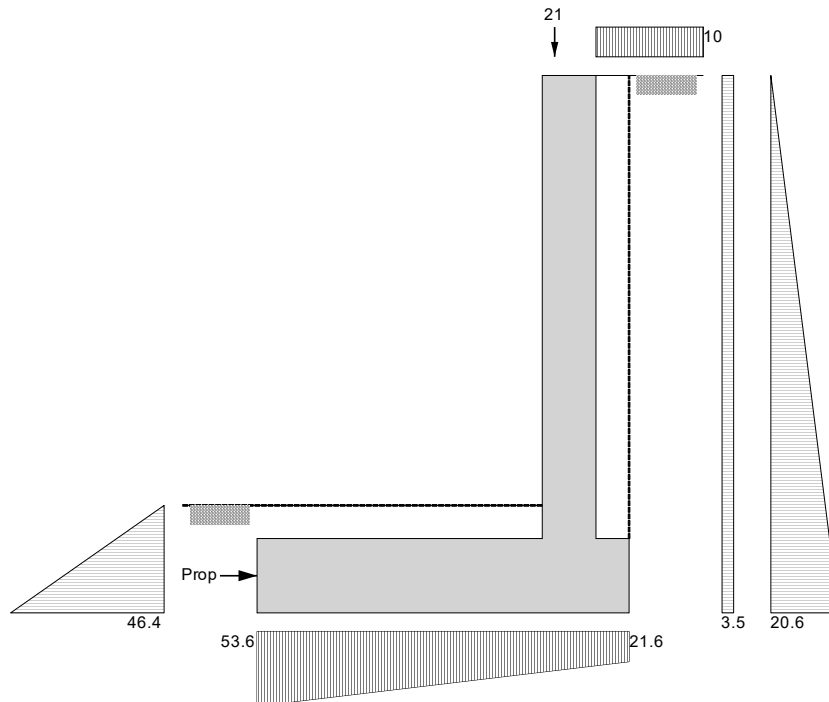
Applied vertical live load on wall $W_{\text{live}} = 0.0 \text{ kN/m}$

Position of applied vertical load on wall $l_{\text{load}} = 1800 \text{ mm}$

Applied horizontal dead load on wall $F_{\text{dead}} = 0.0 \text{ kN/m}$

Applied horizontal live load on wall $F_{\text{live}} = 0.0 \text{ kN/m}$

Height of applied horizontal load on wall $h_{\text{load}} = 0 \text{ mm}$



Loads shown in kN/m, pressures shown in kN/m²

Project 6 Brynseion Street, Troedryhiw				Job no. B1265	
Calcs for Reinforced concrete retaining wall				Start page no./Revision 7 A	
Calcs by AS	Calcs date 02/08/2024	Checked by MJ	Checked date 02/08/2024	Approved by CN	Approved date 02/08/2024

Vertical forces on wall

Wall stem	$W_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall} = 21.5 \text{ kN/m}$
Wall base	$W_{base} = l_{base} \times t_{base} \times \gamma_{base} = 23.9 \text{ kN/m}$
Surcharge	$W_{sur} = \text{Surcharge} \times l_{heel} = 2 \text{ kN/m}$
Moist backfill to top of wall	$W_{m_w} = l_{heel} \times (h_{stem} - h_{sat}) \times \gamma_m = 10.1 \text{ kN/m}$
Soil in front of wall	$W_p = l_{toe} \times d_{cover} \times \gamma_{mb} = 6.2 \text{ kN/m}$
Applied vertical load	$W_v = W_{dead} + W_{live} = 21 \text{ kN/m}$
Total vertical load	$W_{total} = W_{wall} + W_{base} + W_{sur} + W_{m_w} + W_p + W_v = 84.7 \text{ kN/m}$

Horizontal forces on wall

Surcharge	$F_{sur} = K_a \times \cos(90 - \alpha + \delta) \times \text{Surcharge} \times h_{eff} = 11.4 \text{ kN/m}$
Moist backfill above water table	$F_{m_a} = 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water})^2 = 33.4 \text{ kN/m}$
Total horizontal load	$F_{total} = F_{sur} + F_{m_a} = 44.9 \text{ kN/m}$

Calculate propping force

Passive resistance of soil in front of wall	$F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb} = 15.1 \text{ kN/m}$
Propping force	$F_{prop} = \max(F_{total} - F_p - (W_{total} - W_{sur} - W_p) \times \tan(\delta_b), 0 \text{ kN/m})$ $F_{prop} = 4.0 \text{ kN/m}$

Overturning moments

Surcharge	$M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2 = 18.6 \text{ kNm/m}$
Moist backfill above water table	$M_{m_a} = F_{m_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3 = 36.2 \text{ kNm/m}$
Total overturning moment	$M_{ot} = M_{sur} + M_{m_a} = 54.8 \text{ kNm/m}$

Restoring moments

Wall stem	$M_{wall} = W_{wall} \times (l_{toe} + t_{wall} / 2) = 40.5 \text{ kNm/m}$
Wall base	$M_{base} = W_{base} \times l_{base} / 2 = 26.9 \text{ kNm/m}$
Surcharge	$M_{sur_r} = W_{sur} \times (l_{base} - l_{heel} / 2) = 4.3 \text{ kNm/m}$
Moist backfill	$M_{m_r} = (W_{m_w} \times (l_{base} - l_{heel} / 2) + W_{m_s} \times (l_{base} - l_{heel} / 3)) = 21.7 \text{ kNm/m}$
Soil in front of wall	$M_{p_r} = W_p \times l_{toe} / 2 = 5.4 \text{ kNm/m}$
Design vertical load	$M_v = W_v \times l_{load} = 37.8 \text{ kNm/m}$
Total restoring moment	$M_{rest} = M_{wall} + M_{base} + M_{sur_r} + M_{m_r} + M_{p_r} + M_v = 136.5 \text{ kNm/m}$

Check bearing pressure

Total moment for bearing	$M_{total} = M_{rest} - M_{ot} = 81.8 \text{ kNm/m}$
Total vertical reaction	$R = W_{total} = 84.7 \text{ kN/m}$
Distance to reaction	$x_{bar} = M_{total} / R = 966 \text{ mm}$
Eccentricity of reaction	$e = \text{abs}((l_{base} / 2) - x_{bar}) = 159 \text{ mm}$

Reaction acts within middle third of base

Bearing pressure at toe	$p_{toe} = (R / l_{base}) + (6 \times R \times e / l_{base}^2) = 53.6 \text{ kN/m}^2$
Bearing pressure at heel	$p_{heel} = (R / l_{base}) - (6 \times R \times e / l_{base}^2) = 21.6 \text{ kN/m}^2$

PASS - Maximum bearing pressure is less than allowable bearing pressure

Project 6 Brynseion Street, Troedryhiw				Job no. B1265	
Calcs for Reinforced concrete retaining wall				Start page no./Revision 8 A	
Calcs by AS	Calcs date 02/08/2024	Checked by MJ	Checked date 02/08/2024	Approved by CN	Approved date 02/08/2024

RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.09

Ultimate limit state load factors

Dead load factor	$\gamma_{f_d} = 1.4$
Live load factor	$\gamma_{f_l} = 1.6$
Earth and water pressure factor	$\gamma_{f_e} = 1.4$

Factored vertical forces on wall

Wall stem	$W_{wall_f} = \gamma_{f_d} \times h_{stem} \times t_{wall} \times \gamma_{wall} = 30.1 \text{ kN/m}$
Wall base	$W_{base_f} = \gamma_{f_d} \times l_{base} \times t_{base} \times \gamma_{base} = 33.5 \text{ kN/m}$
Surcharge	$W_{sur_f} = \gamma_{f_l} \times \text{Surcharge} \times l_{heel} = 3.2 \text{ kN/m}$
Moist backfill to top of wall	$W_{m_w_f} = \gamma_{f_d} \times l_{heel} \times (h_{stem} - h_{sat}) \times \gamma_m = 14.1 \text{ kN/m}$
Soil in front of wall	$W_{p_f} = \gamma_{f_d} \times l_{toe} \times d_{cover} \times \gamma_{mb} = 8.7 \text{ kN/m}$
Applied vertical load	$W_{v_f} = \gamma_{f_d} \times W_{dead} + \gamma_{f_l} \times W_{live} = 29.4 \text{ kN/m}$
Total vertical load	$W_{total_f} = W_{wall_f} + W_{base_f} + W_{sur_f} + W_{m_w_f} + W_{p_f} + W_{v_f} = 118.9 \text{ kN/m}$

Factored horizontal active forces on wall

Surcharge	$F_{sur_f} = \gamma_{f_l} \times K_a \times \cos(90 - \alpha + \delta) \times \text{Surcharge} \times h_{eff} = 18.3 \text{ kN/m}$
Moist backfill above water table	$F_{m_a_f} = \gamma_{f_e} \times 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water})^2 = 46.8 \text{ kN/m}$
Total horizontal load	$F_{total_f} = F_{sur_f} + F_{m_a_f} = 65.1 \text{ kN/m}$

Calculate propping force

Passive resistance of soil in front of wall	$F_{p_f} = \gamma_{f_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb} = 21.1 \text{ kN/m}$
Propping force	$F_{prop_f} = \max(F_{total_f} - F_{p_f} - (W_{total_f} - W_{sur_f} - W_{p_f}) \times \tan(\delta_b), 0 \text{ kN/m})$ $F_{prop_f} = 7.9 \text{ kN/m}$

Factored overturning moments

Surcharge	$M_{sur_f} = F_{sur_f} \times (h_{eff} - 2 \times d_{ds}) / 2 = 29.7 \text{ kNm/m}$
Moist backfill above water table	$M_{m_a_f} = F_{m_a_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3 = 50.7 \text{ kNm/m}$
Total overturning moment	$M_{ot_f} = M_{sur_f} + M_{m_a_f} = 80.4 \text{ kNm/m}$

Restoring moments

Wall stem	$M_{wall_f} = W_{wall_f} \times (l_{toe} + t_{wall} / 2) = 56.8 \text{ kNm/m}$
Wall base	$M_{base_f} = W_{base_f} \times l_{base} / 2 = 37.6 \text{ kNm/m}$
Surcharge	$M_{sur_r_f} = W_{sur_f} \times (l_{base} - l_{heel} / 2) = 6.9 \text{ kNm/m}$
Moist backfill	$M_{m_r_f} = (W_{m_w_f} \times (l_{base} - l_{heel} / 2) + W_{m_s_f} \times (l_{base} - l_{heel} / 3)) = 30.3 \text{ kNm/m}$
Soil in front of wall	$M_{p_r_f} = W_{p_f} \times l_{toe} / 2 = 7.5 \text{ kNm/m}$
Design vertical load	$M_{v_f} = W_{v_f} \times l_{load} = 52.9 \text{ kNm/m}$
Total restoring moment	$M_{rest_f} = M_{wall_f} + M_{base_f} + M_{sur_r_f} + M_{m_r_f} + M_{p_r_f} + M_{v_f} = 192 \text{ kNm/m}$

Factored bearing pressure

Total moment for bearing	$M_{total_f} = M_{rest_f} - M_{ot_f} = 111.6 \text{ kNm/m}$
Total vertical reaction	$R_f = W_{total_f} = 118.9 \text{ kN/m}$
Distance to reaction	$x_{bar_f} = M_{total_f} / R_f = 938 \text{ mm}$
Eccentricity of reaction	$e_f = \text{abs}((l_{base} / 2) - x_{bar_f}) = 187 \text{ mm}$

Reaction acts within middle third of base

Bearing pressure at toe	$p_{toe_f} = (R_f / l_{base}) + (6 \times R_f \times e_f / l_{base}^2) = 79.2 \text{ kN/m}^2$
Bearing pressure at heel	$p_{heel_f} = (R_f / l_{base}) - (6 \times R_f \times e_f / l_{base}^2) = 26.6 \text{ kN/m}^2$
Rate of change of base reaction	$\text{rate} = (p_{toe_f} - p_{heel_f}) / l_{base} = 23.38 \text{ kN/m}^2/\text{m}$

Project 6 Brynseion Street, Troedryhiw				Job no. B1265	
Calcs for Reinforced concrete retaining wall				Start page no./Revision 9 A	
Calcs by AS	Calcs date 02/08/2024	Checked by MJ	Checked date 02/08/2024	Approved by CN	Approved date 02/08/2024

Bearing pressure at stem / toe

$$p_{\text{stem_toe_f}} = \max(p_{\text{toe_f}} - (\text{rate} \times l_{\text{toe}}), 0 \text{ kN/m}^2) = \mathbf{38.8 \text{ kN/m}^2}$$

Bearing pressure at mid stem

$$p_{\text{stem_mid_f}} = \max(p_{\text{toe_f}} - (\text{rate} \times (l_{\text{toe}} + t_{\text{wall}} / 2)), 0 \text{ kN/m}^2) = \mathbf{35 \text{ kN/m}^2}$$

Bearing pressure at stem / heel

$$p_{\text{stem_heel_f}} = \max(p_{\text{toe_f}} - (\text{rate} \times (l_{\text{toe}} + t_{\text{wall}})), 0 \text{ kN/m}^2) = \mathbf{31.2 \text{ kN/m}^2}$$

Design of reinforced concrete retaining wall toe (BS 8002:1994)

Material properties

Characteristic strength of concrete

$$f_{\text{cu}} = \mathbf{40 \text{ N/mm}^2}$$

Characteristic strength of reinforcement

$$f_y = \mathbf{500 \text{ N/mm}^2}$$

Base details

Minimum area of reinforcement

$$k = \mathbf{0.13 \%}$$

Cover to reinforcement in toe

$$c_{\text{toe}} = \mathbf{30 \text{ mm}}$$

Calculate shear for toe design

Shear from bearing pressure

$$V_{\text{toe_bear}} = (p_{\text{toe_f}} + p_{\text{stem_toe_f}}) \times l_{\text{toe}} / 2 = \mathbf{101.8 \text{ kN/m}}$$

Shear from weight of base

$$V_{\text{toe_wt_base}} = \gamma_{\text{f_d}} \times \gamma_{\text{base}} \times l_{\text{toe}} \times t_{\text{base}} = \mathbf{25.6 \text{ kN/m}}$$

Shear from weight of soil

$$V_{\text{toe_wt_soil}} = w_{\text{p_f}} - (\gamma_{\text{f_d}} \times \gamma_{\text{m}} \times l_{\text{toe}} \times d_{\text{exc}}) = \mathbf{8.7 \text{ kN/m}}$$

Total shear for toe design

$$V_{\text{toe}} = V_{\text{toe_bear}} - V_{\text{toe_wt_base}} - V_{\text{toe_wt_soil}} = \mathbf{67.4 \text{ kN/m}}$$

Calculate moment for toe design

Moment from bearing pressure

$$M_{\text{toe_bear}} = (2 \times p_{\text{toe_f}} + p_{\text{stem_mid_f}}) \times (l_{\text{toe}} + t_{\text{wall}} / 2)^2 / 6 = \mathbf{114.8 \text{ kNm/m}}$$

Moment from weight of base

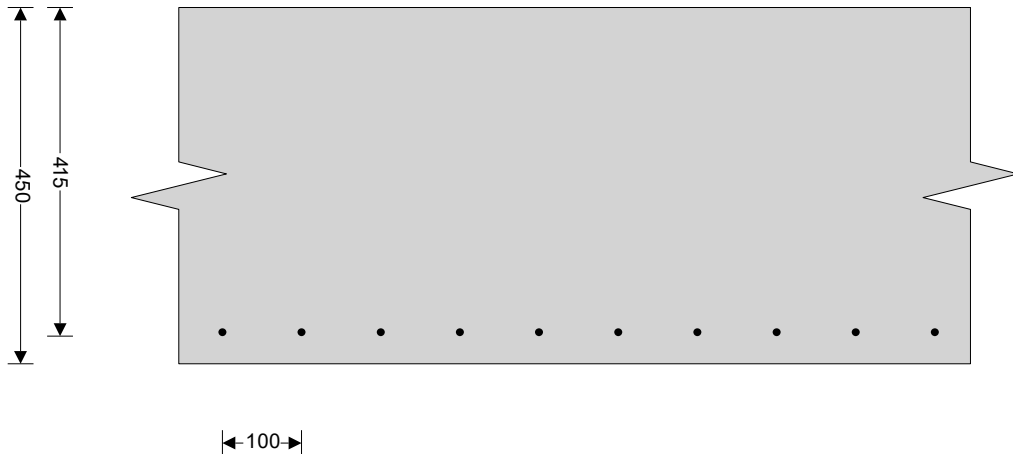
$$M_{\text{toe_wt_base}} = (\gamma_{\text{f_d}} \times \gamma_{\text{base}} \times t_{\text{base}} \times (l_{\text{toe}} + t_{\text{wall}} / 2)^2 / 2) = \mathbf{26.5 \text{ kNm/m}}$$

Moment from weight of soil

$$M_{\text{toe_wt_soil}} = (w_{\text{p_f}} - (\gamma_{\text{f_d}} \times \gamma_{\text{m}} \times l_{\text{toe}} \times d_{\text{exc}})) \times (l_{\text{toe}} + t_{\text{wall}}) / 2 = \mathbf{8.9 \text{ kNm/m}}$$

Total moment for toe design

$$M_{\text{toe}} = M_{\text{toe_bear}} - M_{\text{toe_wt_base}} - M_{\text{toe_wt_soil}} = \mathbf{79.4 \text{ kNm/m}}$$



Check toe in bending

Width of toe

$$b = \mathbf{1000 \text{ mm/m}}$$

Depth of reinforcement

$$d_{\text{toe}} = t_{\text{base}} - c_{\text{toe}} - (\phi_{\text{toe}} / 2) = \mathbf{415.0 \text{ mm}}$$

Constant

$$K_{\text{toe}} = M_{\text{toe}} / (b \times d_{\text{toe}}^2 \times f_{\text{cu}}) = \mathbf{0.012}$$

Compression reinforcement is not required

Lever arm

$$z_{\text{toe}} = \min(0.5 + \sqrt{(0.25 - (\min(K_{\text{toe}}, 0.225) / 0.9))}, 0.95) \times d_{\text{toe}}$$

$$z_{\text{toe}} = \mathbf{394 \text{ mm}}$$

Area of tension reinforcement required

$$A_{\text{s_toe_des}} = M_{\text{toe}} / (0.87 \times f_y \times z_{\text{toe}}) = \mathbf{463 \text{ mm}^2/\text{m}}$$

Minimum area of tension reinforcement

$$A_{\text{s_toe_min}} = k \times b \times t_{\text{base}} = \mathbf{585 \text{ mm}^2/\text{m}}$$

Area of tension reinforcement required

$$A_{\text{s_toe_req}} = \text{Max}(A_{\text{s_toe_des}}, A_{\text{s_toe_min}}) = \mathbf{585 \text{ mm}^2/\text{m}}$$

Reinforcement provided

$$\mathbf{10 \text{ mm dia. bars @ 100 mm centres}}$$

Project 6 Brynseion Street, Troedyrhiw				Job no. B1265	
Calcs for Reinforced concrete retaining wall				Start page no./Revision 10 A	
Calcs by AS	Calcs date 02/08/2024	Checked by MJ	Checked date 02/08/2024	Approved by CN	Approved date 02/08/2024

Area of reinforcement provided

$$A_{s_toe_prov} = 785 \text{ mm}^2/\text{m}$$

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress

$$v_{toe} = V_{toe} / (b \times d_{toe}) = 0.162 \text{ N/mm}^2$$

Allowable shear stress

$$v_{adm} = \min(0.8 \times \sqrt{f_{cu}} / 1 \text{ N/mm}^2, 5) \times 1 \text{ N/mm}^2 = 5.000 \text{ N/mm}^2$$

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress

$$v_{c_toe} = 0.424 \text{ N/mm}^2$$

$v_{toe} < v_{c_toe}$ - No shear reinforcement required

Design of reinforced concrete retaining wall heel (BS 8002:1994)

Material properties

Characteristic strength of concrete

$$f_{cu} = 40 \text{ N/mm}^2$$

Characteristic strength of reinforcement

$$f_y = 500 \text{ N/mm}^2$$

Base details

Minimum area of reinforcement

$$k = 0.13 \%$$

Cover to reinforcement in heel

$$c_{heel} = 30 \text{ mm}$$

Calculate shear for heel design

Shear from bearing pressure

$$V_{heel_bear} = (p_{heel_f} + p_{stem_heel_f}) \times l_{heel} / 2 = 5.8 \text{ kN/m}$$

Shear from weight of base

$$V_{heel_wt_base} = \gamma_{f_d} \times \gamma_{base} \times l_{heel} \times t_{base} = 3 \text{ kN/m}$$

Shear from weight of moist backfill

$$V_{heel_wt_m} = w_{m_w_f} = 14.1 \text{ kN/m}$$

Shear from surcharge

$$V_{heel_sur} = w_{sur_f} = 3.2 \text{ kN/m}$$

Total shear for heel design

$$V_{heel} = -V_{heel_bear} + V_{heel_wt_base} + V_{heel_wt_m} + V_{heel_sur} = 14.5 \text{ kN/m}$$

Calculate moment for heel design

Moment from bearing pressure

$$M_{heel_bear} = (2 \times p_{heel_f} + p_{stem_mid_f}) \times (l_{heel} + t_{wall} / 2)^2 / 6 = 1.9 \text{ kNm/m}$$

Moment from weight of base

$$M_{heel_wt_base} = (\gamma_{f_d} \times \gamma_{base} \times t_{base} \times (l_{heel} + t_{wall} / 2)^2 / 2) = 1 \text{ kNm/m}$$

Moment from weight of moist backfill

$$M_{heel_wt_m} = w_{m_w_f} \times (l_{heel} + t_{wall}) / 2 = 3.7 \text{ kNm/m}$$

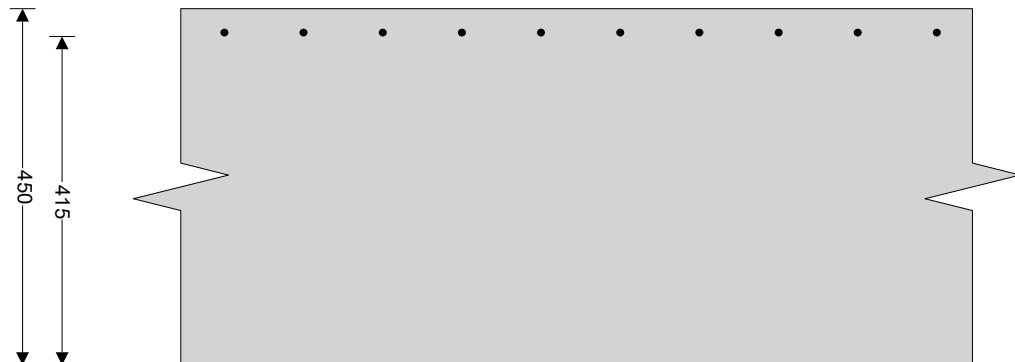
Moment from surcharge

$$M_{heel_sur} = w_{sur_f} \times (l_{heel} + t_{wall}) / 2 = 0.8 \text{ kNm/m}$$

Total moment for heel design

$$M_{heel} = -M_{heel_bear} + M_{heel_wt_base} + M_{heel_wt_m} + M_{heel_sur} = 3.6 \text{ kNm/m}$$

←100→



Check heel in bending

Width of heel

$$b = 1000 \text{ mm/m}$$

Depth of reinforcement

$$d_{heel} = t_{base} - c_{heel} - (\phi_{heel} / 2) = 415.0 \text{ mm}$$

Constant

$$K_{heel} = M_{heel} / (b \times d_{heel}^2 \times f_{cu}) = 0.001$$

Project 6 Brynseion Street, Troedryhiw				Job no. B1265	
Calcs for Reinforced concrete retaining wall				Start page no./Revision 11 A	
Calcs by AS	Calcs date 02/08/2024	Checked by MJ	Checked date 02/08/2024	Approved by CN	Approved date 02/08/2024

Compression reinforcement is not required

Lever arm

$$Z_{heel} = \min(0.5 + \sqrt{(0.25 - (\min(K_{heel}, 0.225) / 0.9))}, 0.95) \times d_{heel}$$

$$Z_{heel} = \mathbf{394 \text{ mm}}$$

Area of tension reinforcement required

$$A_{s_heel_des} = M_{heel} / (0.87 \times f_y \times Z_{heel}) = \mathbf{21 \text{ mm}^2/\text{m}}$$

Minimum area of tension reinforcement

$$A_{s_heel_min} = k \times b \times t_{base} = \mathbf{585 \text{ mm}^2/\text{m}}$$

Area of tension reinforcement required

$$A_{s_heel_req} = \text{Max}(A_{s_heel_des}, A_{s_heel_min}) = \mathbf{585 \text{ mm}^2/\text{m}}$$

Reinforcement provided

$$\mathbf{10 \text{ mm dia. bars @ } 100 \text{ mm centres}}$$

Area of reinforcement provided

$$A_{s_heel_prov} = \mathbf{785 \text{ mm}^2/\text{m}}$$

PASS - Reinforcement provided at the retaining wall heel is adequate

Check shear resistance at heel

Design shear stress

$$V_{heel} = V_{heel} / (b \times d_{heel}) = \mathbf{0.035 \text{ N/mm}^2}$$

Allowable shear stress

$$V_{adm} = \min(0.8 \times \sqrt{f_{cu}} / 1 \text{ N/mm}^2, 5) \times 1 \text{ N/mm}^2 = \mathbf{5.000 \text{ N/mm}^2}$$

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress

$$V_{c_heel} = \mathbf{0.424 \text{ N/mm}^2}$$

$V_{heel} < V_{c_heel}$ - No shear reinforcement required

Design of reinforced concrete retaining wall stem (BS 8002:1994)

Material properties

Characteristic strength of concrete

$$f_{cu} = \mathbf{40 \text{ N/mm}^2}$$

Characteristic strength of reinforcement

$$f_y = \mathbf{500 \text{ N/mm}^2}$$

Wall details

Minimum area of reinforcement

$$k = \mathbf{0.13 \%}$$

Cover to reinforcement in stem

$$C_{stem} = \mathbf{30 \text{ mm}}$$

Cover to reinforcement in wall

$$C_{wall} = \mathbf{30 \text{ mm}}$$

Factored horizontal active forces on stem

Surcharge

$$F_{s_sur_f} = \gamma_{f_l} \times K_a \times \cos(90 - \alpha + \delta) \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds}) = \mathbf{15.8 \text{ kN/m}}$$

Moist backfill above water table

$$F_{s_m_a_f} = 0.5 \times \gamma_{f_e} \times K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2 = \mathbf{34.7 \text{ kN/m}}$$

Calculate shear for stem design

Shear at base of stem

$$V_{stem} = F_{s_sur_f} + F_{s_m_a_f} = \mathbf{50.5 \text{ kN/m}}$$

Calculate moment for stem design

Surcharge

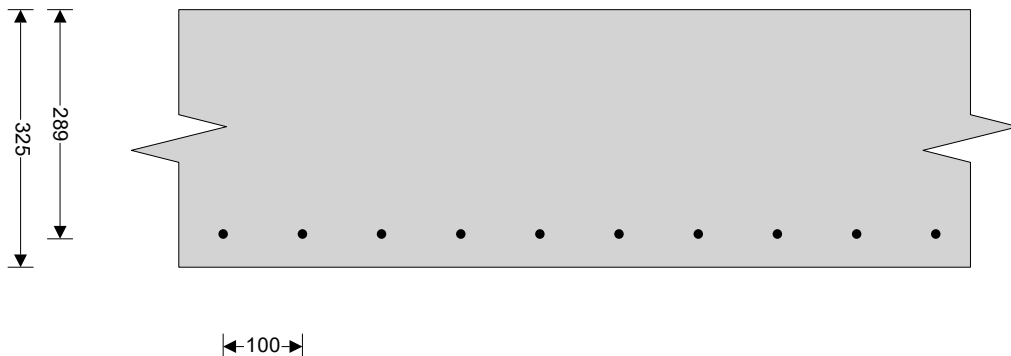
$$M_{s_sur} = F_{s_sur_f} \times (h_{stem} + t_{base}) / 2 = \mathbf{25.6 \text{ kNm/m}}$$

Moist backfill above water table

$$M_{s_m_a} = F_{s_m_a_f} \times (2 \times h_{sat} + h_{eff} - d_{ds} + t_{base} / 2) / 3 = \mathbf{40.2 \text{ kNm/m}}$$

Total moment for stem design

$$M_{stem} = M_{s_sur} + M_{s_m_a} = \mathbf{65.8 \text{ kNm/m}}$$



Project 6 Brynseion Street, Troedyrhiw				Job no. B1265	
Calcs for Reinforced concrete retaining wall				Start page no./Revision 12 A	
Calcs by AS	Calcs date 02/08/2024	Checked by MJ	Checked date 02/08/2024	Approved by CN	Approved date 02/08/2024

Check wall stem in bending

Width of wall stem

$$b = 1000 \text{ mm/m}$$

Depth of reinforcement

$$d_{\text{stem}} = t_{\text{wall}} - c_{\text{stem}} - (\phi_{\text{stem}} / 2) = 289.0 \text{ mm}$$

Constant

$$K_{\text{stem}} = M_{\text{stem}} / (b \times d_{\text{stem}}^2 \times f_{\text{cu}}) = 0.020$$

Compression reinforcement is not required

Lever arm

$$z_{\text{stem}} = \min(0.5 + \sqrt{(0.25 - (\min(K_{\text{stem}}, 0.225) / 0.9))}, 0.95) \times d_{\text{stem}}$$

$$z_{\text{stem}} = 275 \text{ mm}$$

Area of tension reinforcement required

$$A_{s_stem_des} = M_{\text{stem}} / (0.87 \times f_y \times z_{\text{stem}}) = 551 \text{ mm}^2/\text{m}$$

Minimum area of tension reinforcement

$$A_{s_stem_min} = k \times b \times t_{\text{wall}} = 423 \text{ mm}^2/\text{m}$$

Area of tension reinforcement required

$$A_{s_stem_req} = \text{Max}(A_{s_stem_des}, A_{s_stem_min}) = 551 \text{ mm}^2/\text{m}$$

Reinforcement provided

$$12 \text{ mm dia. bars @ } 100 \text{ mm centres}$$

Area of reinforcement provided

$$A_{s_stem_prov} = 1131 \text{ mm}^2/\text{m}$$

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress

$$v_{\text{stem}} = V_{\text{stem}} / (b \times d_{\text{stem}}) = 0.175 \text{ N/mm}^2$$

Allowable shear stress

$$v_{\text{adm}} = \min(0.8 \times \sqrt{f_{\text{cu}}}, 5) \times 1 \text{ N/mm}^2 = 5.000 \text{ N/mm}^2$$

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress

$$v_{c_stem} = 0.586 \text{ N/mm}^2$$

$v_{\text{stem}} < v_{c_stem}$ - No shear reinforcement required

Check retaining wall deflection

Basic span/effective depth ratio

$$\text{ratio}_{\text{bas}} = 7$$

Design service stress

$$f_s = 2 \times f_y \times A_{s_stem_req} / (3 \times A_{s_stem_prov}) = 162.5 \text{ N/mm}^2$$

Modification factor

$$\text{factor}_{\text{tens}} = \min(0.55 + (477 \text{ N/mm}^2 - f_s) / (120 \times (0.9 \text{ N/mm}^2 + (M_{\text{stem}} / (b \times d_{\text{stem}}^2)))), 2) = 2.00$$

Maximum span/effective depth ratio

$$\text{ratio}_{\text{max}} = \text{ratio}_{\text{bas}} \times \text{factor}_{\text{tens}} = 14.00$$

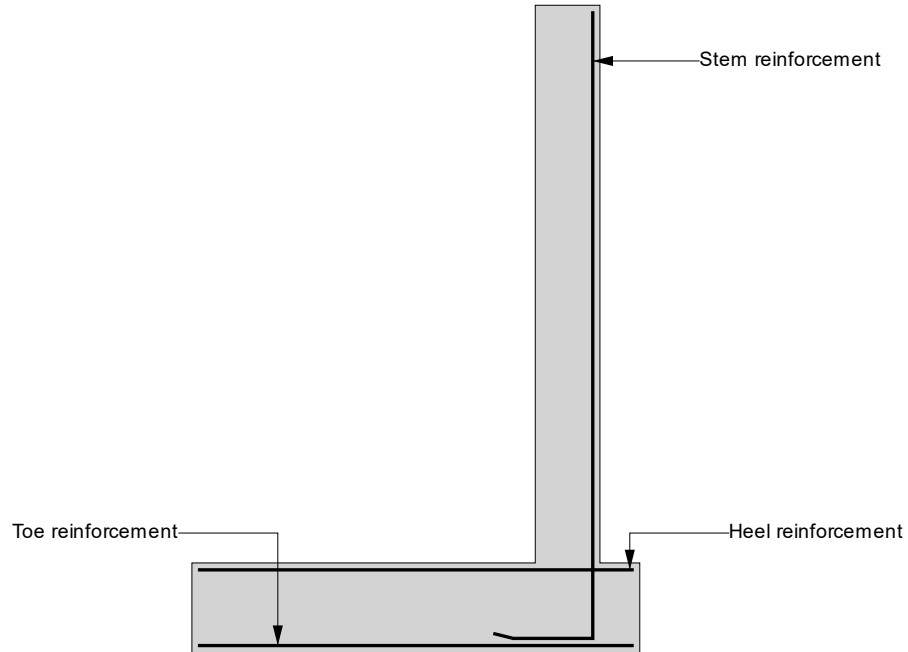
Actual span/effective depth ratio

$$\text{ratio}_{\text{act}} = h_{\text{stem}} / d_{\text{stem}} = 9.69$$

PASS - Span to depth ratio is acceptable

Project 6 Brynseion Street, Troedyrhiw				Job no. B1265	
Calcs for Reinforced concrete retaining wall				Start page no./Revision 13 A	
Calcs by AS	Calcs date 02/08/2024	Checked by MJ	Checked date 02/08/2024	Approved by CN	Approved date 02/08/2024

Indicative retaining wall reinforcement diagram

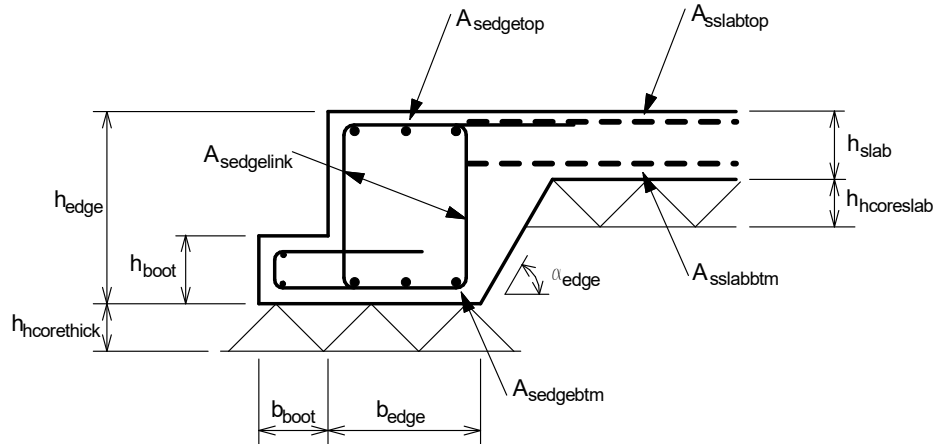


Toe bars - 10 mm dia.@ 100 mm centres - (785 mm²/m)
 Heel bars - 10 mm dia.@ 100 mm centres - (785 mm²/m)
 Stem bars - 12 mm dia.@ 100 mm centres - (1131 mm²/m)

Project 6 Brynseion Street, Troedyrhiw				Job no. B1265	
Calcs for Raft Foundation				Start page no./Revision 14	
Calcs by AS	Calcs date 02/08/2024	Checked by MJ	Checked date 02/08/2024	Approved by CN	Approved date 02/08/2024

RAFT FOUNDATION DESIGN (BS8110 : PART 1 : 1997)

Tedds calculation version 1.0.13



Soil and raft definition

Soil definition

Allowable bearing pressure	$q_{allow} = 100.0 \text{ kN/m}^2$
Depth of hardcore beneath slab	$h_{hcoreslab} = 150 \text{ mm}$ (Dispersal allowed for bearing pressure check)
Depth of hardcore beneath thickenings	$h_{hcorethick} = 150 \text{ mm}$ (Dispersal allowed for bearing pressure check)
Density of hardcore	$\gamma_{hcore} = 23.0 \text{ kN/m}^3$
Basic assumed diameter of local depression	$\phi_{depbasic} = 1500 \text{ mm}$
Diameter under slab modified for hardcore	$\phi_{depslab} = \phi_{depbasic} - h_{hcoreslab} = 1350 \text{ mm}$
Diameter under thickenings modified for hardcore	$\phi_{depthick} = \phi_{depbasic} - h_{hcorethick} = 1350 \text{ mm}$

Raft slab definition

Max dimension/max dimension between joints	$l_{max} = 5.600 \text{ m}$
Slab thickness	$h_{slab} = 175 \text{ mm}$
Concrete strength	$f_{cu} = 35 \text{ N/mm}^2$
Poissons ratio of concrete	$\nu = 0.2$
Slab mesh reinforcement strength	$f_{yslab} = 500 \text{ N/mm}^2$
Partial safety factor for steel reinforcement	$\gamma_s = 1.15$
From C&CA document 'Concrete ground floors' Table 5	
Minimum mesh required in top for shrinkage	A142
Actual mesh provided in top	2 x A393 ($A_{sslabtop} = 786 \text{ mm}^2/\text{m}$)
Mesh provided in bottom	2 x A393 ($A_{sslabbtm} = 786 \text{ mm}^2/\text{m}$)
Top mesh bar diameter	$\phi_{slabtop} = 10 \text{ mm}$
Bottom mesh bar diameter	$\phi_{slabbtm} = 10 \text{ mm}$
Cover to top reinforcement	$C_{top} = 35 \text{ mm}$
Cover to bottom reinforcement	$C_{btm} = 35 \text{ mm}$
Average effective depth of top reinforcement	$d_{tslabav} = h_{slab} - C_{top} - \phi_{slabtop} = 130 \text{ mm}$
Average effective depth of bottom reinforcement	$d_{bslabav} = h_{slab} - C_{btm} - \phi_{slabbtm} = 130 \text{ mm}$
Overall average effective depth	$d_{slabav} = (d_{tslabav} + d_{bslabav})/2 = 130 \text{ mm}$
Minimum effective depth of top reinforcement	$d_{tslabmin} = d_{tslabav} - \phi_{slabtop}/2 = 125 \text{ mm}$
Minimum effective depth of bottom reinforcement	$d_{bslabmin} = d_{bslabav} - \phi_{slabbtm}/2 = 125 \text{ mm}$

Project 6 Brynseion Street, Troedryhiw				Job no. B1265	
Calcs for Raft Foundation				Start page no./Revision 15	
Calcs by AS	Calcs date 02/08/2024	Checked by MJ	Checked date 02/08/2024	Approved by CN	Approved date 02/08/2024

Edge beam definition

Overall depth	$h_{\text{edge}} = 450 \text{ mm}$
Width	$b_{\text{edge}} = 450 \text{ mm}$
Depth of boot	$h_{\text{boot}} = 225 \text{ mm}$
Width of boot	$b_{\text{boot}} = 250 \text{ mm}$
Angle of chamfer to horizontal	$\alpha_{\text{edge}} = 45 \text{ deg}$
Strength of main bar reinforcement	$f_y = 500 \text{ N/mm}^2$
Strength of link reinforcement	$f_{ys} = 500 \text{ N/mm}^2$
Reinforcement provided in top	4 H16 bars ($A_{\text{sedge top}} = 804 \text{ mm}^2$)
Reinforcement provided in bottom	4 H16 bars ($A_{\text{sedge bot}} = 804 \text{ mm}^2$)
Link reinforcement provided	4 H10 legs at 200 ctrs ($A_{sv/s_v} = 1.571 \text{ mm}$)
Bottom cover to links	$C_{\text{beam}} = 35 \text{ mm}$
Effective depth of top reinforcement	$d_{\text{edge top}} = h_{\text{edge}} - C_{\text{top}} - \phi_{\text{slab top}} - \phi_{\text{edge link}} - \phi_{\text{edge top}}/2 = 387 \text{ mm}$
Effective depth of bottom reinforcement	$d_{\text{edge bot}} = h_{\text{edge}} - C_{\text{beam}} - \phi_{\text{edge link}} - \phi_{\text{edge bot}}/2 = 397 \text{ mm}$
Boot main reinforcement	H10 bars at 200 ctrs ($A_{\text{sboot}} = 393 \text{ mm}^2/\text{m}$)
Effective depth of boot reinforcement	$d_{\text{boot}} = h_{\text{boot}} - C_{\text{beam}} - \phi_{\text{boot}}/2 = 185 \text{ mm}$

Internal slab design checks

Basic loading

Slab self weight	$W_{\text{slab}} = 24 \text{ kN/m}^3 \times h_{\text{slab}} = 4.2 \text{ kN/m}^2$
Hardcore	$W_{\text{coreslab}} = \gamma_{\text{hcore}} \times h_{\text{coreslab}} = 3.5 \text{ kN/m}^2$

Applied loading

Uniformly distributed dead load	$W_{\text{Dudl}} = 1.5 \text{ kN/m}^2$
Uniformly distributed live load	$W_{\text{Ludl}} = 1.5 \text{ kN/m}^2$

Internal slab bearing pressure check

Total uniform load at formation level	$W_{\text{udl}} = W_{\text{slab}} + W_{\text{coreslab}} + W_{\text{Dudl}} + W_{\text{Ludl}} = 10.7 \text{ kN/m}^2$
PASS - $w_{\text{udl}} \leq q_{\text{allow}}$ - Applied bearing pressure is less than allowable	

Internal slab bending and shear check

Applied bending moments

Span of slab	$l_{\text{slab}} = \phi_{\text{depslab}} + d_{\text{tslab av}} = 1480 \text{ mm}$
Ultimate self weight udl	$W_{\text{swult}} = 1.4 \times W_{\text{slab}} = 5.9 \text{ kN/m}^2$
Self weight moment at centre	$M_{\text{cs w}} = W_{\text{swult}} \times l_{\text{slab}}^2 \times (1 + \nu) / 64 = 0.2 \text{ kNm/m}$
Self weight moment at edge	$M_{\text{es w}} = W_{\text{swult}} \times l_{\text{slab}}^2 / 32 = 0.4 \text{ kNm/m}$
Self weight shear force at edge	$V_{\text{sw}} = W_{\text{swult}} \times l_{\text{slab}} / 4 = 2.2 \text{ kN/m}$

Moments due to applied uniformly distributed loads

Ultimate applied udl	$W_{\text{udlult}} = 1.4 \times W_{\text{Dudl}} + 1.6 \times W_{\text{Ludl}} = 4.5 \text{ kN/m}^2$
Moment at centre	$M_{\text{cudl}} = W_{\text{udlult}} \times l_{\text{slab}}^2 \times (1 + \nu) / 64 = 0.2 \text{ kNm/m}$
Moment at edge	$M_{\text{eudl}} = W_{\text{udlult}} \times l_{\text{slab}}^2 / 32 = 0.3 \text{ kNm/m}$
Shear force at edge	$V_{\text{udl}} = W_{\text{udlult}} \times l_{\text{slab}} / 4 = 1.7 \text{ kN/m}$

Resultant moments and shears

Total moment at edge	$M_{\Sigma e} = 0.7 \text{ kNm/m}$
Total moment at centre	$M_{\Sigma c} = 0.4 \text{ kNm/m}$
Total shear force	$V_{\Sigma} = 3.8 \text{ kN/m}$

Reinforcement required in top

K factor	$K_{\text{slab top}} = M_{\Sigma e} / (f_{cu} \times d_{\text{tslab av}}^2) = 0.001$
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Lever arm

$$Z_{slabtop} = d_{slabav} \times \min(0.95, 0.5 + \sqrt{(0.25 - K_{slabtop}/0.9)}) = \mathbf{123.5 \text{ mm}}$$

Area of steel required for bending

$$A_{sslabtopbend} = M_{\Sigma c} / ((1.0/\gamma_s) \times f_{yslab} \times Z_{slabtop}) = \mathbf{13 \text{ mm}^2/\text{m}}$$

Minimum area of steel required

$$A_{sslabmin} = 0.0013 \times h_{slab} = \mathbf{228 \text{ mm}^2/\text{m}}$$

Area of steel required

$$A_{sslabtopreq} = \max(A_{sslabtopbend}, A_{sslabmin}) = \mathbf{228 \text{ mm}^2/\text{m}}$$

PASS - $A_{sslabtopreq} \leq A_{sslabtop}$ - Area of reinforcement provided in top to span local depressions is adequate

Reinforcement required in bottom

K factor

$$K_{slabbtm} = M_{\Sigma c} / (f_{cu} \times d_{slabav}^2) = \mathbf{0.001}$$

Lever arm

$$Z_{slabbtm} = d_{slabav} \times \min(0.95, 0.5 + \sqrt{(0.25 - K_{slabbtm}/0.9)}) = \mathbf{123.5 \text{ mm}}$$

Area of steel required for bending

$$A_{sslabbtmbend} = M_{\Sigma c} / ((1.0/\gamma_s) \times f_{yslab} \times Z_{slabbtm}) = \mathbf{8 \text{ mm}^2/\text{m}}$$

Area of steel required

$$A_{sslabbtmreq} = \max(A_{sslabbtmbend}, A_{sslabmin}) = \mathbf{228 \text{ mm}^2/\text{m}}$$

PASS - $A_{sslabbtmreq} \leq A_{sslabbtm}$ - Area of reinforcement provided in bottom to span local depressions is adequate

Shear check

Applied shear stress

$$v = V_{\Sigma} / d_{slabmin} = \mathbf{0.031 \text{ N/mm}^2}$$

Tension steel ratio

$$\rho = 100 \times A_{sslabtop} / d_{slabmin} = \mathbf{0.629}$$

From BS8110-1:1997 - Table 3.8

Design concrete shear strength

$$v_c = \mathbf{0.810 \text{ N/mm}^2}$$

PASS - $v \leq v_c$ - Shear capacity of the slab is adequate

Internal slab deflection check

Basic allowable span to depth ratio

$$\text{Ratio}_{\text{basic}} = \mathbf{26.0}$$

Moment factor

$$M_{\text{factor}} = M_{\Sigma c} / d_{slabav}^2 = \mathbf{0.025 \text{ N/mm}^2}$$

Steel service stress

$$f_s = 2/3 \times f_{yslab} \times A_{sslabbtmbend} / A_{sslabbtm} = \mathbf{3.367 \text{ N/mm}^2}$$

Modification factor

$$MF_{\text{slab}} = \min(2.0, 0.55 + [(477 \text{ N/mm}^2 - f_s) / (120 \times (0.9 \text{ N/mm}^2 + M_{\text{factor}}))])$$

$$MF_{\text{slab}} = \mathbf{2.000}$$

Modified allowable span to depth ratio

$$\text{Ratio}_{\text{allow}} = \text{Ratio}_{\text{basic}} \times MF_{\text{slab}} = \mathbf{52.000}$$

Actual span to depth ratio

$$\text{Ratio}_{\text{actual}} = l_{\text{slab}} / d_{slabav} = \mathbf{11.385}$$

PASS - $\text{Ratio}_{\text{actual}} \leq \text{Ratio}_{\text{allow}}$ - Slab span to depth ratio is adequate

Edge beam design checks

Basic loading

Hardcore

$$W_{\text{corethick}} = \gamma_{\text{hcore}} \times h_{\text{corethick}} = \mathbf{3.5 \text{ kN/m}^2}$$

Edge beam

Rectangular beam element

$$W_{\text{beam}} = 24 \text{ kN/m}^3 \times h_{\text{edge}} \times b_{\text{edge}} = \mathbf{4.9 \text{ kN/m}}$$

Boot element

$$W_{\text{boot}} = 24 \text{ kN/m}^3 \times h_{\text{boot}} \times b_{\text{boot}} = \mathbf{1.4 \text{ kN/m}}$$

Chamfer element

$$W_{\text{chamfer}} = 24 \text{ kN/m}^3 \times (h_{\text{edge}} - h_{\text{slab}})^2 / (2 \times \tan(\alpha_{\text{edge}})) = \mathbf{0.9 \text{ kN/m}}$$

Slab element

$$W_{\text{slabelmt}} = 24 \text{ kN/m}^3 \times h_{\text{slab}} \times (h_{\text{edge}} - h_{\text{slab}}) / \tan(\alpha_{\text{edge}}) = \mathbf{1.2 \text{ kN/m}}$$

Edge beam self weight

$$W_{\text{edge}} = W_{\text{beam}} + W_{\text{boot}} + W_{\text{chamfer}} + W_{\text{slabelmt}} = \mathbf{8.3 \text{ kN/m}}$$

Edge load number 1

Load type

Longitudinal line load

Dead load

$$W_{\text{Dedge1}} = \mathbf{15.0 \text{ kN/m}}$$

Live load

$$W_{\text{Ledge1}} = \mathbf{0.0 \text{ kN/m}}$$

Ultimate load

$$W_{\text{ultedge1}} = 1.4 \times W_{\text{Dedge1}} + 1.6 \times W_{\text{Ledge1}} = \mathbf{21.0 \text{ kN/m}}$$

Longitudinal line load width

$$b_{\text{edge1}} = \mathbf{100 \text{ mm}}$$

Centroid of load from outside face of raft

$$x_{\text{edge1}} = \mathbf{50 \text{ mm}}$$

Edge load number 2

Load type

Longitudinal line load

Dead load

$$W_{\text{Dedge2}} = \mathbf{15.0 \text{ kN/m}}$$

Live load

$$w_{Ledge2} = 5.0 \text{ kN/m}$$

Ultimate load

$$w_{ultedge2} = 1.4 \times w_{Dedge2} + 1.6 \times w_{Ledge2} = 29.0 \text{ kN/m}$$

Longitudinal line load width

$$b_{edge2} = 100 \text{ mm}$$

Centroid of load from outside face of raft

$$x_{edge2} = 250 \text{ mm}$$

Edge beam bearing pressure check

Effective bearing width of edge beam

$$b_{bearing} = b_{edge} + b_{boot} + (h_{edge} - h_{slab})/\tan(\alpha_{edge}) = 975 \text{ mm}$$

Total uniform load at formation level

$$w_{udledge} = w_{Dudl} + w_{Ludl} + w_{edge}/b_{bearing} + w_{hcorethick} = 14.9 \text{ kN/m}^2$$

Centroid of longitudinal and equivalent line loads from outside face of raft

Load x distance for edge load 1

$$\text{Moment}_1 = w_{ultedge1} \times x_{edge1} = 1.1 \text{ kN}$$

Load x distance for edge load 2

$$\text{Moment}_2 = w_{ultedge2} \times x_{edge2} = 7.3 \text{ kN}$$

 Sum of ultimate longitud'l and equivalent line loads $\Sigma UDL = 50.0 \text{ kN/m}$

Sum of load x distances

$$\Sigma \text{Moment} = 8.3 \text{ kN}$$

Centroid of loads

$$x_{bar} = \Sigma \text{Moment} / \Sigma UDL = 166 \text{ mm}$$

Initially assume no moment transferred into slab due to load/reaction eccentricity

 Sum of unfactored longitud'l and eff'tive line loads $\Sigma UDLsls = 35.0 \text{ kN/m}$

Allowable bearing width

$$b_{allow} = 2 \times x_{bar} + 2 \times h_{hcoreslab} \times \tan(30) = 505 \text{ mm}$$

Bearing pressure due to line/point loads

$$q_{linepoint} = \Sigma UDLsls / b_{allow} = 69.3 \text{ kN/m}^2$$

Total applied bearing pressure

$$q_{edge} = q_{linepoint} + w_{udledge} = 84.2 \text{ kN/m}^2$$

PASS - $q_{edge} \leq q_{allow}$ - Allowable bearing pressure is not exceeded

Edge beam bending check

Divider for moments due to udl's

$$\beta_{udl} = 10.0$$

Applied bending moments

Span of edge beam

$$l_{edge} = \phi_{depthick} + d_{edgetop} = 1737 \text{ mm}$$

Ultimate self weight udl

$$w_{edgeult} = 1.4 \times w_{edge} = 11.6 \text{ kN/m}$$

Ultimate slab udl (approx)

$$w_{edgeslab} = \max(0 \text{ kN/m}, 1.4 \times w_{slab} \times ((\phi_{depthick}/2 \times 3/4) - (b_{edge} + (h_{edge} - h_{slab})/\tan(\alpha_{edge}))))$$

$$w_{edgeslab} = 0.0 \text{ kN/m}$$

Self weight and slab bending moment

$$M_{edgesw} = (w_{edgeult} + w_{edgeslab}) \times l_{edge}^2 / \beta_{udl} = 3.5 \text{ kNm}$$

Self weight shear force

$$V_{edgesw} = (w_{edgeult} + w_{edgeslab}) \times l_{edge} / 2 = 10.1 \text{ kN}$$

Moments due to applied uniformly distributed loads

Ultimate udl (approx)

$$w_{edgeudl} = w_{udlult} \times \phi_{depthick} / 2 \times 3/4 = 2.3 \text{ kN/m}$$

Bending moment

$$M_{edgeudl} = w_{edgeudl} \times l_{edge}^2 / \beta_{udl} = 0.7 \text{ kNm}$$

Shear force

$$V_{edgeudl} = w_{edgeudl} \times l_{edge} / 2 = 2.0 \text{ kN}$$

Moment and shear due to load number 1

Bending moment

$$M_{edge1} = w_{ultedge1} \times l_{edge}^2 / \beta_{udl} = 6.3 \text{ kNm}$$

Shear force

$$V_{edge1} = w_{ultedge1} \times l_{edge} / 2 = 18.2 \text{ kN}$$

Moment and shear due to load number 2

Bending moment

$$M_{edge2} = w_{ultedge2} \times l_{edge}^2 / \beta_{udl} = 8.7 \text{ kNm}$$

Shear force

$$V_{edge2} = w_{ultedge2} \times l_{edge} / 2 = 25.2 \text{ kN}$$

Resultant moments and shears

Total moment (hogging and sagging)

$$M_{\Sigma edge} = 19.3 \text{ kNm}$$

Maximum shear force

$$V_{\Sigma edge} = 55.5 \text{ kN}$$

Reinforcement required in top

Width of section in compression zone

$$b_{edgetop} = b_{edge} + b_{boot} = 700 \text{ mm}$$

Average web width

$$b_w = b_{edge} + (h_{edge} / \tan(\alpha_{edge})) / 2 = 675 \text{ mm}$$

Project 6 Brynseion Street, Troedryhiw				Job no. B1265	
Calcs for Raft Foundation				Start page no./Revision 18	
Calcs by AS	Calcs date 02/08/2024	Checked by MJ	Checked date 02/08/2024	Approved by CN	Approved date 02/08/2024

K factor $K_{edge\ top} = M_{\Sigma edge} / (f_{cu} \times b_{edge\ top} \times d_{edge\ top}^2) = \mathbf{0.005}$
 Lever arm $Z_{edge\ top} = d_{edge\ top} \times \min(0.95, 0.5 + \sqrt{(0.25 - K_{edge\ top}/0.9)}) = \mathbf{368\ mm}$
 Area of steel required for bending $A_{s\ edge\ top\ bend} = M_{\Sigma edge} / ((1.0/\gamma_s) \times f_y \times Z_{edge\ top}) = \mathbf{121\ mm^2}$
 Minimum area of steel required $A_{s\ edge\ top\ min} = 0.0013 \times 1.0 \times b_w \times h_{edge} = \mathbf{395\ mm^2}$
 Area of steel required $A_{s\ edge\ top\ req} = \max(A_{s\ edge\ top\ bend}, A_{s\ edge\ top\ min}) = \mathbf{395\ mm^2}$
PASS - $A_{s\ edge\ top\ req} \leq A_{s\ edge\ top}$ - Area of reinforcement provided in top of edge beams is adequate

Reinforcement required in bottom

Width of section in compression zone $b_{edge\ botm} = b_{edge} + (h_{edge} - h_{slab}) / \tan(\alpha_{edge}) + 0.1 \times l_{edge} = \mathbf{899\ mm}$
 K factor $K_{edge\ botm} = M_{\Sigma edge} / (f_{cu} \times b_{edge\ botm} \times d_{edge\ botm}^2) = \mathbf{0.004}$
 Lever arm $Z_{edge\ botm} = d_{edge\ botm} \times \min(0.95, 0.5 + \sqrt{(0.25 - K_{edge\ botm}/0.9)}) = \mathbf{377\ mm}$
 Area of steel required for bending $A_{s\ edge\ botm\ bend} = M_{\Sigma edge} / ((1.0/\gamma_s) \times f_y \times Z_{edge\ botm}) = \mathbf{118\ mm^2}$
 Minimum area of steel required $A_{s\ edge\ botm\ min} = 0.0013 \times 1.0 \times b_w \times h_{edge} = \mathbf{395\ mm^2}$
 Area of steel required $A_{s\ edge\ botm\ req} = \max(A_{s\ edge\ botm\ bend}, A_{s\ edge\ botm\ min}) = \mathbf{395\ mm^2}$
PASS - $A_{s\ edge\ botm\ req} \leq A_{s\ edge\ botm}$ - Area of reinforcement provided in bottom of edge beams is adequate

Edge beam shear check

Applied shear stress $V_{edge} = V_{\Sigma edge} / (b_w \times d_{edge\ top}) = \mathbf{0.212\ N/mm^2}$
 Tension steel ratio $\rho_{edge} = 100 \times A_{s\ edge\ top} / (b_w \times d_{edge\ top}) = \mathbf{0.308}$
 From BS8110-1:1997 - Table 3.8
 Design concrete shear strength $V_{c\ edge} = \mathbf{0.481\ N/mm^2}$
 $V_{edge} \leq V_{c\ edge} + 0.4N/mm^2$ - Therefore minimum links required
 Link area to spacing ratio required $A_{sv_upon_sv\ req\ edge} = 0.4N/mm^2 \times b_w / ((1.0/\gamma_s) \times f_{ys}) = \mathbf{0.621\ mm}$
 Link area to spacing ratio provided $A_{sv_upon_sv\ prov\ edge} = N_{edge\ link} \times \pi \times \phi_{edge\ link}^2 / (4 \times S_{v\ edge}) = \mathbf{1.571\ mm}$
PASS - $A_{sv_upon_sv\ req\ edge} \leq A_{sv_upon_sv\ prov\ edge}$ - Shear reinforcement provided in edge beams is adequate

Boot design check

Effective cantilever span $l_{boot} = b_{boot} + d_{boot}/2 = \mathbf{343\ mm}$
 Approximate ultimate bearing pressure $q_{ult} = 1.55 \times q_{allow} = \mathbf{155.0\ kN/m^2}$
 Cantilever moment $M_{boot} = q_{ult} \times l_{boot}^2 / 2 = \mathbf{9.1\ kNm/m}$
 Shear force $V_{boot} = q_{ult} \times l_{boot} = \mathbf{53.1\ kN/m}$
 K factor $K_{boot} = M_{boot} / (f_{cu} \times d_{boot}^2) = \mathbf{0.008}$
 Lever arm $Z_{boot} = d_{boot} \times \min(0.95, 0.5 + \sqrt{(0.25 - K_{boot}/0.9)}) = \mathbf{176\ mm}$
 Area of reinforcement required $A_{s\ boot\ req} = M_{boot} / ((1.0/\gamma_s) \times f_y \times Z_{boot}) = \mathbf{119\ mm^2/m}$
PASS - $A_{s\ boot\ req} \leq A_{s\ boot}$ - Area of reinforcement provided in boot is adequate for bending
 Applied shear stress $V_{boot} = V_{boot} / d_{boot} = \mathbf{0.287\ N/mm^2}$
 Tension steel ratio $\rho_{boot} = 100 \times A_{s\ boot} / d_{boot} = \mathbf{0.212}$
 From BS8110-1:1997 - Table 3.8
 Design concrete shear strength $V_{c\ boot} = \mathbf{0.511\ N/mm^2}$
PASS - $V_{boot} \leq V_{c\ boot}$ - Shear capacity of the boot is adequate

Corner design checks

Basic loading

Corner load number 1

Load type	Line load in x direction
Dead load	$W_{D\ corner1} = \mathbf{15.0\ kN/m}$
Live load	$W_{L\ corner1} = \mathbf{0.0\ kN/m}$
Ultimate load	$W_{ult\ corner1} = 1.4 \times W_{D\ corner1} + 1.6 \times W_{L\ corner1} = \mathbf{21.0\ kN/m}$
Centroid of load from outside face of raft	$y_{corner1} = \mathbf{50\ mm}$

Corner load number 2

Load type

Dead load

Live load

Ultimate load

Centroid of load from outside face of raft

Line load in x direction

$$W_{Dcorner2} = 15.0 \text{ kN/m}$$

$$W_{Lcorner2} = 2.0 \text{ kN/m}$$

$$W_{ultcorner2} = 1.4 \times W_{Dcorner2} + 1.6 \times W_{Lcorner2} = 24.2 \text{ kN/m}$$

$$y_{corner2} = 250 \text{ mm}$$

Corner load number 3

Load type

Dead load

Live load

Ultimate load

Centroid of load from outside face of raft

Line load in y direction

$$W_{Dcorner3} = 15.0 \text{ kN/m}$$

$$W_{Lcorner3} = 0.0 \text{ kN/m}$$

$$W_{ultcorner3} = 1.4 \times W_{Dcorner3} + 1.6 \times W_{Lcorner3} = 21.0 \text{ kN/m}$$

$$x_{corner3} = 250 \text{ mm}$$

Corner load number 4

Load type

Dead load

Live load

Ultimate load

Centroid of load from outside face of raft

Line load in y direction

$$W_{Dcorner4} = 15.0 \text{ kN/m}$$

$$W_{Lcorner4} = 7.0 \text{ kN/m}$$

$$W_{ultcorner4} = 1.4 \times W_{Dcorner4} + 1.6 \times W_{Lcorner4} = 32.2 \text{ kN/m}$$

$$x_{corner4} = 50 \text{ mm}$$

Corner bearing pressure check

Total uniform load at formation level

$$W_{udlcorner} = W_{Dudl} + W_{Ludl} + W_{edge}/b_{bearing} + W_{hcorethick} = 14.9 \text{ kN/m}^2$$

Net bearing press avail to resist line/point loads

$$q_{netcorner} = q_{allow} - W_{udlcorner} = 85.1 \text{ kN/m}^2$$

Total line/point loads

Total unfactored line load in x direction

$$W_{\Sigma line x} = 32.0 \text{ kN/m}$$

Total ultimate line load in x direction

$$W_{\Sigma ultline x} = 45.2 \text{ kN/m}$$

Total unfactored line load in y direction

$$W_{\Sigma line y} = 37.0 \text{ kN/m}$$

Total ultimate line load in y direction

$$W_{\Sigma ultline y} = 53.2 \text{ kN/m}$$

Total unfactored point load

$$W_{\Sigma point} = 0.0 \text{ kN}$$

Total ultimate point load

$$W_{\Sigma ultpoint} = 0.0 \text{ kN}$$

Length of side of sq reqd to resist line/point loads

$$p_{corner} = [W_{\Sigma line x} + W_{\Sigma line y} + \sqrt{((W_{\Sigma line x} + W_{\Sigma line y})^2 + 4 \times q_{netcorner} \times W_{\Sigma point})}] / (2 \times q_{netcorner})$$

$$p_{corner} = 811 \text{ mm}$$

Bending moment about x-axis due to load/reaction eccentricity

Moment due to load 1 (x line)

$$M_{x1} = \max(0 \text{ kNm}, W_{ultcorner1} \times p_{corner} \times (p_{corner}/2 - y_{corner1})) = 6.1 \text{ kNm}$$

Moment due to load 2 (x line)

$$M_{x2} = \max(0 \text{ kNm}, W_{ultcorner2} \times p_{corner} \times (p_{corner}/2 - y_{corner2})) = 3.1 \text{ kNm}$$

Total moment about x axis

$$M_{\Sigma x} = 9.1 \text{ kNm}$$

Bending moment about y-axis due to load/reaction eccentricity

Moment due to load 3 (y line)

$$M_{y3} = \max(0 \text{ kNm}, W_{ultcorner3} \times p_{corner} \times (p_{corner}/2 - x_{corner3})) = 2.6 \text{ kNm}$$

Moment due to load 4 (y line)

$$M_{y4} = \max(0 \text{ kNm}, W_{ultcorner4} \times p_{corner} \times (p_{corner}/2 - x_{corner4})) = 9.3 \text{ kNm}$$

Total moment about y axis

$$M_{\Sigma y} = 11.9 \text{ kNm}$$

Check top reinforcement in edge beams for load/reaction eccentric moment

Max moment due to load/reaction eccentricity

$$M_{\Sigma} = \max(M_{\Sigma x}, M_{\Sigma y}) = 11.9 \text{ kNm}$$

Assume all of this moment is resisted by edge beam

From edge beam design checks away from corners

Moment due to edge beam spanning depression

$$M_{\Sigma edge} = 19.3 \text{ kNm}$$

Total moment to be resisted

$$M_{\Sigma cornerbp} = M_{\Sigma} + M_{\Sigma edge} = 31.2 \text{ kNm}$$

Width of section in compression zone

$$b_{edgetop} = b_{edge} + b_{boot} = 700 \text{ mm}$$

K factor

$$K_{cornerbp} = M_{\Sigma cornerbp} / (f_{cu} \times b_{edgetop} \times d_{edgetop}^2) = 0.009$$

Lever arm

$$Z_{cornerbp} = d_{edgetop} \times \min(0.95, 0.5 + \sqrt{(0.25 - K_{cornerbp}/0.9)}) = \mathbf{368 \text{ mm}}$$

Total area of top steel required

$$A_{scornerbp} = M_{\Sigma cornerbp} / ((1.0/\gamma_s) \times f_y \times Z_{cornerbp}) = \mathbf{195 \text{ mm}^2}$$

PASS - $A_{scornerbp} \leq A_{sedgetop}$ - Area of reinforcement provided to resist eccentric moment is adequate
The allowable bearing pressure at the corner will not be exceeded

Corner beam bending check

Cantilever span of edge beam

$$l_{corner} = \phi_{depthick} / \sqrt{(2)} + d_{edgetop} / 2 = \mathbf{1148 \text{ mm}}$$

Moment and shear due to self weight

Ultimate self weight udl

$$W_{edgeult} = 1.4 \times W_{edge} = \mathbf{11.6 \text{ kN/m}}$$

Average ultimate slab udl (approx)

$$W_{cornerslab} = \max(0 \text{ kN/m}, 1.4 \times W_{slab} \times (\phi_{depthick} / (\sqrt{(2)} \times 2) - (b_{edge} + (h_{edge} - h_{slab}) / \tan(\alpha_{edge}))))$$

$$W_{cornerslab} = \mathbf{0.0 \text{ kN/m}}$$

Self weight and slab bending moment

$$M_{cornersw} = (W_{edgeult} + W_{cornerslab}) \times l_{corner}^2 / 2 = \mathbf{7.6 \text{ kNm}}$$

Self weight and slab shear force

$$V_{cornersw} = (W_{edgeult} + W_{cornerslab}) \times l_{corner} = \mathbf{13.3 \text{ kN}}$$

Moment and shear due to udl's

Maximum ultimate udl

$$W_{cornerudl} = ((1.4 \times W_{Dudl}) + (1.6 \times W_{Ludl})) \times \phi_{depthick} / \sqrt{(2)} = \mathbf{4.3 \text{ kN/m}}$$

Bending moment

$$M_{cornerudl} = W_{cornerudl} \times l_{corner}^2 / 6 = \mathbf{0.9 \text{ kNm}}$$

Shear force

$$V_{cornerudl} = W_{cornerudl} \times l_{corner} / 2 = \mathbf{2.5 \text{ kN}}$$

Moment and shear due to line loads in x direction

Bending moment

$$M_{cornerlinex} = W_{\Sigma ultlinex} \times l_{corner}^2 / 2 = \mathbf{29.8 \text{ kNm}}$$

Shear force

$$V_{cornerlinex} = W_{\Sigma ultlinex} \times l_{corner} = \mathbf{51.9 \text{ kN}}$$

Moment and shear due to line loads in y direction

Bending moment

$$M_{cornerliney} = W_{\Sigma ultliney} \times l_{corner}^2 / 2 = \mathbf{35.1 \text{ kNm}}$$

Shear force

$$V_{cornerliney} = W_{\Sigma ultliney} \times l_{corner} = \mathbf{61.1 \text{ kN}}$$

Total moments and shears due to point loads

Bending moment about x axis

$$M_{cornerpointx} = \mathbf{0.0 \text{ kNm}}$$

Bending moment about y axis

$$M_{cornerpointy} = \mathbf{0.0 \text{ kNm}}$$

Shear force

$$V_{cornerpoint} = \mathbf{0.0 \text{ kN}}$$

Resultant moments and shears

Total moment about x axis

$$M_{\Sigma cornerx} = M_{cornersw} + M_{cornerudl} + M_{cornerliney} + M_{cornerpointx} = \mathbf{43.6 \text{ kNm}}$$

Total shear force about x axis

$$V_{\Sigma cornerx} = V_{cornersw} + V_{cornerudl} + V_{cornerliney} + V_{cornerpoint} = \mathbf{76.8 \text{ kN}}$$

Total moment about y axis

$$M_{\Sigma cornery} = M_{cornersw} + M_{cornerudl} + M_{cornerlinex} + M_{cornerpointy} = \mathbf{38.4 \text{ kNm}}$$

Total shear force about y axis

$$V_{\Sigma cornery} = V_{cornersw} + V_{cornerudl} + V_{cornerlinex} + V_{cornerpoint} = \mathbf{67.7 \text{ kN}}$$

Deflection of both edge beams at corner will be the same therefore design for average of these moments and shears

Design bending moment

$$M_{\Sigma corner} = (M_{\Sigma cornerx} + M_{\Sigma cornery}) / 2 = \mathbf{41.0 \text{ kNm}}$$

Design shear force

$$V_{\Sigma corner} = (V_{\Sigma cornerx} + V_{\Sigma cornery}) / 2 = \mathbf{72.2 \text{ kN}}$$

Reinforcement required in top of edge beam

K factor

$$K_{corner} = M_{\Sigma corner} / (f_{cu} \times b_{edgetop} \times d_{edgetop}^2) = \mathbf{0.011}$$

Lever arm

$$Z_{corner} = d_{edgetop} \times \min(0.95, 0.5 + \sqrt{(0.25 - K_{corner}/0.9)}) = \mathbf{368 \text{ mm}}$$

Area of steel required for bending

$$A_{scornerbend} = M_{\Sigma corner} / ((1.0/\gamma_s) \times f_y \times Z_{corner}) = \mathbf{257 \text{ mm}^2}$$

Minimum area of steel required

$$A_{scornermin} = A_{sedgetopmin} = \mathbf{395 \text{ mm}^2}$$

Area of steel required

$$A_{scorner} = \max(A_{scornerbend}, A_{scornermin}) = \mathbf{395 \text{ mm}^2}$$

PASS - $A_{scorner} \leq A_{sedgetop}$ - Area of reinforcement provided in top of edge beams at corners is adequate

Corner beam shear check

Average web width

$$b_w = b_{edge} + (h_{edge} / \tan(\alpha_{edge})) / 2 = \mathbf{675 \text{ mm}}$$

Applied shear stress

$$v_{corner} = V_{\Sigma corner} / (b_w \times d_{edgetop}) = \mathbf{0.277 \text{ N/mm}^2}$$

Project 6 Brynseion Street, Troedyrhiw				Job no. B1265	
Calcs for Raft Foundation				Start page no./Revision 21	
Calcs by AS	Calcs date 02/08/2024	Checked by MJ	Checked date 02/08/2024	Approved by CN	Approved date 02/08/2024

Tension steel ratio

$$\rho_{\text{corner}} = 100 \times A_{\text{sedgetop}} / (b_w \times d_{\text{edgetop}}) = \mathbf{0.308}$$

From BS8110-1:1997 - Table 3.8

Design concrete shear strength

$$V_{\text{ccorner}} = \mathbf{0.477 \text{ N/mm}^2}$$

$$V_{\text{corner}} \leq V_{\text{ccorner}} + \mathbf{0.4 \text{ N/mm}^2} - \text{Therefore minimum links required}$$

Link area to spacing ratio required

$$A_{\text{sv_upon_svreqcorner}} = 0.4 \text{ N/mm}^2 \times b_w / ((1.0 / \gamma_s) \times f_{ys}) = \mathbf{0.621 \text{ mm}}$$

Link area to spacing ratio provided

$$A_{\text{sv_upon_svprovedge}} = N_{\text{edgelink}} \times \pi \times \phi_{\text{edgelink}}^2 / (4 \times S_{\text{vedge}}) = \mathbf{1.571 \text{ mm}}$$

PASS - $A_{\text{sv_upon_svreqcorner}} \leq A_{\text{sv_upon_svprovedge}}$ - Shear reinforcement provided in edge beams at corners is adequate

Corner beam deflection check

Basic allowable span to depth ratio

$$\text{Ratio}_{\text{basiccorner}} = \mathbf{7.0}$$

Moment factor

$$M_{\text{factorcorner}} = M_{\Sigma \text{corner}} / (b_{\text{edgetop}} \times d_{\text{edgetop}}^2) = \mathbf{0.391 \text{ N/mm}^2}$$

Steel service stress

$$f_{\text{scorner}} = 2/3 \times f_y \times A_{\text{scornerbend}} / A_{\text{sedgetop}} = \mathbf{106.314 \text{ N/mm}^2}$$

Modification factor

$$MF_{\text{corner}} = \min(2.0, 0.55 + [(477 \text{ N/mm}^2 - f_{\text{scorner}}) / (120 \times (0.9 \text{ N/mm}^2 + M_{\text{factorcorner}}))])$$

$$MF_{\text{corner}} = \mathbf{2.000}$$

Modified allowable span to depth ratio

$$\text{Ratio}_{\text{allowcorner}} = \text{Ratio}_{\text{basiccorner}} \times MF_{\text{corner}} = \mathbf{14.000}$$

Actual span to depth ratio

$$\text{Ratio}_{\text{actualcorner}} = l_{\text{corner}} / d_{\text{edgetop}} = \mathbf{2.967}$$

PASS - $\text{Ratio}_{\text{actualcorner}} \leq \text{Ratio}_{\text{allowcorner}}$ - Edge beam span to depth ratio is adequate