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Structural Design

10 Graig Road, Trebanos

March 2021

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March 2021

Site name: 10 Graig Road, Trebanos

Client name: Tudur Jones
Type of report: Structural Design

Prepared by: Iwan Griffiths BEng (Hons) ICE IStructE

Signed 

Date: 5th March 2021

Revision History:

Rev.	Date	Comments
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APPENDIX A Detailed Drawing

1.Introduction

1.1. Brief

Following instructions received from the Client, Mr Tudur Jones, a structural analysis and design of the proposed construction of a retaining wall was undertaken.

The client proposes to extend his house at 10 Graig Road, Trebanos. The proposed development requires that the existing retaining wall be removed and a new retaining wall be constructed further into the slope at the rear of the property.

A site visit was undertaken to make a visual inspection and take measurements. We had suggested to the client that a geotechnical survey would add further insights into the ground conditions, and the client has decided not to proceed with such an investigation. The calculations are therefore based on conservative estimates.

The bearing ground appeared to be made up of cohesive clayey soil, and slopes upwards away from the rear of the proposed retaining wall with an angle of less than 10 degrees..

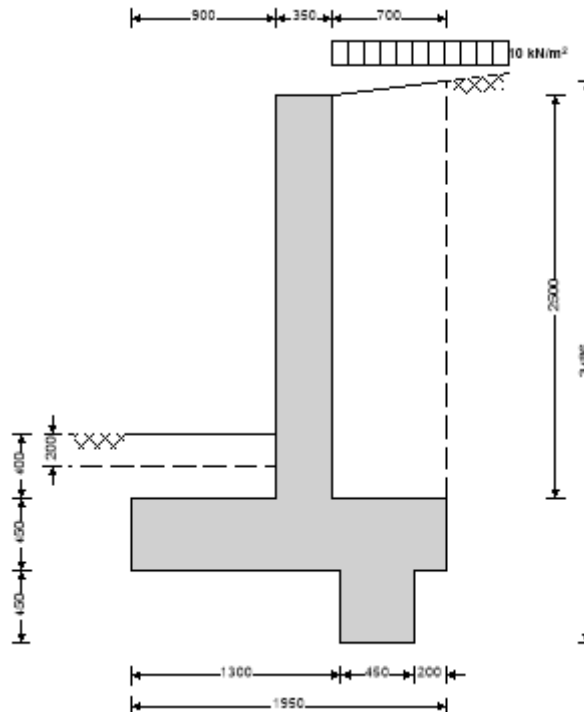
The analysis and supporting calculations for the proposed retaining walls' dimensions follow, along with construction specifications that include drainage and expansion joint details.

2. CALCULATIONS

Project Retaining Wall - 10 Graig Road, Trebanos				Job no. GC-76	
Calcs for Tudur Jones				Start page no./Revision 1	
Calcs by IG	Calcs date 04/03/2021	Checked by IG	Checked date 04/03/2021	Approved by IG	Approved date 04/03/2021

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.08



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

Unpropped cantilever

$$\begin{aligned}h_{\text{stem}} &= \mathbf{2500} \text{ mm} \\t_{\text{wall}} &= \mathbf{350} \text{ mm} \\l_{\text{toe}} &= \mathbf{900} \text{ mm} \\l_{\text{heel}} &= \mathbf{700} \text{ mm} \\l_{\text{base}} &= l_{\text{toe}} + l_{\text{heel}} + t_{\text{wall}} = \mathbf{1950} \text{ mm} \\t_{\text{base}} &= \mathbf{450} \text{ mm} \\d_{\text{ds}} &= \mathbf{450} \text{ mm} \\l_{\text{ds}} &= \mathbf{1300} \text{ mm} \\t_{\text{ds}} &= \mathbf{450} \text{ mm} \\h_{\text{wall}} &= h_{\text{stem}} + t_{\text{base}} + d_{\text{ds}} = \mathbf{3400} \text{ mm} \\d_{\text{cover}} &= \mathbf{400} \text{ mm} \\d_{\text{exc}} &= \mathbf{200} \text{ mm} \\h_{\text{water}} &= \mathbf{0} \text{ mm} \\h_{\text{sat}} &= \max(h_{\text{water}} - t_{\text{base}} - d_{\text{ds}}, 0 \text{ mm}) = \mathbf{0} \text{ mm} \\\gamma_{\text{wall}} &= \mathbf{23.6} \text{ kN/m}^3 \\\gamma_{\text{base}} &= \mathbf{23.6} \text{ kN/m}^3 \\\alpha &= \mathbf{90.0} \text{ deg} \\\beta &= \mathbf{7.0} \text{ deg} \\h_{\text{eff}} &= h_{\text{wall}} + l_{\text{heel}} \times \tan(\beta) = \mathbf{3486} \text{ mm}\end{aligned}$$

Retained material details

Mobilisation factor	M = 1.5
Moist density of retained material	$\gamma_m = 16.0 \text{ kN/m}^3$

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Saturated density of retained material $\gamma_s = 20.0 \text{ kN/m}^3$

Design shear strength $\phi' = 22.6 \text{ deg}$

Angle of wall friction $\delta = 17.3 \text{ deg}$

Base material details

Soft clay

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 $P_{\text{bearing}} = 150 \text{ kN/m}^2$

Using Coulomb theory

Active pressure coefficient for retained material

$$K_a = \sin(\alpha + \phi')^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta) \times [1 + \sqrt{(\sin(\phi' + \delta) \times \sin(\phi' - \beta) / (\sin(\alpha - \delta) \times \sin(\alpha + \beta)))^2}] = 0.439$$

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 $K_0 = 1 - \sin(\phi') = 0.616$

Loading details

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

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

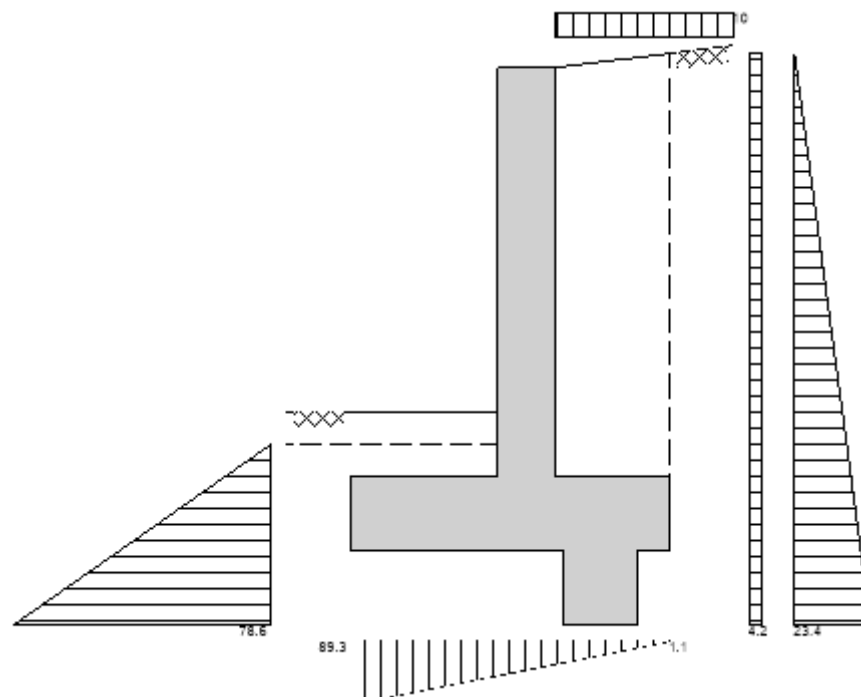
Applied vertical live load on wall $W_{\text{live}} = 0.0 \text{ kN/m}$

Position of applied vertical load on wall $l_{\text{load}} = 0 \text{ mm}$

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

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Vertical forces on wall

Wall stem	$W_{wall} = h_{stem} * t_{wall} * \gamma_{wall} = 20.7 \text{ kN/m}$
Wall base	$W_{base} = l_{base} * t_{base} * \gamma_{base} = 20.7 \text{ kN/m}$
Wall downstand	$W_{ds} = d_{ds} * t_{ds} * \gamma_{base} = 4.8 \text{ kN/m}$
Surcharge	$W_{sur} = \text{Surcharge} * l_{heel} = 7 \text{ kN/m}$
Moist backfill to top of wall	$W_{m_w} = l_{heel} * (h_{stem} - h_{sat}) * \gamma_m = 28 \text{ kN/m}$
Moist backfill above top of wall	$W_{m_s} = 0.5 * l_{heel}^2 * \tan(\beta) * \gamma_m = 0.5 \text{ kN/m}$
Soil in front of wall	$W_p = l_{toe} * d_{cover} * \gamma_{mb} = 6.5 \text{ kN/m}$
Total vertical load	$W_{total} = W_{wall} + W_{base} + W_{ds} + W_{sur} + W_{m_w} + W_{m_s} + W_p = 88.1 \text{ kN/m}$

Horizontal forces on wall

Surcharge	$F_{sur} = K_a * \cos(90 - \alpha + \delta) * \text{Surcharge} * h_{eff} = 14.6 \text{ kN/m}$
Moist backfill above water table	$F_{m_a} = 0.5 * K_a * \cos(90 - \alpha + \delta) * \gamma_m * (h_{eff} - h_{water})^2 = 40.7 \text{ kN/m}$
Total horizontal load	$F_{total} = F_{sur} + F_{m_a} = 55.3 \text{ kN/m}$

Calculate stability against sliding

Passive resistance of soil in front of wall	$F_p = 0.5 * K_p * \cos(\delta_b) * (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 * \gamma_{mb} = 43.2 \text{ kN/m}$
Resistance to sliding	$F_{res} = F_p + (W_{total} - W_{sur} - W_p) * \tan(\delta_b) = 68.3 \text{ kN/m}$
<i>PASS - Resistance force is greater than sliding force</i>	

Overturning moments

Surcharge	$M_{sur} = F_{sur} * (h_{eff} - 2 * d_{ds}) / 2 = 18.9 \text{ kNm/m}$
Moist backfill above water table	$M_{m_a} = F_{m_a} * (h_{eff} + 2 * h_{water} - 3 * d_{ds}) / 3 = 29 \text{ kNm/m}$
Soil in front of wall	$M_{p_o} = F_p * [2 * d_{ds} - t_{base} - d_{cover} + d_{exc}] / 3 = 3.6 \text{ kNm/m}$
Total overturning moment	$M_{ot} = M_{sur} + M_{m_a} + M_{p_o} = 51.5 \text{ kNm/m}$

Restoring moments

Wall stem	$M_{wall} = W_{wall} * (l_{toe} + t_{wall} / 2) = 22.2 \text{ kNm/m}$
Wall base	$M_{base} = W_{base} * l_{base} / 2 = 20.2 \text{ kNm/m}$
Wall downstand	$M_{ds} = W_{ds} * (l_{ds} + t_{ds} / 2) = 7.3 \text{ kNm/m}$
Moist backfill	$M_{m_r} = (W_{m_w} * (l_{base} - l_{heel} / 2) + W_{m_s} * (l_{base} - l_{heel} / 3)) = 45.6 \text{ kNm/m}$
Total restoring moment	$M_{rest} = M_{wall} + M_{base} + M_{ds} + M_{m_r} = 95.3 \text{ kNm/m}$

Check stability against overturning

Total overturning moment	$M_{ot} = 51.5 \text{ kNm/m}$
Total restoring moment	$M_{rest} = 95.3 \text{ kNm/m}$
<i>PASS - Restoring moment is greater than overturning moment</i>	

Check bearing pressure

Surcharge	$M_{sur_r} = W_{sur} * (l_{base} - l_{heel} / 2) = 11.2 \text{ kNm/m}$
Soil in front of wall	$M_{p_r} = W_p * l_{toe} / 2 = 2.9 \text{ kNm/m}$
Total moment for bearing	$M_{total} = M_{rest} - M_{ot} + M_{sur_r} + M_{p_r} = 58 \text{ kNm/m}$
Total vertical reaction	$R = W_{total} = 88.1 \text{ kN/m}$
Distance to reaction	$X_{bar} = M_{total} / R = 658 \text{ mm}$
Eccentricity of reaction	$e = \text{abs}((l_{base} / 2) - X_{bar}) = 317 \text{ mm}$
<i>Reaction acts within middle third of base</i>	
Bearing pressure at toe	$p_{toe} = (R / l_{base}) + (6 * R * e / l_{base}^2) = 89.3 \text{ kN/m}^2$
Bearing pressure at heel	$p_{heel} = (R / l_{base}) - (6 * R * e / l_{base}^2) = 1.1 \text{ kN/m}^2$
<i>PASS - Maximum bearing pressure is less than allowable bearing pressure</i>	

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RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.08

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	$W_{wall_f} = \gamma_{f_d} * h_{stem} * t_{wall} * \gamma_{wall} = 28.9 \text{ kN/m}$
Wall base	$W_{base_f} = \gamma_{f_d} * l_{base} * t_{base} * \gamma_{base} = 29 \text{ kN/m}$
Wall downstand	$W_{ds_f} = \gamma_{f_d} * d_{ds} * t_{ds} * \gamma_{base} = 6.7 \text{ kN/m}$
Surcharge	$W_{sur_f} = \gamma_{f_l} * \text{Surcharge} * l_{heel} = 11.2 \text{ kN/m}$
Moist backfill to top of wall	$W_{m_w_f} = \gamma_{f_d} * l_{heel} * (h_{stem} - h_{sat}) * \gamma_m = 39.2 \text{ kN/m}$
Moist backfill above top of wall	$W_{m_s_f} = \gamma_{f_d} * 0.5 * l_{heel}^2 * \tan(\beta) * \gamma_m = 0.7 \text{ kN/m}$
Soil in front of wall	$W_{p_f} = \gamma_{f_d} * l_{toe} * d_{cover} * \gamma_{mb} = 9.1 \text{ kN/m}$
Total vertical load kN/m	$W_{total_f} = W_{wall_f} + W_{base_f} + W_{ds_f} + W_{sur_f} + W_{m_w_f} + W_{m_s_f} + W_{p_f} = 124.7$

Factored horizontal at-rest forces on wall

Surcharge	$F_{sur_f} = \gamma_{f_l} * K_0 * \text{Surcharge} * h_{eff} = 34.3 \text{ kN/m}$
Moist backfill above water table	$F_{m_a_f} = \gamma_{f_e} * 0.5 * K_0 * \gamma_m * (h_{eff} - h_{water})^2 = 83.8 \text{ kN/m}$
Total horizontal load	$F_{total_f} = F_{sur_f} + F_{m_a_f} = 118.1 \text{ kN/m}$
Passive resistance of soil in front of wall kN/m	$F_{p_f} = \gamma_{f_e} * 0.5 * K_p * \cos(\delta_b) * (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 * \gamma_{mb} = 60.5$

Factored overturning moments

Surcharge	$M_{sur_f} = F_{sur_f} * (h_{eff} - 2 * d_{ds}) / 2 = 44.4 \text{ kNm/m}$
Moist backfill above water table	$M_{m_a_f} = F_{m_a_f} * (h_{eff} + 2 * h_{water} - 3 * d_{ds}) / 3 = 59.7 \text{ kNm/m}$
Soil in front of wall	$M_{p_o_f} = F_{p_f} * [2 * d_{ds} - t_{base} - d_{cover} + d_{exc}] / 3 = 5 \text{ kNm/m}$
Total overturning moment	$M_{ot_f} = M_{sur_f} + M_{m_a_f} + M_{p_o_f} = 109.1 \text{ kNm/m}$

Restoring moments

Wall stem	$M_{wall_f} = W_{wall_f} * (l_{toe} + t_{wall} / 2) = 31.1 \text{ kNm/m}$
Wall base	$M_{base_f} = W_{base_f} * l_{base} / 2 = 28.3 \text{ kNm/m}$
Wall downstand	$M_{ds_f} = W_{ds_f} * (l_{ds} + t_{ds} / 2) = 10.2 \text{ kNm/m}$
Surcharge	$M_{sur_r_f} = W_{sur_f} * (l_{base} - l_{heel} / 2) = 17.9 \text{ kNm/m}$
Moist backfill	$M_{m_r_f} = (W_{m_w_f} * (l_{base} - l_{heel} / 2) + W_{m_s_f} * (l_{base} - l_{heel} / 3)) = 63.9 \text{ kNm/m}$
Soil in front of wall	$M_{p_r_f} = W_{p_f} * l_{toe} / 2 = 4.1 \text{ kNm/m}$
Total restoring moment	$M_{rest_f} = M_{wall_f} + M_{base_f} + M_{ds_f} + M_{sur_r_f} + M_{m_r_f} + M_{p_r_f} = 155.4 \text{ kNm/m}$

Factored bearing pressure

Total moment for bearing	$M_{total_f} = M_{rest_f} - M_{ot_f} = 46.3 \text{ kNm/m}$
Total vertical reaction	$R_f = W_{total_f} = 124.7 \text{ kN/m}$
Distance to reaction	$X_{bar_f} = M_{total_f} / R_f = 371 \text{ mm}$
Eccentricity of reaction	$e_f = \text{abs}((l_{base} / 2) - X_{bar_f}) = 604 \text{ mm}$
<i>Reaction acts outside middle third of base</i>	
Bearing pressure at toe	$p_{toe_f} = R_f / (1.5 * X_{bar_f}) = 223.9 \text{ kN/m}^2$
Bearing pressure at heel	$p_{heel_f} = 0 \text{ kN/m}^2 = 0 \text{ kN/m}^2$
Rate of change of base reaction	$\text{rate} = p_{toe_f} / (3 * X_{bar_f}) = 201.01 \text{ kN/m}^2/\text{m}$
Bearing pressure at stem / toe	$p_{stem_toe_f} = \text{max}(p_{toe_f} - (\text{rate} * l_{toe}), 0 \text{ kN/m}^2) = 43 \text{ kN/m}^2$

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Bearing pressure at mid stem

$$p_{stem_mid_f} = \max(p_{toe_f} - (\text{rate} * (l_{toe} + t_{wall} / 2)), 0 \text{ kN/m}^2) = \mathbf{7.9 \text{ kN/m}^2}$$

Bearing pressure at stem / heel

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

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

Material properties

Characteristic strength of concrete

$$f_{cu} = \mathbf{30 \text{ N/mm}^2}$$

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

$$C_{toe} = \mathbf{50 \text{ mm}}$$

Calculate shear for toe design

Shear from bearing pressure

$$V_{toe_bear} = (p_{toe_f} + p_{stem_toe_f}) * l_{toe} / 2 = \mathbf{120.1 \text{ kN/m}}$$

Shear from weight of base

$$V_{toe_wt_base} = \gamma_{f_d} * \gamma_{base} * l_{toe} * t_{base} = \mathbf{13.4 \text{ kN/m}}$$

Shear from weight of soil

$$V_{toe_wt_soil} = W_{p_f} - (\gamma_{f_d} * \gamma_m * l_{toe} * d_{exc}) = \mathbf{5 \text{ kN/m}}$$

Total shear for toe design

$$V_{toe} = V_{toe_bear} - V_{toe_wt_base} - V_{toe_wt_soil} = \mathbf{101.7 \text{ kN/m}}$$

Calculate moment for toe design

Moment from bearing pressure

$$M_{toe_bear} = (2 * p_{toe_f} + p_{stem_mid_f}) * (l_{toe} + t_{wall} / 2)^2 / 6 = \mathbf{87.8 \text{ kNm/m}}$$

Moment from weight of base

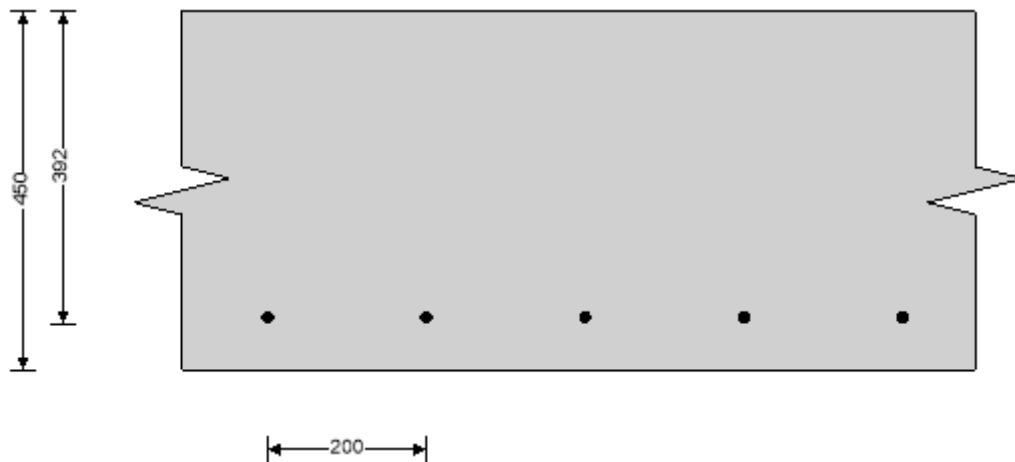
$$M_{toe_wt_base} = (\gamma_{f_d} * \gamma_{base} * t_{base} * (l_{toe} + t_{wall} / 2)^2 / 2) = \mathbf{8.6 \text{ kNm/m}}$$

Moment from weight of soil

$$M_{toe_wt_soil} = (W_{p_f} - (\gamma_{f_d} * \gamma_m * l_{toe} * d_{exc})) * (l_{toe} + t_{wall}) / 2 = \mathbf{3.2 \text{ kNm/m}}$$

Total moment for toe design

$$M_{toe} = M_{toe_bear} - M_{toe_wt_base} - M_{toe_wt_soil} = \mathbf{76 \text{ kNm/m}}$$



Check toe in bending

Width of toe

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

Depth of reinforcement

$$d_{toe} = t_{base} - C_{toe} - (\phi_{toe} / 2) = \mathbf{392.0 \text{ mm}}$$

Constant

$$K_{toe} = M_{toe} / (b * d_{toe}^2 * f_{cu}) = \mathbf{0.016}$$

Compression reinforcement is not required

Lever arm

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

$$z_{toe} = \mathbf{372 \text{ mm}}$$

Area of tension reinforcement required

$$A_{s_toe_des} = M_{toe} / (0.87 * f_y * z_{toe}) = \mathbf{469 \text{ mm}^2/\text{m}}$$

Minimum area of tension reinforcement

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

Area of tension reinforcement required

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

Reinforcement provided

$$\mathbf{16 \text{ mm dia. bars @ 200 mm centres}}$$

Area of reinforcement provided

$$A_{s_toe_prov} = \mathbf{1005 \text{ mm}^2/\text{m}}$$

PASS - Reinforcement provided at the retaining wall toe is adequate

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Check shear resistance at toe

Design shear stress

$$v_{toe} = V_{toe} / (b \times d_{toe}) = \mathbf{0.259 \text{ N/mm}^2}$$

Allowable shear stress

$$v_{adm} = \min(0.8 \times \sqrt{f_{cu}} / 1 \text{ N/mm}^2, 5) \times 1 \text{ N/mm}^2 = \mathbf{4.382 \text{ N/mm}^2}$$

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress

$$v_{c_toe} = \mathbf{0.429 \text{ N/mm}^2}$$

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

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

Material properties

Characteristic strength of concrete

$$f_{cu} = \mathbf{30 \text{ N/mm}^2}$$

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 heel

$$c_{heel} = \mathbf{50 \text{ mm}}$$

Calculate shear for heel design

Shear from weight of base

$$V_{heel_wt_base} = \gamma_{f_d} \times \gamma_{base} \times l_{heel} \times t_{base} = \mathbf{10.4 \text{ kN/m}}$$

Shear from weight of downstand

$$V_{heel_wt_ds} = \gamma_{f_d} \times \gamma_{base} \times d_{ds} \times t_{ds} = \mathbf{6.7 \text{ kN/m}}$$

Shear from weight of moist backfill

$$V_{heel_wt_m} = W_{m_w_f} + W_{m_s_f} = \mathbf{39.9 \text{ kN/m}}$$

Shear from surcharge

$$V_{heel_sur} = W_{sur_f} = \mathbf{11.2 \text{ kN/m}}$$

Total shear for heel design

$$V_{heel} = V_{heel_wt_base} + V_{heel_wt_ds} + V_{heel_wt_m} + V_{heel_sur} = \mathbf{68.2 \text{ kN/m}}$$

Calculate moment for heel design

Moment from weight of base

$$M_{heel_wt_base} = (\gamma_{f_d} \times \gamma_{base} \times t_{base} \times (l_{heel} + t_{wall} / 2)^2 / 2) = \mathbf{5.7 \text{ kNm/m}}$$

Moment from weight of downstand

$$M_{heel_wt_ds} = \gamma_{f_d} \times \gamma_{base} \times d_{ds} \times t_{ds} \times (l_{ds} - l_{toe} + (t_{ds} - t_{wall}) / 2) = \mathbf{3 \text{ kNm/m}}$$

Moment from weight of moist backfill
kNm/m

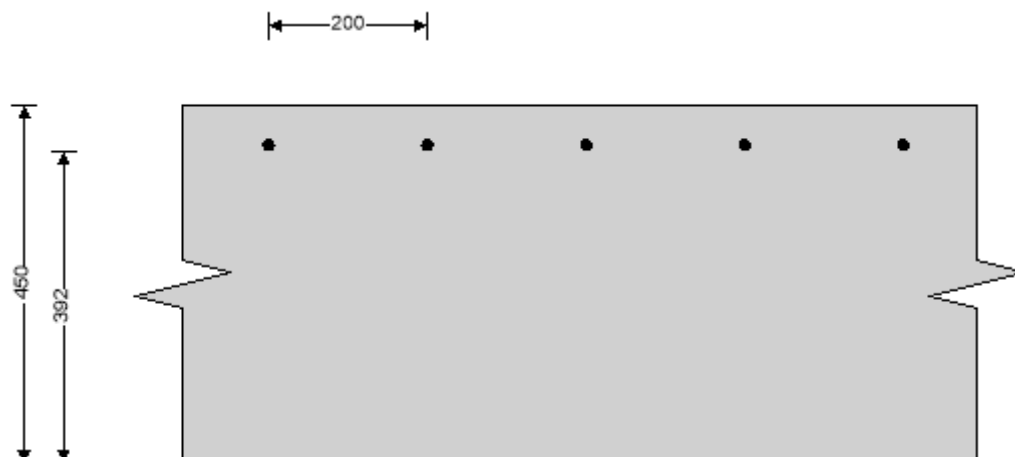
$$M_{heel_wt_m} = W_{m_w_f} \times (l_{heel} + t_{wall}) / 2 + W_{m_s_f} \times (2 \times l_{heel} / 3 + t_{wall} / 2) = \mathbf{21}$$

Moment from surcharge

$$M_{heel_sur} = W_{sur_f} \times (l_{heel} + t_{wall}) / 2 = \mathbf{5.9 \text{ kNm/m}}$$

Total moment for heel design

$$M_{heel} = M_{heel_wt_base} + M_{heel_wt_ds} + M_{heel_wt_m} + M_{heel_sur} = \mathbf{35.6 \text{ kNm/m}}$$



Check heel in bending

Width of heel

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

Depth of reinforcement

$$d_{heel} = t_{base} - c_{heel} - (\phi_{heel} / 2) = \mathbf{392.0 \text{ mm}}$$

Constant

$$K_{heel} = M_{heel} / (b \times d_{heel}^2 \times f_{cu}) = \mathbf{0.008}$$

Compression reinforcement is not required

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Lever arm

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

$$Z_{heel} = \mathbf{372 \text{ mm}}$$

Area of tension reinforcement required

$$A_{s_heel_des} = M_{heel} / (0.87 \times f_y \times Z_{heel}) = \mathbf{220 \text{ mm}^2/\text{m}}$$

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

$$\mathbf{16 \text{ mm dia. bars @ 200 mm centres}}$$

Area of reinforcement provided

$$A_{s_heel_prov} = \mathbf{1005 \text{ mm}^2/\text{m}}$$

PASS - Reinforcement provided at the retaining wall heel is adequate

Check shear resistance at heel

Design shear stress

$$V_{heel} = V_{heel} / (b \times d_{heel}) = \mathbf{0.174 \text{ N/mm}^2}$$

Allowable shear stress

$$V_{adm} = \min(0.8 \times \sqrt{f_{cu}} / 1 \text{ N/mm}^2, 5) \times 1 \text{ N/mm}^2 = \mathbf{4.382 \text{ N/mm}^2}$$

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress

$$V_{c_heel} = \mathbf{0.429 \text{ N/mm}^2}$$

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

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

Material properties

Characteristic strength of concrete

$$f_{cu} = \mathbf{30 \text{ N/mm}^2}$$

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 downstand

$$C_{ds} = \mathbf{50 \text{ mm}}$$

Calculate shear for downstand design

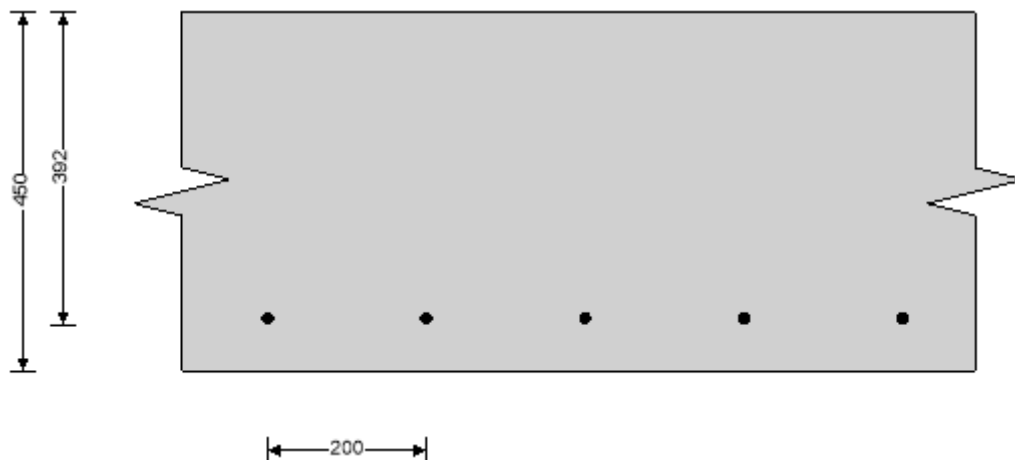
Total shear for downstand design

$$V_{down} = \gamma_{f_e} \times K_p \times \cos(\delta_b) \times \gamma_m \times d_{ds} \times (d_{cover} + t_{base} + d_{ds} / 2) = \mathbf{43 \text{ kN/m}}$$

Calculate moment for downstand design

Total moment for downstand design

$$M_{down} = \gamma_{f_e} \times K_p \times \cos(\delta_b) \times \gamma_m \times d_{ds} \times [(d_{cover} + t_{base}) \times (t_{base} + d_{ds}) + d_{ds} \times (t_{base} / 2 + 2 \times d_{ds} / 3)] / 2 = \mathbf{20 \text{ kNm/m}}$$



Check downstand in bending

Width of downstand

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

Depth of reinforcement

$$d_{down} = t_{ds} - C_{ds} - (\phi_{down} / 2) = \mathbf{392.0 \text{ mm}}$$

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Constant

$$K_{down} = M_{down} / (b \times d_{down}^2 \times f_{cu}) = \mathbf{0.004}$$

Compression reinforcement is not required

Lever arm

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

$$Z_{down} = \mathbf{372 \text{ mm}}$$

Area of tension reinforcement required

$$A_{s_down_des} = M_{down} / (0.87 \times f_y \times Z_{down}) = \mathbf{124 \text{ mm}^2/\text{m}}$$

Minimum area of tension reinforcement

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

Area of tension reinforcement required

$$A_{s_down_req} = \text{Max}(A_{s_down_des}, A_{s_down_min}) = \mathbf{585 \text{ mm}^2/\text{m}}$$

Reinforcement provided

$$\mathbf{16 \text{ mm dia. bars @ 200 mm centres}}$$

Area of reinforcement provided

$$A_{s_down_prov} = \mathbf{1005 \text{ mm}^2/\text{m}}$$

PASS - Reinforcement provided at the retaining wall downstand is adequate

Check shear resistance at downstand

Design shear stress

$$V_{down} = V_{down} / (b \times d_{down}) = \mathbf{0.110 \text{ N/mm}^2}$$

Allowable shear stress

$$V_{adm} = \min(0.8 \times \sqrt{f_{cu}} / 1 \text{ N/mm}^2, 5) \times 1 \text{ N/mm}^2 = \mathbf{4.382 \text{ N/mm}^2}$$

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress

$$V_{c_down} = \mathbf{0.429 \text{ N/mm}^2}$$

V_{down} < V_{c_down} - No shear reinforcement required

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

Material properties

Characteristic strength of concrete

$$f_{cu} = \mathbf{30 \text{ N/mm}^2}$$

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

$$C_{stem} = \mathbf{50 \text{ mm}}$$

Cover to reinforcement in wall

$$C_{wall} = \mathbf{50 \text{ mm}}$$

Factored horizontal at-rest forces on stem

Surcharge

$$F_{s_sur_f} = \gamma_{f_l} \times K_0 \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds}) = \mathbf{25.5 \text{ kN/m}}$$

Moist backfill above water table

$$F_{s_m_a_f} = 0.5 \times \gamma_{f_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2 = \mathbf{46.1 \text{ kN/m}}$$

Calculate shear for stem design

Shear at base of stem

$$V_{stem} = F_{s_sur_f} + F_{s_m_a_f} = \mathbf{71.6 \text{ kN/m}}$$

Calculate moment for stem design

Surcharge

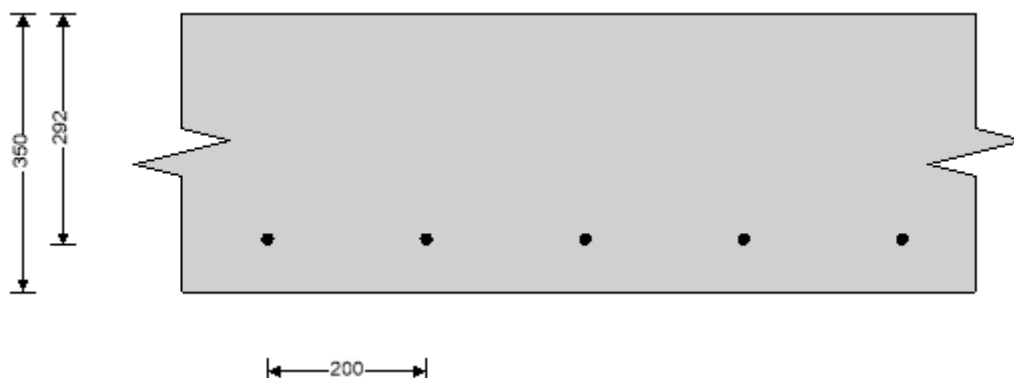
$$M_{s_sur} = F_{s_sur_f} \times (h_{stem} + t_{base}) / 2 = \mathbf{37.6 \text{ kNm/m}}$$

Moist backfill above water table

$$M_{s_m_a} = F_{s_m_a_f} \times (2 \times h_{sat} + h_{eff} - d_{ds} + t_{base} / 2) / 3 = \mathbf{50.1 \text{ kNm/m}}$$

Total moment for stem design

$$M_{stem} = M_{s_sur} + M_{s_m_a} = \mathbf{87.7 \text{ kNm/m}}$$



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Check wall stem in bending

Width of wall stem

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

Depth of reinforcement

$$d_{\text{stem}} = t_{\text{wall}} - c_{\text{stem}} - (\phi_{\text{stem}} / 2) = 292.0 \text{ mm}$$

Constant

$$K_{\text{stem}} = M_{\text{stem}} / (b \times d_{\text{stem}}^2 \times f_{\text{cu}}) = 0.034$$

Compression reinforcement is not required

Lever arm

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

$$Z_{\text{stem}} = 277 \text{ mm}$$

Area of tension reinforcement required

$$A_{s_stem_des} = M_{\text{stem}} / (0.87 \times f_y \times Z_{\text{stem}}) = 727 \text{ mm}^2/\text{m}$$

Minimum area of tension reinforcement

$$A_{s_stem_min} = k \times b \times t_{\text{wall}} = 455 \text{ mm}^2/\text{m}$$

Area of tension reinforcement required

$$A_{s_stem_req} = \text{Max}(A_{s_stem_des}, A_{s_stem_min}) = 727 \text{ mm}^2/\text{m}$$

Reinforcement provided

16 mm dia.bars @ 200 mm centres

Area of reinforcement provided

$$A_{s_stem_prov} = 1005 \text{ mm}^2/\text{m}$$

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress

$$V_{\text{stem}} = V_{\text{stem}} / (b \times d_{\text{stem}}) = 0.245 \text{ N/mm}^2$$

Allowable shear stress

$$V_{\text{adm}} = \min(0.8 \times \sqrt{f_{\text{cu}} / 1 \text{ N/mm}^2}, 5) \times 1 \text{ N/mm}^2 = 4.382 \text{ N/mm}^2$$

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress

$$V_{c_stem} = 0.509 \text{ N/mm}^2$$

V_{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

$$f_s = 2 \times f_y \times A_{s_stem_req} / (3 \times A_{s_stem_prov}) = 241.0 \text{ N/mm}^2$$

Modification factor

$$\text{factor}_{\text{tens}} = \min(0.55 + (477 \text{ N/mm}^2 - f_s) / (120 \times (0.9 \text{ N/mm}^2 + (M_{\text{stem}} / (b \times d_{\text{stem}}^2)))), 2) = 1.57$$

Maximum span/effective depth ratio

$$\text{ratio}_{\text{max}} = \text{ratio}_{\text{bas}} \times \text{factor}_{\text{tens}} = 10.99$$

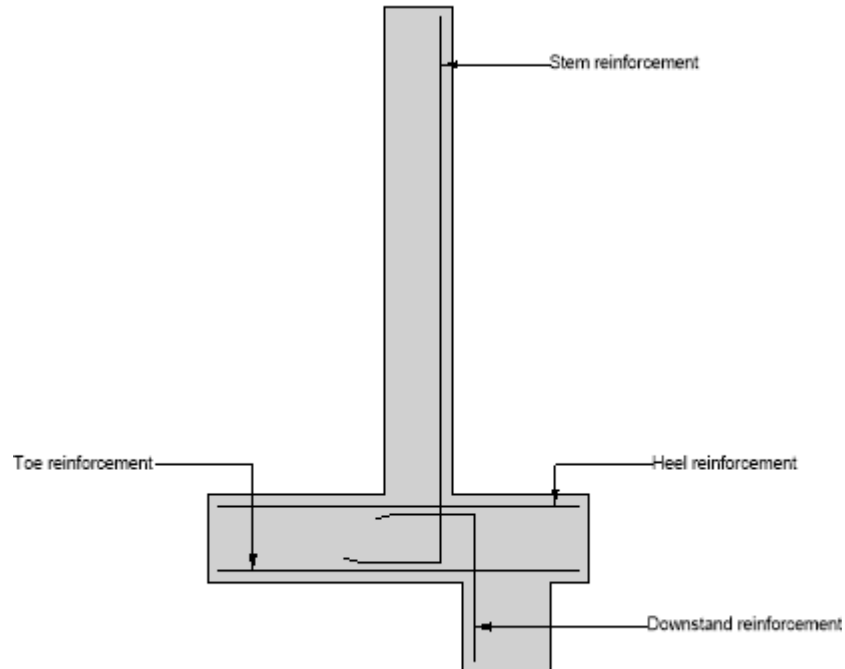
Actual span/effective depth ratio

$$\text{ratio}_{\text{act}} = h_{\text{stem}} / d_{\text{stem}} = 8.56$$

PASS - Span to depth ratio is acceptable

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Indicative retaining wall reinforcement diagram



Toe bars - 16 mm dia.@ 200 mm centres - (1005 mm²/m)
 Heel bars - 16 mm dia.@ 200 mm centres - (1005 mm²/m)
 Downstand bars - 16 mm dia.@ 200 mm centres - (1005 mm²/m)
 Stem bars - 16 mm dia.@ 200 mm centres - (1005 mm²/m)

3. SPECIFICATIONS

The wall stem should be constructed from hollow concrete blocks filled with poured concrete to strength C35.

Please refer to APPENDIX A for retaining wall dimensions.

The concrete base should be constructed from C35 Strength Concrete.

2 layers of A252 Mesh should be placed at the top of the foundation slab with 50mm of concrete cover.

2 layers of A252 Mesh should be placed at the bottom of the foundation slab with 50mm of concrete cover.

T16 bars should be placed vertically and spaced at 200mm centres in the wall stem and foundation upstand.

Coarse gravel should be used at backfill to the wall.

The back face, i.e. the retained ground facing side should be lined with a waterproof damp proof course. The damp proof course should not cover the drainage pipes.

A filter membrane should be placed above and behind the backfill material in order to prevent silt and fine aggregate from permeating into the fill that could prevent proper drainage of the retained ground.

50mm diameter plastic pipes should be placed at the bottom of the walls's stem from front face to back, at approximately 1.5m spacing along the length of the walls to provide drainage. Rodent screens can be put on the front face of each pipe.

A 150mm diameter perforated drain should also be placed behind the wall, near the stem bottom.

Expansion joints should be spaced at 6m intervals along the length of the walls and 3m from any corners. The joints should be filled with expansion joint filler and poly-sealant should be used on the exposed face of the expansion joint. The wall sections on either side of the expansion joint should be tied using slip ties at each block layer.

It is advised that coping be placed on top of the walls to prevent the ingress of rainwater. A high bonding layer of damp proof course should be placed between the coping and the wall stem material.

3. OTHER NOTES

Construction work not to be started until the calculations have been approved by Building Control. All construction work should be carried out by a competent builder. The builder is responsible for all temporary supports and is to ensure that the retained ground is adequately supported during the works.

Walls exceeding 9m long should be provided with intermediate buttressing support. Intermediate buttressing walls should not be less than 550mm long.

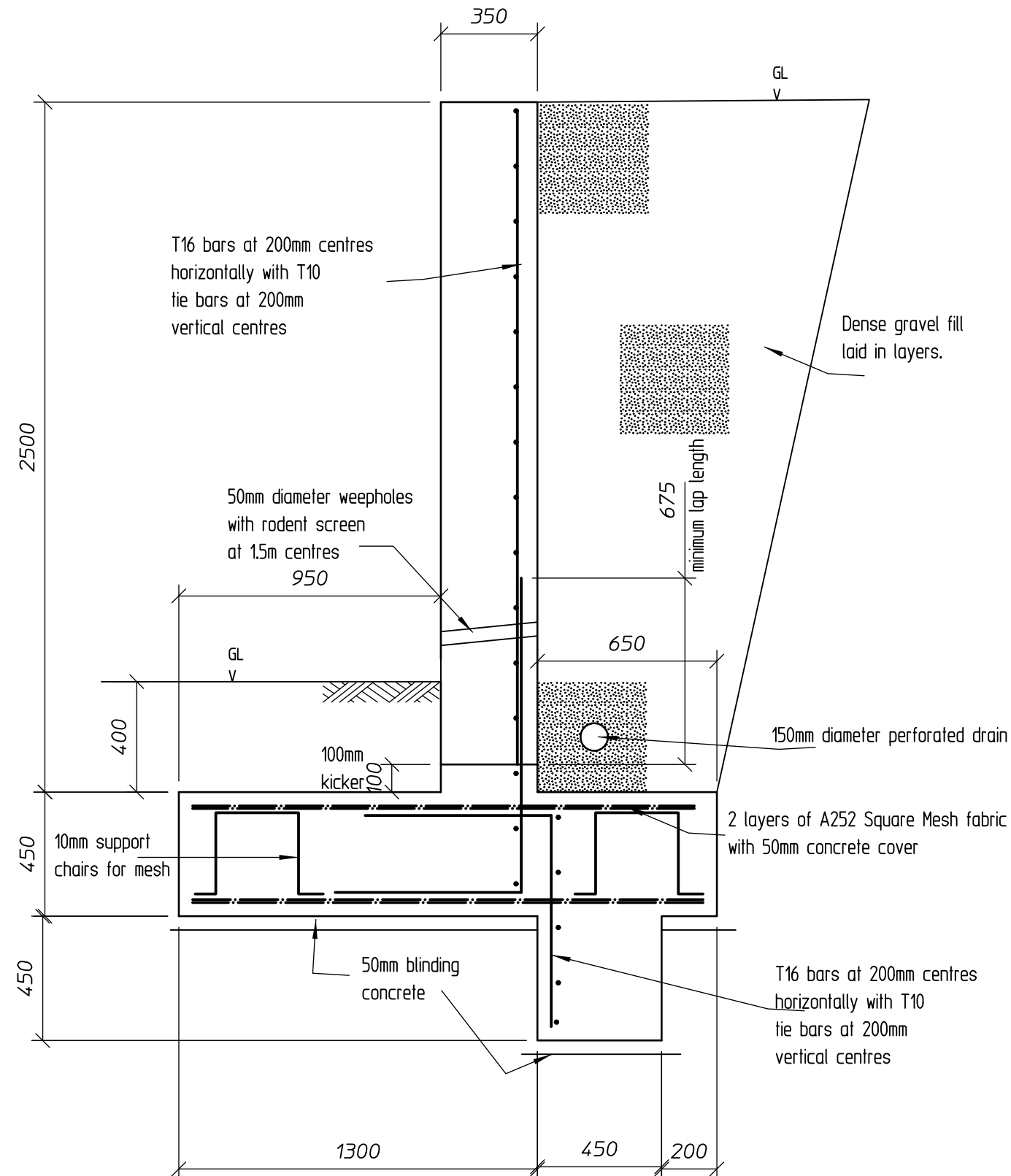
Buttressing end return walls and intermediate buttressing supports should be provided in accordance with Approved Document 'A', which can be downloaded from the following website; www.planningportal.gov.uk. CDM Regulations - Under the Construction (Design & Management) Regulations 2015 for commercial clients, the client duties apply in full.

For Domestic clients, the client duties pass on to the Principal Contractor or Sole Contractor. For more information visit www.hse.gov.uk.

For Domestic clients constructing a party wall, it is advised that legal advice is sought regarding the Party Wall Act 1996, prior to construction.

10 Graig Road, Trebanos
March 2021

APPENDIX A



NOTES

NOTES

Expansion joints spaced at 6m intervals along length of wall and filled with expansion joint sealer and poly-sealant used on exposed face of expansion joint.

A252 mesh shall have a minimum lap length of 400mm.

All T16 bars shall have a minimum lap length of 675mm.

T10 bars shall have a minimum lap length of 420mm.

Concrete shall be RC35

Concrete at kicker to be scabbled to provide a good bonding face prior to construction of wall section.

Mesh support chairs at 1m centres.

All dimensions shall be checked on site. Any discrepancies shall be reported to the Engineer.

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Project

TREBANOS -10 GRAIG ROAD

Title

RETAINING WALL - CROSS SECTION

Job No.	GC-76	Drawn	LD	date	5/03/21
Org No.	R1	Checked	LD	Scale	1/20 at A3