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Structural Design

11 Bryn Llywellyn, Alltwen

February 2021

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February 2021

Site name: 11 Bryn Llywellyn, Alltwn

Client name: Ms. Elaine David
Type of report: Structural Design

Prepared by: Iwan Griffiths BEng (Hons) ICE IStructE

Signed

A handwritten signature in black ink, appearing to be 'Iwan Griffiths', written over a horizontal line.

Date: 2nd February 2021

Revision History:

Rev.	Date	Comments
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1.Introduction

1.1. Brief

Following instructions received from the Client, Ms Elaine David, a structural analysis and design of the proposed construction of a retaining wall was undertaken.

The client proposes to extend her house at 11 Bryn Llywellyn, Alltwen. 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 approximately 3 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

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RETAINING WALL ANALYSIS

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

Tedds calculation version 2.9.11

Retaining wall details

Stem type	Cantilever with stepped rear face
Stem height	$h_{\text{stem}} = 1500$ mm
Number of steps	$N_{\text{steps}} = 3$
Height of step 1	$h_{s1} = 500$ mm
Thickness of step 1	$t_{s1} = 1500$ mm
Height of step 2	$h_{s2} = 500$ mm
Thickness of step 2	$t_{s2} = 1000$ mm
Height of step 3	$h_{s3} = 500$ mm
Thickness of step 3	$t_{s3} = 500$ mm
Angle to rear face of stem	$\alpha = 90$ deg
Stem density	$\gamma_{\text{stem}} = 25$ kN/m ³
Toe length	$l_{\text{toe}} = 350$ mm
Heel length	$l_{\text{heel}} = 700$ mm
Base thickness	$t_{\text{base}} = 500$ mm
Key position	$p_{\text{key}} = 2050$ mm
Key depth	$d_{\text{key}} = 350$ mm
Key thickness	$t_{\text{key}} = 500$ mm
Base density	$\gamma_{\text{base}} = 25$ kN/m ³
Height of retained soil	$h_{\text{ret}} = 1400$ mm
Angle of soil surface	$\beta = 3$ deg
Depth of cover	$d_{\text{cover}} = 0$ mm

Retained soil properties

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

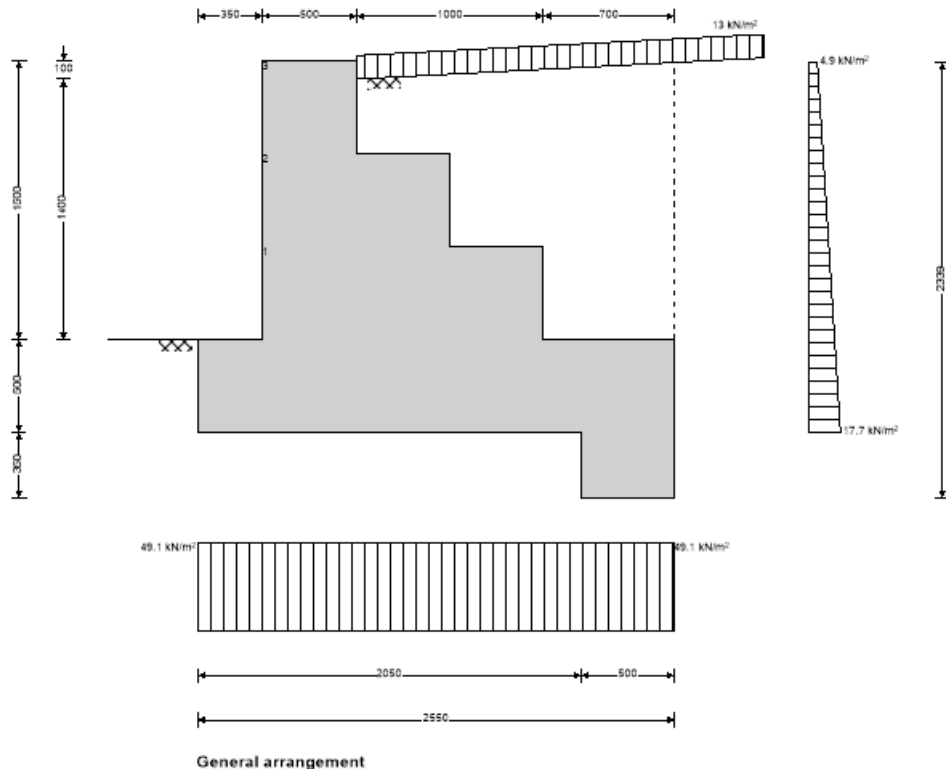
Base soil properties

Soil type	Soft clay
Soil density	$\gamma_b = 17$ kN/m ³
Characteristic cohesion	$c'_{b,k} = 0$ kN/m ²
Characteristic effective shear resistance angle	$\phi'_{b,k} = 18$ deg
Characteristic wall friction angle	$\delta_{b,k} = 9$ deg
Characteristic base friction angle	$\delta_{bb,k} = 12$ deg

Loading details

Variable surcharge load	Surcharge _q = 10 kN/m ²
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Calculate retaining wall geometry

Base length

$$l_{base} = l_{toe} + t_{s1} + l_{heel} = 2550 \text{ mm}$$

Base height

$$h_{base} = t_{base} + d_{key} = 850 \text{ mm}$$

Moist soil height

$$h_{moist} = h_{soil} = 1400 \text{ mm}$$

Length of surcharge load

$$l_{sur} = (l_{heel} + t_{s1} - t_{s3}) = 1700 \text{ mm}$$

- Distance to vertical component

$$x_{sur_v} = l_{base} - (l_{heel} + t_{s1} - t_{s3}) / 2 = 1700 \text{ mm}$$

Effective height of wall

$$h_{eff} = h_{base} + d_{cover} + h_{ret} + l_{sur} * \tan(\beta) = 2339 \text{ mm}$$

- Distance to horizontal component

$$x_{sur_h} = h_{eff} / 2 - d_{key} = 820 \text{ mm}$$

- Distance to horizontal component above key

$$x_{sur_h_a} = (h_{eff} - d_{key}) / 2 = 995 \text{ mm}$$

Area of wall stem

$$A_{stem} = h_{s1} * t_{s1} + h_{s2} * t_{s2} + h_{s3} * t_{s3} = 1.5 \text{ m}^2$$

- Distance to vertical component

$$x_{stem} = l_{base} - (h_{s1} * t_{s1} * (l_{heel} + t_{s1} - t_{s3} / 2) + h_{s2} * t_{s2} * (l_{heel} + t_{s1} - t_{s2} / 2) + h_{s3} * t_{s3} * (l_{heel} + t_{s1} - t_{s3} / 2)) / A_{stem} = 933 \text{ mm}$$

Area of wall base

$$A_{base} = l_{base} * t_{base} + d_{key} * t_{key} = 1.45 \text{ m}^2$$

- Distance to vertical component

$$x_{base} = (l_{base}^2 * t_{base} / 2 + d_{key} * t_{key} * (p_{key} + t_{key} / 2)) / A_{base} = 1399 \text{ mm}$$

Area of moist soil

$$A_{moist} = l_{heel} * h_{s1} + (l_{heel} + t_{s1} - t_{s2}) * h_{s2} + (l_{heel} + t_{s1} - t_{s3}) * (h_{soil} - (h_{s1} + h_{s2})) + \tan(\beta) * (l_{heel} + t_{s1} - t_{s3})^2 / 2 = 1.706 \text{ m}^2$$

- Distance to vertical component

$$x_{moist_v} = l_{base} - (l_{heel} * h_{s1} * l_{heel} / 2 + (l_{heel} + t_{s1} - t_{s2}) * h_{s2} * (l_{heel} + t_{s1} - t_{s2}) / 2 + (l_{heel} + t_{s1} - t_{s3}) * (h_{soil} - (h_{s1} + h_{s2})) * (l_{heel} + t_{s1} - t_{s3}) / 2 + \tan(\beta) * (l_{heel} + t_{s1} - t_{s3})^3 / 6) / A_{moist} = 1903 \text{ mm}$$

- Distance to horizontal component

$$x_{moist_h} = h_{eff} / 3 - d_{key} = 430 \text{ mm}$$

- Distance to horizontal component above key

$$x_{moist_h_a} = (h_{eff} - d_{key}) / 3 = 663 \text{ mm}$$

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Design approach 1

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

Partial factor set	A1
Permanent unfavourable action	$\gamma_G = 1.35$
Permanent favourable action	$\gamma_{Gf} = 1.00$
Variable unfavourable action	$\gamma_Q = 1.50$
Variable favourable action	$\gamma_{Qf} = 0.00$

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

Soil parameter set	M1
Angle of shearing resistance	$\gamma_{\phi'} = 1.00$
Effective cohesion	$\gamma_{c'} = 1.00$
Weight density	$\gamma_r = 1.00$

Library item Partial factors output

Retained soil properties

Design moist density	$\gamma_{mr}' = \gamma_{mr} / \gamma_r = 17 \text{ kN/m}^3$
Design saturated density	$\gamma_{sr}' = \gamma_{sr} / \gamma_r = 20.5 \text{ kN/m}^3$
Design effective shear resistance angle	$\phi'_{r,d} = \text{atan}(\tan(\phi'_{r,k}) / \gamma_{\phi'}) = 30 \text{ deg}$
Design wall friction angle	$\delta_{r,d} = \text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}) = 15 \text{ deg}$

Base soil properties

Design soil density	$\gamma_b' = \gamma_b / \gamma_r = 17 \text{ kN/m}^3$
Design effective shear resistance angle	$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_{\phi'}) = 18 \text{ deg}$
Design wall friction angle	$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_{\phi'}) = 9 \text{ deg}$
Design base friction angle	$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_{\phi'}) = 12 \text{ deg}$
Design effective cohesion	$c'_{b,d} = c'_{b,k} / \gamma_{c'} = 0 \text{ kN/m}^2$

Using Coulomb theory

Active pressure coefficient	$K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 * \sin(\alpha - \delta_{r,d}) * [1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) * \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) * \sin(\alpha + \beta))}]^2) = 0.312$
Passive pressure coefficient	$K_P = \sin(90 - \phi'_{b,d})^2 / (\sin(90 + \delta_{b,d}) * [1 - \sqrt{(\sin(\phi'_{b,d} + \delta_{b,d}) * \sin(\phi'_{b,d} - \delta_{b,d}) / (\sin(90 + \delta_{b,d}))}]^2) = 2.359$

Sliding check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} * A_{stem} * \gamma_{stem} = 37.5 \text{ kN/m}$
Wall base	$F_{base} = \gamma_{Gf} * A_{base} * \gamma_{base} = 36.3 \text{ kN/m}$
Moist retained soil	$F_{moist_v} = \gamma_{Gf} * A_{moist} * \gamma_{mr}' = 29 \text{ kN/m}$
Total	$F_{total_v} = F_{stem} + F_{base} + F_{moist_v} = 102.7 \text{ kN/m}$

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A * \cos(\delta_{r,d}) * \gamma_Q * \text{Surcharge}_Q * h_{eff} = 10.6 \text{ kN/m}$
Moist retained soil	$F_{moist_h} = \gamma_G * K_A * \cos(\delta_{r,d}) * \gamma_{mr}' * h_{eff}^2 / 2 = 18.9 \text{ kN/m}$
Total	$F_{total_h} = F_{sur_h} + F_{moist_h} = 29.5 \text{ kN/m}$

Check stability against sliding

Base soil resistance	$F_{exc_h} = \gamma_{Gf} * K_P * \cos(\delta_{b,d}) * \gamma_b' * (h_{pass} + h_{base})^2 / 2 = 14.3 \text{ kN/m}$
Base friction	$F_{friction} = F_{total_v} * \tan(\delta_{bb,d}) = 21.8 \text{ kN/m}$

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Resistance to sliding
Factor of safety

$$F_{rest} = F_{exc_h} + F_{friction} = \mathbf{36.1 \text{ kN/m}}$$

$$Fo_{Ssl} = F_{rest} / F_{total_h} = \mathbf{1.224}$$

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem

$$F_{stem} = \gamma_G * A_{stem} * \gamma_{stem} = \mathbf{37.5 \text{ kN/m}}$$

Wall base

$$F_{base} = \gamma_G * A_{base} * \gamma_{base} = \mathbf{36.3 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_v} = \gamma_G * A_{moist} * \gamma_{mr}' = \mathbf{29 \text{ kN/m}}$$

Total

$$F_{total_v} = F_{stem} + F_{base} + F_{moist_v} = \mathbf{102.7 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{sur_h} = K_A * \cos(\delta_{r,d}) * \gamma_Q * \text{Surcharge}_Q * (h_{eff} - d_{key}) = \mathbf{9 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_h} = \gamma_G * K_A * \cos(\delta_{r,d}) * \gamma_{mr}' * (h_{eff} - d_{key})^2 / 2 = \mathbf{13.7 \text{ kN/m}}$$

Base soil

$$F_{exc_h} = -\gamma_G * K_P * \cos(\delta_{b,d}) * \gamma_b' * (h_{pass} + h_{base})^2 / 2 = \mathbf{-14.3 \text{ kN/m}}$$

Total

$$F_{total_h} = F_{sur_h} + F_{moist_h} + F_{exc_h} = \mathbf{8.4 \text{ kN/m}}$$

Overturning moments on wall

Surcharge load

$$M_{sur_OT} = F_{sur_h} * X_{sur_h_a} = \mathbf{9 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist_OT} = F_{moist_h} * X_{moist_h_a} = \mathbf{9.1 \text{ kNm/m}}$$

Base soil

$$M_{exc_OT} = F_{exc_h} * X_{exc_h} = \mathbf{1 \text{ kNm/m}}$$

Total

$$M_{total_OT} = M_{sur_OT} + M_{moist_OT} + M_{exc_OT} = \mathbf{19 \text{ kNm/m}}$$

Restoring moments on wall

Wall stem

$$M_{stem_R} = F_{stem} * X_{stem} = \mathbf{35 \text{ kNm/m}}$$

Wall base

$$M_{base_R} = F_{base} * X_{base} = \mathbf{50.7 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist_R} = F_{moist_v} * X_{moist_v} = \mathbf{55.2 \text{ kNm/m}}$$

Total

$$M_{total_R} = M_{stem_R} + M_{base_R} + M_{moist_R} = \mathbf{140.9 \text{ kNm/m}}$$

Check stability against overturning

Factor of safety

$$Fo_{Sot} = M_{total_R} / M_{total_OT} = \mathbf{7.422}$$

PASS - Maximum restoring moment is greater than overturning moment

Bearing pressure check

Vertical forces on wall

Wall stem

$$F_{stem} = \gamma_G * A_{stem} * \gamma_{stem} = \mathbf{50.6 \text{ kN/m}}$$

Wall base

$$F_{base} = \gamma_G * A_{base} * \gamma_{base} = \mathbf{48.9 \text{ kN/m}}$$

Surcharge load

$$F_{sur_v} = \gamma_Q * \text{Surcharge}_Q * (l_{heel} + t_{s1} - t_{s3}) = \mathbf{25.5 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_v} = \gamma_G * A_{moist} * \gamma_{mr}' = \mathbf{39.1 \text{ kN/m}}$$

Total

$$F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{moist_v} = \mathbf{164.2 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{sur_h} = K_A * \cos(\delta_{r,d}) * \gamma_Q * \text{Surcharge}_Q * (h_{eff} - d_{key}) = \mathbf{9 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_h} = \gamma_G * K_A * \cos(\delta_{r,d}) * \gamma_{mr}' * (h_{eff} - d_{key})^2 / 2 = \mathbf{13.7 \text{ kN/m}}$$

Base soil

$$F_{pass_h} = -\gamma_G * K_P * \cos(\delta_{b,d}) * \gamma_b' * (d_{cover} + h_{base})^2 / 2 = \mathbf{-14.3 \text{ kN/m}}$$

Total

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

Moments on wall

Wall stem

$$M_{stem} = F_{stem} * X_{stem} = \mathbf{47.3 \text{ kNm/m}}$$

Wall base

$$M_{base} = F_{base} * X_{base} = \mathbf{68.4 \text{ kNm/m}}$$

Surcharge load

$$M_{sur} = F_{sur_v} * X_{sur_v} - F_{sur_h} * X_{sur_h_a} = \mathbf{34.4 \text{ kNm/m}}$$

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Moist retained soil

$$M_{\text{moist}} = F_{\text{moist}_v} \times X_{\text{moist}_v} - F_{\text{moist}_h} \times X_{\text{moist}_h_a} = \mathbf{65.4 \text{ kNm/m}}$$

Base soil

$$M_{\text{pass}} = -F_{\text{pass}_h} \times X_{\text{pass}_h} = \mathbf{-1 \text{ kNm/m}}$$

Total

$$M_{\text{total}} = M_{\text{stem}} + M_{\text{base}} + M_{\text{sur}} + M_{\text{moist}} + M_{\text{pass}} = \mathbf{214.6 \text{ kNm/m}}$$

Check bearing pressure

Distance to reaction

$$\bar{x} = M_{\text{total}} / F_{\text{total}_v} = \mathbf{1307 \text{ mm}}$$

Eccentricity of reaction

$$e = \bar{x} - l_{\text{base}} / 2 = \mathbf{32 \text{ mm}}$$

Loaded length of base

$$l_{\text{load}} = 2 \times (l_{\text{base}} - \bar{x}) = \mathbf{2487 \text{ mm}}$$

Bearing pressure at toe

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

Bearing pressure at heel

$$q_{\text{heel}} = F_{\text{total}_v} / l_{\text{load}} = \mathbf{66 \text{ kN/m}^2}$$

Effective overburden pressure

$$q = (t_{\text{base}} + d_{\text{cover}}) \times \gamma'_b = \mathbf{8.5 \text{ kN/m}^2}$$

Design effective overburden pressure

$$q' = q / \gamma_\gamma = \mathbf{8.5 \text{ kN/m}^2}$$

Bearing resistance factors

$$N_q = \text{Exp}(\pi \times \tan(\phi'_{b,d})) \times (\tan(45 \text{ deg} + \phi'_{b,d} / 2))^2 = \mathbf{5.258}$$

$$N_c = (N_q - 1) \times \cot(\phi'_{b,d}) = \mathbf{13.104}$$

$$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b,d}) = \mathbf{2.767}$$

Foundation shape factors

$$S_q = \mathbf{1}$$

$$S_\gamma = \mathbf{1}$$

$$S_c = \mathbf{1}$$

Load inclination factors

$$H = F_{\text{sur}_h} + F_{\text{moist}_h} + F_{\text{pass}_h} = \mathbf{8.4 \text{ kN/m}}$$

$$V = F_{\text{total}_v} = \mathbf{164.2 \text{ kN/m}}$$

$$m = \mathbf{2}$$

$$i_q = [1 - H / (V + l_{\text{load}} \times c'_{b,d} \times \cot(\phi'_{b,d}))]^m = \mathbf{0.9}$$

$$i_\gamma = [1 - H / (V + l_{\text{load}} \times c'_{b,d} \times \cot(\phi'_{b,d}))]^{(m+1)} = \mathbf{0.854}$$

$$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b,d})) = \mathbf{0.877}$$

Net ultimate bearing capacity

$$n_f = c'_{b,d} \times N_c \times S_c \times i_c + q' \times N_q \times S_q \times i_q + 0.5 \times \gamma'_b \times l_{\text{load}} \times N_\gamma \times S_\gamma \times i_\gamma = \mathbf{90.2 \text{ kN/m}^2}$$

Factor of safety

$$FoS_{bp} = n_f / \max(q_{\text{toe}}, q_{\text{heel}}) = \mathbf{1.366}$$

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

Design approach 1

Partial factors on actions - Table A.3 - Combination 2

Partial factor set

$$A2$$

Permanent unfavourable action

$$\gamma_G = \mathbf{1.00}$$

Permanent favourable action

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

Variable unfavourable action

$$\gamma_Q = \mathbf{1.30}$$

Variable favourable action

$$\gamma_{Qf} = \mathbf{0.00}$$

Partial factors for soil parameters – Table A.4 - Combination 2

Soil parameter set

$$M2$$

Angle of shearing resistance

$$\gamma_\phi = \mathbf{1.25}$$

Effective cohesion

$$\gamma_{c'} = \mathbf{1.25}$$

Weight density

$$\gamma_\gamma = \mathbf{1.00}$$

Library item Partial factors output

Retained soil properties

Design moist density

$$\gamma_{mr}' = \gamma_{mr} / \gamma_\gamma = \mathbf{17 \text{ kN/m}^3}$$

Design saturated density

$$\gamma_{sr}' = \gamma_{sr} / \gamma_\gamma = \mathbf{20.5 \text{ kN/m}^3}$$

Design effective shear resistance angle

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

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Design wall friction angle

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

Base soil properties

Design soil density

$$\gamma_{b'} = \gamma_b / \gamma_r = \mathbf{17 \text{ kN/m}^3}$$

Design effective shear resistance angle

$$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_{\psi}) = \mathbf{14.6 \text{ deg}}$$

Design wall friction angle

$$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_{\psi}) = \mathbf{7.2 \text{ deg}}$$

Design base friction angle

$$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_{\psi}) = \mathbf{9.7 \text{ deg}}$$

Design effective cohesion

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

Using Coulomb theory

Active pressure coefficient

$$K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \sin(\alpha - \delta_{r,d}) * [1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) * \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) * \sin(\alpha + \beta))}]^2) = \mathbf{0.386}$$

Passive pressure coefficient

$$K_P = \sin(90 - \phi'_{b,d})^2 / (\sin(90 + \delta_{b,d}) * [1 - \sqrt{(\sin(\phi'_{b,d} + \delta_{b,d}) * \sin(\phi'_{b,d} - (\sin(90 + \delta_{b,d})))}]^2) = \mathbf{1.965}$$

Sliding check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = \gamma_{Gf} * A_{\text{stem}} * \gamma_{\text{stem}} = \mathbf{37.5 \text{ kN/m}}$$

Wall base

$$F_{\text{base}} = \gamma_{Gf} * A_{\text{base}} * \gamma_{\text{base}} = \mathbf{36.3 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_v} = \gamma_{Gf} * A_{\text{moist}} * \gamma_{mr'} = \mathbf{29 \text{ kN/m}}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{moist}_v} = \mathbf{102.7 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_A * \cos(\delta_{r,d}) * \gamma_Q * \text{Surcharge}_Q * h_{\text{eff}} = \mathbf{11.5 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_h} = \gamma_G * K_A * \cos(\delta_{r,d}) * \gamma_{mr'} * h_{\text{eff}}^2 / 2 = \mathbf{17.6 \text{ kN/m}}$$

Total

$$F_{\text{total}_h} = F_{\text{sur}_h} + F_{\text{moist}_h} = \mathbf{29 \text{ kN/m}}$$

Check stability against sliding

Base soil resistance

$$F_{\text{exc}_h} = \gamma_{Gf} * K_P * \cos(\delta_{b,d}) * \gamma_{b'} * (h_{\text{pass}} + h_{\text{base}})^2 / 2 = \mathbf{12 \text{ kN/m}}$$

Base friction

$$F_{\text{friction}} = F_{\text{total}_v} * \tan(\delta_{bb,d}) = \mathbf{17.5 \text{ kN/m}}$$

Resistance to sliding

$$F_{\text{rest}} = F_{\text{exc}_h} + F_{\text{friction}} = \mathbf{29.4 \text{ kN/m}}$$

Factor of safety

$$FoS_{Sl} = F_{\text{rest}} / F_{\text{total}_h} = \mathbf{1.014}$$

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = \gamma_{Gf} * A_{\text{stem}} * \gamma_{\text{stem}} = \mathbf{37.5 \text{ kN/m}}$$

Wall base

$$F_{\text{base}} = \gamma_{Gf} * A_{\text{base}} * \gamma_{\text{base}} = \mathbf{36.3 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_v} = \gamma_{Gf} * A_{\text{moist}} * \gamma_{mr'} = \mathbf{29 \text{ kN/m}}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{moist}_v} = \mathbf{102.7 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_A * \cos(\delta_{r,d}) * \gamma_Q * \text{Surcharge}_Q * (h_{\text{eff}} - d_{\text{key}}) = \mathbf{9.8 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_h} = \gamma_G * K_A * \cos(\delta_{r,d}) * \gamma_{mr'} * (h_{\text{eff}} - d_{\text{key}})^2 / 2 = \mathbf{12.7 \text{ kN/m}}$$

Base soil

$$F_{\text{exc}_h} = -\gamma_{Gf} * K_P * \cos(\delta_{b,d}) * \gamma_{b'} * (h_{\text{pass}} + h_{\text{base}})^2 / 2 = \mathbf{-12 \text{ kN/m}}$$

Total

$$F_{\text{total}_h} = F_{\text{sur}_h} + F_{\text{moist}_h} + F_{\text{exc}_h} = \mathbf{10.5 \text{ kN/m}}$$

Overturning moments on wall

Surcharge load

$$M_{\text{sur}_OT} = F_{\text{sur}_h} * X_{\text{sur}_h_a} = \mathbf{9.7 \text{ kNm/m}}$$

Moist retained soil

$$M_{\text{moist}_OT} = F_{\text{moist}_h} * X_{\text{moist}_h_a} = \mathbf{8.4 \text{ kNm/m}}$$

Base soil

$$M_{\text{exc}_OT} = F_{\text{exc}_h} * X_{\text{exc}_h} = \mathbf{0.8 \text{ kNm/m}}$$

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Total

$$M_{total_OT} = M_{sur_OT} + M_{moist_OT} + M_{exc_OT} = \mathbf{18.9 \text{ kNm/m}}$$

Restoring moments on wall

Wall stem

$$M_{stem_R} = F_{stem} * X_{stem} = \mathbf{35 \text{ kNm/m}}$$

Wall base

$$M_{base_R} = F_{base} * X_{base} = \mathbf{50.7 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist_R} = F_{moist_v} * X_{moist_v} = \mathbf{55.2 \text{ kNm/m}}$$

Total

$$M_{total_R} = M_{stem_R} + M_{base_R} + M_{moist_R} = \mathbf{140.9 \text{ kNm/m}}$$

Check stability against overturning

Factor of safety

$$FoS_{ot} = M_{total_R} / M_{total_OT} = \mathbf{7.446}$$

PASS - Maximum restoring moment is greater than overturning moment

Bearing pressure check

Vertical forces on wall

Wall stem

$$F_{stem} = \gamma_G * A_{stem} * \gamma_{stem} = \mathbf{37.5 \text{ kN/m}}$$

Wall base

$$F_{base} = \gamma_G * A_{base} * \gamma_{base} = \mathbf{36.3 \text{ kN/m}}$$

Surcharge load

$$F_{sur_v} = \gamma_Q * \text{Surcharge}_Q * (l_{heel} + t_{s1} - t_{s3}) = \mathbf{22.1 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_v} = \gamma_G * A_{moist} * \gamma_{mr}' = \mathbf{29 \text{ kN/m}}$$

Total

$$F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{moist_v} = \mathbf{124.8 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{sur_h} = K_A * \cos(\delta_{r,d}) * \gamma_Q * \text{Surcharge}_Q * (h_{eff} - d_{key}) = \mathbf{9.8 \text{ kN/m}}$$

Moist retained soil

$$F_{moist_h} = \gamma_G * K_A * \cos(\delta_{r,d}) * \gamma_{mr}' * (h_{eff} - d_{key})^2 / 2 = \mathbf{12.7 \text{ kN/m}}$$

Base soil

$$F_{pass_h} = -\gamma_G * K_P * \cos(\delta_{b,d}) * \gamma_b' * (d_{cover} + h_{base})^2 / 2 = \mathbf{-12 \text{ kN/m}}$$

Total

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

Moments on wall

Wall stem

$$M_{stem} = F_{stem} * X_{stem} = \mathbf{35 \text{ kNm/m}}$$

Wall base

$$M_{base} = F_{base} * X_{base} = \mathbf{50.7 \text{ kNm/m}}$$

Surcharge load

$$M_{sur} = F_{sur_v} * X_{sur_v} - F_{sur_h} * X_{sur_h_a} = \mathbf{27.9 \text{ kNm/m}}$$

Moist retained soil

$$M_{moist} = F_{moist_v} * X_{moist_v} - F_{moist_h} * X_{moist_h_a} = \mathbf{46.8 \text{ kNm/m}}$$

Base soil

$$M_{pass} = -F_{pass_h} * X_{pass_h} = \mathbf{-0.8 \text{ kNm/m}}$$

Total

$$M_{total} = M_{stem} + M_{base} + M_{sur} + M_{moist} + M_{pass} = \mathbf{159.5 \text{ kNm/m}}$$

Check bearing pressure

Distance to reaction

$$\bar{x} = M_{total} / F_{total_v} = \mathbf{1278 \text{ mm}}$$

Eccentricity of reaction

$$e = \bar{x} - l_{base} / 2 = \mathbf{3 \text{ mm}}$$

Loaded length of base

$$l_{load} = 2 * (l_{base} - \bar{x}) = \mathbf{2544 \text{ mm}}$$

Bearing pressure at toe

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

Bearing pressure at heel

$$q_{heel} = F_{total_v} / l_{load} = \mathbf{49.1 \text{ kN/m}^2}$$

Effective overburden pressure

$$q = (l_{base} + d_{cover}) * \gamma_b' = \mathbf{8.5 \text{ kN/m}^2}$$

Design effective overburden pressure

$$q' = q / \gamma_\gamma = \mathbf{8.5 \text{ kN/m}^2}$$

Bearing resistance factors

$$N_q = \text{Exp}(\pi * \tan(\phi'_{b,d})) * (\tan(45 \text{ deg} + \phi'_{b,d} / 2))^2 = \mathbf{3.784}$$

$$N_c = (N_q - 1) * \cot(\phi'_{b,d}) = \mathbf{10.711}$$

$$N_\gamma = 2 * (N_q - 1) * \tan(\phi'_{b,d}) = \mathbf{1.447}$$

Foundation shape factors

$$S_q = \mathbf{1}$$

$$S_\gamma = \mathbf{1}$$

$$S_c = \mathbf{1}$$

Load inclination factors

$$H = F_{sur_h} + F_{moist_h} + F_{pass_h} = \mathbf{10.5 \text{ kN/m}}$$

$$V = F_{total_v} = \mathbf{124.8 \text{ kN/m}}$$

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$$m = 2$$

$$i_q = [1 - H / (V + I_{load} \times C'_{b,d} \times \cot(\phi'_{b,d}))]^m = \mathbf{0.839}$$

$$i_\gamma = [1 - H / (V + I_{load} \times C'_{b,d} \times \cot(\phi'_{b,d}))]^{(m+1)} = \mathbf{0.769}$$

$$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b,d})) = \mathbf{0.781}$$

Net ultimate bearing capacity

$$n_f = C'_{b,d} \times N_c \times S_c \times i_c + q' \times N_q \times S_q \times i_q + 0.5 \times \gamma'_b \times I_{load} \times N_\gamma \times S_\gamma \times i_\gamma = \mathbf{51.1 \text{ kN/m}^2}$$

Factor of safety

$$FoS_{bp} = n_f / \max(q_{toe}, q_{heel}) = \mathbf{1.04}$$

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

RETAINING WALL DESIGN

In accordance with EN1992-1-1:2004 incorporating Corrigendum dated January 2008 and the UK National Annex incorporating National Amendment No.1 and EN1996-1-1:2005 incorporating Corrigenda dated February 2006 and July 2009 and the UK National Annex

Tedds calculation version 2.9.11

Concrete details - Table 3.1 - Strength and deformation characteristics for concrete

Concrete strength class	C30/37
Characteristic compressive cylinder strength	$f_{ck} = \mathbf{30 \text{ N/mm}^2}$
Characteristic compressive cube strength	$f_{ck,cube} = \mathbf{37 \text{ N/mm}^2}$
Mean value of compressive cylinder strength	$f_{cm} = f_{ck} + 8 \text{ N/mm}^2 = \mathbf{38 \text{ N/mm}^2}$
Mean value of axial tensile strength	$f_{ctm} = 0.3 \text{ N/mm}^2 \times (f_{ck} / 1 \text{ N/mm}^2)^{2/3} = \mathbf{2.9 \text{ N/mm}^2}$
5% fractile of axial tensile strength	$f_{ctk,0.05} = 0.7 \times f_{ctm} = \mathbf{2.0 \text{ N/mm}^2}$
Secant modulus of elasticity of concrete	$E_{cm} = 22 \text{ kN/mm}^2 \times (f_{cm} / 10 \text{ N/mm}^2)^{0.3} = \mathbf{32837 \text{ N/mm}^2}$
Partial factor for concrete - Table 2.1N	$\gamma_C = \mathbf{1.50}$
Compressive strength coefficient - cl.3.1.6(1)	$\alpha_{cc} = \mathbf{0.85}$
Design compressive concrete strength - exp.3.15	$f_{cd} = \alpha_{cc} \times f_{ck} / \gamma_C = \mathbf{17.0 \text{ N/mm}^2}$
Maximum aggregate size	$h_{agg} = \mathbf{20 \text{ mm}}$
Ultimate strain - Table 3.1	$\epsilon_{cu2} = \mathbf{0.0035}$
Shortening strain - Table 3.1	$\epsilon_{cu3} = \mathbf{0.0035}$
Effective compression zone height factor	$\lambda = \mathbf{0.80}$
Effective strength factor	$\eta = \mathbf{1.00}$
Bending coefficient k_1	$K_1 = \mathbf{0.40}$
Bending coefficient k_2	$K_2 = 1.00 \times (0.6 + 0.0014/\epsilon_{cu2}) = \mathbf{1.00}$
Bending coefficient k_3	$K_3 = \mathbf{0.40}$
Bending coefficient k_4	$K_4 = 1.00 \times (0.6 + 0.0014/\epsilon_{cu2}) = \mathbf{1.00}$

Reinforcement details

Characteristic yield strength of reinforcement	$f_{yk} = \mathbf{500 \text{ N/mm}^2}$
Modulus of elasticity of reinforcement	$E_s = \mathbf{200000 \text{ N/mm}^2}$
Partial factor for reinforcing steel - Table 2.1N	$\gamma_S = \mathbf{1.15}$
Design yield strength of reinforcement	$f_{yd} = f_{yk} / \gamma_S = \mathbf{435 \text{ N/mm}^2}$

Cover to reinforcement

Top face of base	$C_{bt} = \mathbf{50 \text{ mm}}$
Bottom face of base	$C_{bb} = \mathbf{75 \text{ mm}}$

Masonry details - Section 3.1

Masonry type	Aggregate concrete laid flat - Group 1
Normalised mean compressive strength	$f_b = \mathbf{7.3 \text{ N/mm}^2}$
Characteristic flexural strength - cl.6.3.4(1)	$f_{xk} = \mathbf{0 \text{ N/mm}^2}$

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Initial shear strength - Table NA.5

$f_{vko} = 0.15 \text{ N/mm}^2$

Mortar details - Section 3.2

Mortar type

General purpose - M4, prescribed mix

Compressive strength of mortar

$f_m = 4 \text{ N/mm}^2$

Ultimate limit states - Table NA.1

Class of execution control

1

Category of manufacture control

1

Partial factor for direct or flexural compression

$\gamma_{Mc} = 2.3$

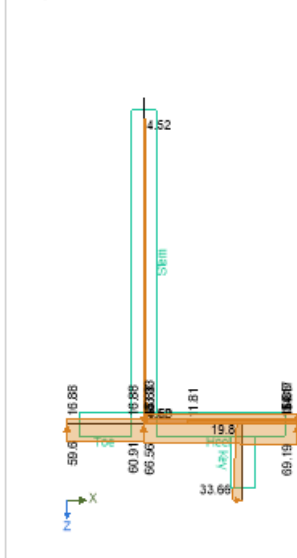
Partial factor for flexural tension

$\gamma_{Mt} = 2.3$

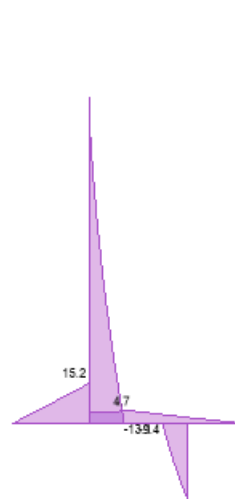
Partial factor for shear

$\gamma_{Mv} = 2.5$

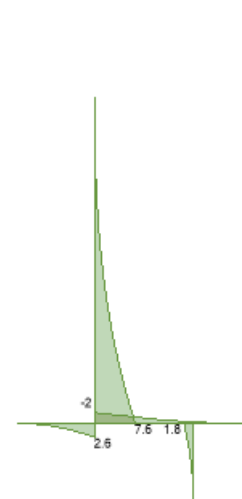
Loading details - Combination No.1 - kN/m²



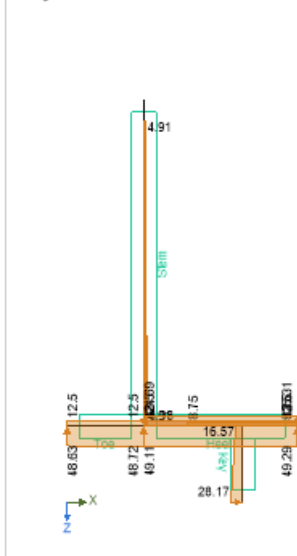
Shear force - Combination No.1 - kN/m



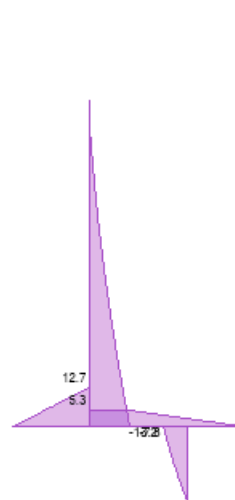
Bending moment - Combination No.1 - kNm/m



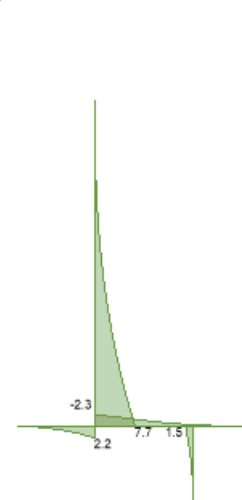
Loading details - Combination No.2 - kN/m²



Shear force - Combination No.2 - kN/m



Bending moment - Combination No.2 - kNm/m



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Check stem design at base of stem

Depth of section $t = 1500$ mm

Masonry characteristics

Compressive strength constants - Table NA.4 $K = 0.5 * (100\% - n) / 100\% = 0.500$

Characteristic compressive strength - cl.3.6.1.2(1) $f_k = K * f_b^{0.7} * f_m^{0.3} = 3.047$ N/mm²

Design compressive strength $f_d = f_k / \gamma_{Mc} = 1.325$ N/mm²

Design flexural strength $f_{xd} = f_{xk} / \gamma_{Mt} = 0$ N/mm²

Height of masonry $h_{wt} = h_{stem} = 1500$ mm

Compressive axial force combination 0 $F_x = \gamma_{Gf} * \gamma_{stem} * (h_{s1} * t_{s1} + h_{s2} * t_{s2} + h_{s3} * t_{s3}) = 37.5$ kN/m

Moment combination 0 $M_x = \gamma_{Gf} * \gamma_{stem} * (h_{s1} * t_{s1} * t_{s1} / 2 + h_{s2} * t_{s2} * t_{s2} / 2 + h_{s3} * t_{s3} * t_{s3} / 2) = 21.9$ kNm/m

Eccentricity of axial load $e = \max(\text{abs}(t / 2 - M_x / F_x), 0.05 * t) = 166.7$ mm

Capacity reduction factor - exp.6.4 $\Phi = 1 - 2 * e / t = 0.778$

Design vertical resistance - exp.6.2 $N_{Rd} = \Phi * t * f_d = 1545.7$ kN/m

Design vertical compressive stress $\sigma_d = \min(F_x / t, 0.15 * N_{Rd} / t) = 0.025$ N/mm²

Apparent design flexural strength - exp.6.16 $f_{xd,app} = f_{xd} + \sigma_d = 0.025$ N/mm²

Limit of charact. shear strength - exp. 3.1 $f_{vk,lim} = 0.065 * f_b = 0.475$ N/mm²

Characteristic shear strength - exp.3.5 $f_{vk} = \min(f_{vko} + 0.4 * \sigma_d, f_{vk,lim}) = 0.16$ N/mm²

Design shear strength $f_{vd} = f_{vk} / \gamma_{Mv} = 0.064$ N/mm²

Library item: Masonry characteristics output

Unreinforced masonry walls subjected to lateral loading - Section 6.3

Design bending moment combination 2 $M = 7.743$ kNm/m

Elastic section modulus of wall $Z = t^2 / 6 = 375000000$ mm³/m

Moment of resistance of masonry - exp.6.15 $M_{Rd} = f_{xd,app} * Z = 9.375$ kNm/m

$M / M_{Rd} = 0.826$

PASS - Moment of resistance exceeds applied design moment

Unreinforced masonry walls subjected to shear loading - Section 6.2

Design shear force $V = 13.157$ kN/m

Maximum compressive stress $\sigma_{max} = F_x / t + M / Z = 0.046$ N/mm²

Minimum compressive stress $\sigma_{min} = F_x / t - M / Z = 0.004$ N/mm²

Thickness of wall in compression $t_c = t = 1500$ mm

Design shear resistance - exp.6.13 $V_{Rd} = f_{vd} * t_c = 96$ kN/m

$V / V_{Rd} = 0.137$

PASS - Design shear resistance exceeds applied design shear force

Check stem design at 500 mm

Depth of section $t = 1000$ mm

Masonry characteristics

Compressive strength constants - Table NA.4 $K = 0.5 * (100\% - n) / 100\% = 0.500$

Characteristic compressive strength - cl.3.6.1.2(1) $f_k = K * f_b^{0.7} * f_m^{0.3} = 3.047$ N/mm²

Design compressive strength $f_d = f_k / \gamma_{Mc} = 1.325$ N/mm²

Design flexural strength $f_{xd} = f_{xk} / \gamma_{Mt} = 0$ N/mm²

Height of masonry $h_{wt} = h_{stem} - 500$ mm = 1000 mm

Compressive axial force combination 0 $F_x = \gamma_{Gf} * \gamma_{stem} * (h_{s2} * t_{s2} + h_{s3} * t_{s3}) = 18.8$ kN/m

Moment combination 0 $M_x = \gamma_{Gf} * \gamma_{stem} * (h_{s2} * t_{s2} * t_{s2} / 2 + h_{s3} * t_{s3} * t_{s3} / 2) = 7.8$ kNm/m

Eccentricity of axial load $e = \max(\text{abs}(t / 2 - M_x / F_x), 0.05 * t) = 83.3$ mm

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Capacity reduction factor - exp.6.4	$\Phi = 1 - 2 \times e / t = \mathbf{0.833}$
Design vertical resistance - exp.6.2	$N_{Rd} = \Phi \times t \times f_d = \mathbf{1104.1 \text{ kN/m}}$
Design vertical compressive stress	$\sigma_d = \min(F_x / t, 0.15 \times N_{Rd} / t) = \mathbf{0.019 \text{ N/mm}^2}$
Apparent design flexural strength - exp.6.16	$f_{xd,app} = f_{xd} + \sigma_d = \mathbf{0.019 \text{ N/mm}^2}$
Limit of charact. shear strength - exp. 3.1	$f_{vk,lim} = 0.065 \times f_b = \mathbf{0.475 \text{ N/mm}^2}$
Characteristic shear strength - exp.3.5	$f_{vk} = \min(f_{vko} + 0.4 \times \sigma_d, f_{vk,lim}) = \mathbf{0.158 \text{ N/mm}^2}$
Design shear strength	$f_{vd} = f_{vk} / \gamma_{Mv} = \mathbf{0.063 \text{ N/mm}^2}$

Library item: Masonry characteristics output

Unreinforced masonry walls subjected to lateral loading - Section 6.3

Design bending moment combination 2	$M = \mathbf{2.767 \text{ kNm/m}}$
Elastic section modulus of wall	$Z = t^2 / 6 = \mathbf{166666667 \text{ mm}^3/\text{m}}$
Moment of resistance of masonry - exp.6.15	$M_{Rd} = f_{xd,app} \times Z = \mathbf{3.125 \text{ kNm/m}}$
	$M / M_{Rd} = \mathbf{0.885}$
	<i>PASS - Moment of resistance exceeds applied design moment</i>

Unreinforced masonry walls subjected to shear loading - Section 6.2

Design shear force	$V = \mathbf{7.015 \text{ kN/m}}$
Maximum compressive stress	$\sigma_{max} = F_x / t + M / Z = \mathbf{0.035 \text{ N/mm}^2}$
Minimum compressive stress	$\sigma_{min} = F_x / t - M / Z = \mathbf{0.002 \text{ N/mm}^2}$
Thickness of wall in compression	$t_c = t = \mathbf{1000 \text{ mm}}$
Design shear resistance - exp.6.13	$V_{Rd} = f_{vd} \times t_c = \mathbf{63 \text{ kN/m}}$
	$V / V_{Rd} = \mathbf{0.111}$
	<i>PASS - Design shear resistance exceeds applied design shear force</i>

Check stem design at 1000 mm

Depth of section	$t = \mathbf{500 \text{ mm}}$
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Masonry characteristics

Compressive strength constants - Table NA.4	$K = 0.5 \times (100\% - n) / 100\% = 0.500$
Characteristic compressive strength - cl.3.6.1.2(1)	$f_k = K \times f_b^{0.7} \times f_m^{0.3} = \mathbf{3.047 \text{ N/mm}^2}$
Design compressive strength	$f_d = f_k / \gamma_{Mc} = \mathbf{1.325 \text{ N/mm}^2}$
Design flexural strength	$f_{xd} = f_{xk} / \gamma_{Mt} = \mathbf{0 \text{ N/mm}^2}$
Height of masonry	$h_{wt} = h_{stem} - 1000 \text{ mm} = \mathbf{500 \text{ mm}}$
Compressive axial force combination 0	$F_x = \gamma_{Gf} \times \gamma_{stem} \times h_{s3} \times t_{s3} = \mathbf{6.3 \text{ kN/m}}$
Moment combination 0	$M_x = \gamma_{Gf} \times \gamma_{stem} \times h_{s3} \times t_{s3} \times t_{s3} / 2 = \mathbf{1.6 \text{ kNm/m}}$
Eccentricity of axial load	$e = \max(\text{abs}(t / 2 - M_x / F_x), 0.05 \times t) = \mathbf{25 \text{ mm}}$
Capacity reduction factor - exp.6.4	$\Phi = 1 - 2 \times e / t = \mathbf{0.9}$
Design vertical resistance - exp.6.2	$N_{Rd} = \Phi \times t \times f_d = \mathbf{596.2 \text{ kN/m}}$
Design vertical compressive stress	$\sigma_d = \min(F_x / t, 0.15 \times N_{Rd} / t) = \mathbf{0.013 \text{ N/mm}^2}$
Apparent design flexural strength - exp.6.16	$f_{xd,app} = f_{xd} + \sigma_d = \mathbf{0.013 \text{ N/mm}^2}$
Limit of charact. shear strength - exp. 3.1	$f_{vk,lim} = 0.065 \times f_b = \mathbf{0.475 \text{ N/mm}^2}$
Characteristic shear strength - exp.3.5	$f_{vk} = \min(f_{vko} + 0.4 \times \sigma_d, f_{vk,lim}) = \mathbf{0.155 \text{ N/mm}^2}$
Design shear strength	$f_{vd} = f_{vk} / \gamma_{Mv} = \mathbf{0.062 \text{ N/mm}^2}$

Library item: Masonry characteristics output

Unreinforced masonry walls subjected to lateral loading - Section 6.3

Design bending moment combination 2	$M = \mathbf{0.461 \text{ kNm/m}}$
Elastic section modulus of wall	$Z = t^2 / 6 = \mathbf{41666667 \text{ mm}^3/\text{m}}$
Moment of resistance of masonry - exp.6.15	$M_{Rd} = f_{xd,app} \times Z = \mathbf{0.521 \text{ kNm/m}}$

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$$M / M_{Rd} = 0.885$$

PASS - Moment of resistance exceeds applied design moment

Unreinforced masonry walls subjected to shear loading - Section 6.2

Design shear force

$$V = 2.476 \text{ kN/m}$$

Maximum compressive stress

$$\sigma_{\max} = F_x / t + M / Z = 0.024 \text{ N/mm}^2$$

Minimum compressive stress

$$\sigma_{\min} = F_x / t - M / Z = 0.001 \text{ N/mm}^2$$

Thickness of wall in compression

$$t_c = t = 500 \text{ mm}$$

Design shear resistance - exp.6.13

$$V_{Rd} = f_{vd} \times t_c = 31 \text{ kN/m}$$

$$V / V_{Rd} = 0.080$$

PASS - Design shear resistance exceeds applied design shear force

Check base design at toe

Depth of section

$$h = 500 \text{ mm}$$

Rectangular section in flexure - Section 6.1

Design bending moment combination 1

$$M = 2.6 \text{ kNm/m}$$

Depth to tension reinforcement

$$d = h - C_{bb} - \phi_{bb} / 2 = 415 \text{ mm}$$

$$K = M / (d^2 \times f_{ck}) = 0.001$$

$$K' = (2 \times \eta \times \alpha_{cc} / \gamma_c) \times (1 - \lambda \times (\delta - K_1) / (2 \times K_2)) \times (\lambda \times (\delta - K_1) / (2 \times K_2))$$

$$K' = 0.207$$

$K' > K$ - No compression reinforcement is required

Lever arm

$$z = d \times \min(1 - 0.5 \times A_{sr2,prov} \times f_{yd} / (d \times f_d), 0.95) = 351 \text{ mm}$$

Depth of neutral axis

$$x = 2.5 \times (d - z) = 161 \text{ mm}$$

Area of tension reinforcement required

$$A_{bb,req} = M / (f_{yd} \times z) = 17 \text{ mm}^2/\text{m}$$

Tension reinforcement provided

$$20 \text{ dia. bars @ } 200 \text{ c/c}$$

Area of tension reinforcement provided

$$A_{bb,prov} = \pi \times \phi_{bb}^2 / (4 \times S_{bb}) = 1571 \text{ mm}^2/\text{m}$$

Minimum area of reinforcement - exp.9.1N

$$A_{bb,min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = 625 \text{ mm}^2/\text{m}$$

Maximum area of reinforcement - cl.9.2.1.1(3)

$$A_{bb,max} = 0.04 \times h = 20000 \text{ mm}^2/\text{m}$$

$$\max(A_{bb,req}, A_{bb,min}) / A_{bb,prov} = 0.398$$

PASS - Area of reinforcement provided is greater than area of reinforcement required

Library item: Rectangular single output

Crack control - Section 7.3

Limiting crack width

$$w_{\max} = 0.3 \text{ mm}$$

Variable load factor - EN1990 – Table A1.1

$$\psi_2 = 0.6$$

Serviceability bending moment

$$M_{sIs} = 1.8 \text{ kNm/m}$$

Tensile stress in reinforcement

$$\sigma_s = M_{sIs} / (A_{bb,prov} \times z) = 3.2 \text{ N/mm}^2$$

Load duration

$$\text{Long term}$$

Load duration factor

$$k_t = 0.4$$

Effective area of concrete in tension

$$A_{c,eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$$

$$A_{c,eff} = 112972 \text{ mm}^2/\text{m}$$

Mean value of concrete tensile strength

$$f_{ct,eff} = f_{ctm} = 2.9 \text{ N/mm}^2$$

Reinforcement ratio

$$\rho_{p,eff} = A_{bb,prov} / A_{c,eff} = 0.014$$

Modular ratio

$$\alpha_e = E_s / E_{cm} = 6.091$$

Bond property coefficient

$$k_1 = 0.8$$

Strain distribution coefficient

$$k_2 = 0.5$$

$$k_3 = 3.4$$

$$k_4 = 0.425$$

Maximum crack spacing - exp.7.11

$$s_{r,max} = k_3 \times C_{bb} + k_1 \times k_2 \times k_4 \times \phi_{bb} / \rho_{p,eff} = 500 \text{ mm}$$

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Maximum crack width - exp.7.8

$$w_k = s_{r,max} \times \max(\sigma_s - k_t \times (f_{ct,eff} / \rho_{p,eff}) \times (1 + \alpha_e \times \rho_{p,eff}), 0.6 \times \sigma_s) / E_s$$

$$w_k = \mathbf{0.005 \text{ mm}}$$

$$w_k / w_{max} = \mathbf{0.016}$$

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force

$$V = \mathbf{15.2 \text{ kN/m}}$$

$$C_{Rd,c} = 0.18 / \gamma_c = \mathbf{0.120}$$

$$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = \mathbf{1.694}$$

Longitudinal reinforcement ratio

$$\rho_l = \min(A_{bb,prov} / d, 0.02) = \mathbf{0.004}$$

$$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5} = \mathbf{0.423 \text{ N/mm}^2}$$

Design shear resistance - exp.6.2a & 6.2b

$$V_{Rd,c} = \max(C_{Rd,c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$$

$$V_{Rd,c} = \mathbf{189.6 \text{ kN/m}}$$

$$V / V_{Rd,c} = \mathbf{0.080}$$

PASS - Design shear resistance exceeds design shear force

Check base design at heel

Depth of section

$$h = \mathbf{500 \text{ mm}}$$

Rectangular section in flexure - Section 6.1

Design bending moment combination 2

$$M = \mathbf{2.3 \text{ kNm/m}}$$

Depth to tension reinforcement

$$d = h - c_{bt} - \phi_{bt} / 2 = \mathbf{440 \text{ mm}}$$

$$K = M / (d^2 \times f_{ck}) = \mathbf{0.000}$$

$$K' = (2 \times \eta \times \alpha_{cc} / \gamma_c) \times (1 - \lambda \times (\delta - K_1) / (2 \times K_2)) \times (\lambda \times (\delta - K_1) / (2 \times K_2))$$

$$K' = \mathbf{0.207}$$

K' > K - No compression reinforcement is required

Lever arm

$$z = d \times \min(1 - 0.5 \times A_{sr2,prov} \times f_{yd} / (d \times f_d), 0.95) = \mathbf{376 \text{ mm}}$$

Depth of neutral axis

$$x = 2.5 \times (d - z) = \mathbf{161 \text{ mm}}$$

Area of tension reinforcement required

$$A_{bt,req} = M / (f_{yd} \times z) = \mathbf{14 \text{ mm}^2/\text{m}}$$

Tension reinforcement provided

$$20 \text{ dia. bars @ } 200 \text{ c/c}$$

Area of tension reinforcement provided

$$A_{bt,prov} = \pi \times \phi_{bt}^2 / (4 \times S_{bt}) = \mathbf{1571 \text{ mm}^2/\text{m}}$$

Minimum area of reinforcement - exp.9.1N

$$A_{bt,min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = \mathbf{663 \text{ mm}^2/\text{m}}$$

Maximum area of reinforcement - cl.9.2.1.1(3)

$$A_{bt,max} = 0.04 \times h = \mathbf{20000 \text{ mm}^2/\text{m}}$$

$$\max(A_{bt,req}, A_{bt,min}) / A_{bt,prov} = \mathbf{0.422}$$

PASS - Area of reinforcement provided is greater than area of reinforcement required

Library item: Rectangular single output

Crack control - Section 7.3

Limiting crack width

$$w_{max} = \mathbf{0.3 \text{ mm}}$$

Variable load factor - EN1990 – Table A1.1

$$\psi_2 = \mathbf{0.6}$$

Serviceability bending moment

$$M_{sls} = \mathbf{0.1 \text{ kNm/m}}$$

Tensile stress in reinforcement

$$\sigma_s = M_{sls} / (A_{bt,prov} \times z) = \mathbf{0.2 \text{ N/mm}^2}$$

Load duration

$$\text{Long term}$$

Load duration factor

$$k_t = \mathbf{0.4}$$

Effective area of concrete in tension

$$A_{c,eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$$

$$A_{c,eff} = \mathbf{112972 \text{ mm}^2/\text{m}}$$

Mean value of concrete tensile strength

$$f_{ct,eff} = f_{ctm} = \mathbf{2.9 \text{ N/mm}^2}$$

Reinforcement ratio

$$\rho_{p,eff} = A_{bt,prov} / A_{c,eff} = \mathbf{0.014}$$

Modular ratio

$$\alpha_e = E_s / E_{cm} = \mathbf{6.091}$$

Bond property coefficient

$$k_1 = \mathbf{0.8}$$

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Strain distribution coefficient

$$k_2 = 0.5$$

$$k_3 = 3.4$$

$$k_4 = 0.425$$

Maximum crack spacing - exp.7.11

$$s_{r,max} = k_3 * C_{bt} + k_1 * k_2 * k_4 * \phi_{bt} / \rho_{p,eff} = 415 \text{ mm}$$

Maximum crack width - exp.7.8

$$w_k = s_{r,max} * \max(\sigma_s - k_t * (f_{ct,eff} / \rho_{p,eff}) * (1 + \alpha_e * \rho_{p,eff}), 0.6 * \sigma_s) / E_s$$

$$w_k = 0 \text{ mm}$$

$$w_k / w_{max} = 0.001$$

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force

$$V = 5.3 \text{ kN/m}$$

$$C_{Rd,c} = 0.18 / \gamma_c = 0.120$$

$$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = 1.674$$

Longitudinal reinforcement ratio

$$\rho_l = \min(A_{bt,prov} / d, 0.02) = 0.004$$

$$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} * k^{3/2} * f_{ck}^{0.5} = 0.415 \text{ N/mm}^2$$

Design shear resistance - exp.6.2a & 6.2b

$$V_{Rd,c} = \max(C_{Rd,c} * k * (100 \text{ N}^2/\text{mm}^4 * \rho_l * f_{ck})^{1/3}, v_{min}) * d$$

$$V_{Rd,c} = 194.9 \text{ kN/m}$$

$$V / V_{Rd,c} = 0.027$$

PASS - Design shear resistance exceeds design shear force

Check key design

Depth of section

$$h = 500 \text{ mm}$$

Rectangular section in flexure - Section 6.1

Design bending moment combination 1

$$M = 1.8 \text{ kNm/m}$$

Depth to tension reinforcement

$$d = h - C_{bb} - \phi_k / 2 = 415 \text{ mm}$$

$$K = M / (d^2 * f_{ck}) = 0.000$$

$$K' = (2 * \eta * \alpha_{cc} / \gamma_c) * (1 - \lambda * (\delta - K_1) / (2 * K_2)) * (\lambda * (\delta - K_1) / (2 * K_2))$$

$$K' = 0.207$$

K' > K - No compression reinforcement is required

Lever arm

$$z = d * \min(1 - 0.5 * A_{sr2,prov} * f_{yd} / (d * f_d), 0.95) = 351 \text{ mm}$$

Depth of neutral axis

$$x = 2.5 * (d - z) = 161 \text{ mm}$$

Area of tension reinforcement required

$$A_{k,req} = M / (f_{yd} * z) = 12 \text{ mm}^2/\text{m}$$

Tension reinforcement provided

$$20 \text{ dia.bars @ } 200 \text{ c/c}$$

Area of tension reinforcement provided

$$A_{k,prov} = \pi * \phi_k^2 / (4 * s_k) = 1571 \text{ mm}^2/\text{m}$$

Minimum area of reinforcement - exp.9.1N

$$A_{k,min} = \max(0.26 * f_{ctm} / f_{yk}, 0.0013) * d = 625 \text{ mm}^2/\text{m}$$

Maximum area of reinforcement - cl.9.2.1.1(3)

$$A_{k,max} = 0.04 * h = 20000 \text{ mm}^2/\text{m}$$

$$\max(A_{k,req}, A_{k,min}) / A_{k,prov} = 0.398$$

PASS - Area of reinforcement provided is greater than area of reinforcement required

Library item: Rectangular single output

Crack control - Section 7.3

Limiting crack width

$$w_{max} = 0.3 \text{ mm}$$

Variable load factor - EN1990 – Table A1.1

$$\psi_2 = 0.6$$

Serviceability bending moment

$$M_{sls} = 1.8 \text{ kNm/m}$$

Tensile stress in reinforcement

$$\sigma_s = M_{sls} / (A_{k,prov} * z) = 3.2 \text{ N/mm}^2$$

Load duration

$$\text{Long term}$$

Load duration factor

$$k_t = 0.4$$

Effective area of concrete in tension

$$A_{c,eff} = \min(2.5 * (h - d), (h - x) / 3, h / 2)$$

$$A_{c,eff} = 112972 \text{ mm}^2/\text{m}$$

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Mean value of concrete tensile strength

$$f_{ct,eff} = f_{ctm} = \mathbf{2.9 \text{ N/mm}^2}$$

Reinforcement ratio

$$\rho_{p,eff} = A_{k,prov} / A_{c,eff} = \mathbf{0.014}$$

Modular ratio

$$\alpha_e = E_s / E_{cm} = \mathbf{6.091}$$

Bond property coefficient

$$k_1 = \mathbf{0.8}$$

Strain distribution coefficient

$$k_2 = \mathbf{0.5}$$

$$k_3 = \mathbf{3.4}$$

$$k_4 = \mathbf{0.425}$$

Maximum crack spacing - exp.7.11

$$s_{r,max} = k_3 * C_{bb} + k_1 * k_2 * k_4 * \phi_k / \rho_{p,eff} = \mathbf{500 \text{ mm}}$$

Maximum crack width - exp.7.8

$$w_k = s_{r,max} * \max(\sigma_s - k_t * (f_{ct,eff} / \rho_{p,eff}) * (1 + \alpha_e * \rho_{p,eff}), 0.6 * \sigma_s) / E_s$$

$$w_k = \mathbf{0.005 \text{ mm}}$$

$$w_k / w_{max} = \mathbf{0.016}$$

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force

$$V = \mathbf{9.4 \text{ kN/m}}$$

$$C_{Rd,c} = 0.18 / \gamma_c = \mathbf{0.120}$$

$$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = \mathbf{1.694}$$

Longitudinal reinforcement ratio

$$\rho_l = \min(A_{k,prov} / d, 0.02) = \mathbf{0.004}$$

$$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} * k^{3/2} * f_{ck}^{0.5} = \mathbf{0.423 \text{ N/mm}^2}$$

Design shear resistance - exp.6.2a & 6.2b

$$V_{Rd,c} = \max(C_{Rd,c} * k * (100 \text{ N}^2/\text{mm}^4 * \rho_l * f_{ck})^{1/3}, v_{min}) * d$$

$$V_{Rd,c} = \mathbf{189.6 \text{ kN/m}}$$

$$V / V_{Rd,c} = \mathbf{0.049}$$

PASS - Design shear resistance exceeds design shear force

Secondary transverse reinforcement to base - Section 9.3

Minimum area of reinforcement – cl.9.3.1.1(2)

$$A_{bx,req} = 0.2 * A_{bb,prov} = \mathbf{314 \text{ mm}^2/\text{m}}$$

Maximum spacing of reinforcement – cl.9.3.1.1(3)

$$s_{bx,max} = \mathbf{450 \text{ mm}}$$

Transverse reinforcement provided

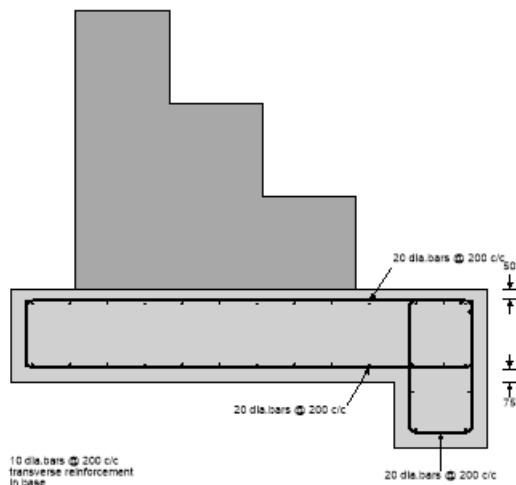
$$\mathbf{10 \text{ dia.bars @ } 200 \text{ c/c}}$$

Area of transverse reinforcement provided

$$A_{bx,prov} = \pi * \phi_{bx}^2 / (4 * s_{bx}) = \mathbf{393 \text{ mm}^2/\text{m}}$$

PASS - Area of reinforcement provided is greater than area of reinforcement required

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Reinforcement details

3. SPECIFICATIONS

Due to the wall's relatively small height an unreinforced masonry wall is proposed. As the wall retains sloping ground upwards from the rear of the wall it is proposed that the wall features a stepped rear face.

Please refer to APPENDIX A for retaining wall dimensions.

The wall stem should be constructed from 7N concrete blocks, laid flat.

The concrete base should be constructed from C30 Strength Concrete.

2 layers of A393 Mesh should be placed at the top of the foundation slab with 50mm of concrete cover.

2 layers of A393 Mesh should be placed at the bottom of the foundation slab with 50mm of concrete cover.

2 layers of A393 Mesh should be placed at the bottom of the foundation heel with 50mm of concrete cover.

Strength Class M4 mortar should be used in the construction of the walls.

Cement Sand mix ratio for M4 mortar follow:

i.e. Portland cement or Sulphate resisting Portland cement and lime, with or without air entraining additive.

1:1:5 to 6

Masonry cement containing Portland cement and lime in approx 1:1 ratio, and air entraining additive.

1:3 ½ :to 4

Masonry cement containing Portland cement (min 75%) and inorganic materials other than lime, and air entraining additive.

1:4 to 5

Portland cement or Sulphate resisting Portland cement and an air entraining additive.

1:5 to 6

Coarse gravel should be used at backfill to the walls, and slope at a forty-five degree angle against the ground behind them.

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.

100mm diameter plastic pipes should be placed at the bottom of the walls' stems 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.

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.

11 Bryn Llywellyn, Alltwen
February 2021

APPENDIX A

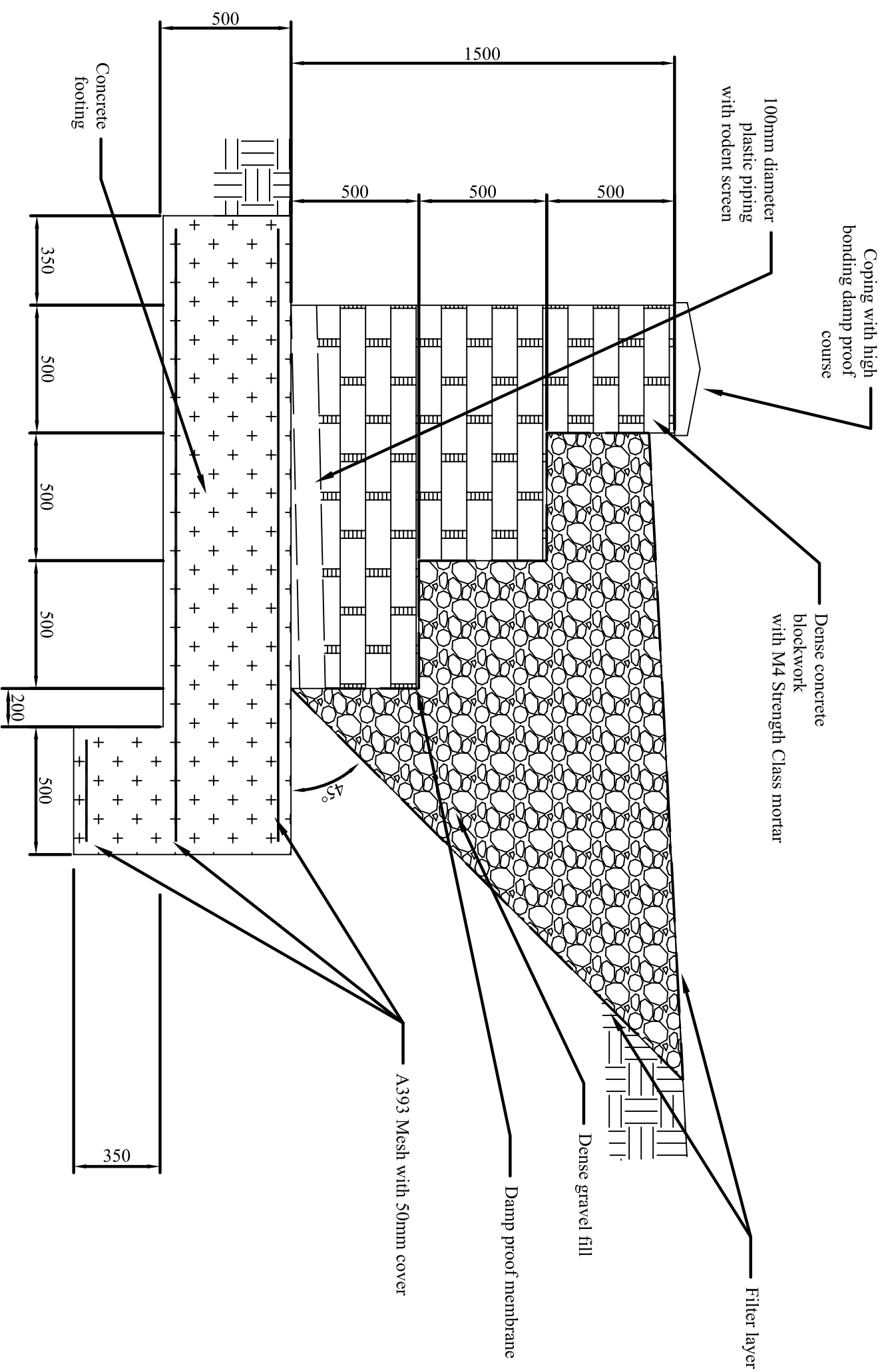
NOTES:

Drainage pipes to be spaced at 1.5m intervals along length of wall.

Expansion joints should be spaced at 6m intervals along length of wall.

Expansion joints to be filled with expansion joint filler and poly-sealant used on the exposed face of expansion joint.

Slip ties to be placed accross the expansion joints at each block layer.



CROSS SECTION

SCALE: 1:20

GRADE CONSULTING Ltd. Tel: 01554 707045 info@gradeconsulting.co.uk www.gradeconsulting.co.uk		
PROJECT: Proposed Retaining Wall, 11 Bryn Llywellyn, Alltwn		
TITLE: Retaining Wall Detail		
Drg No: GC-64-1	Drawn: IG Checked IG	Date: 02//02/2021