



AXIOM
Structural Design Ltd

STRUCTURAL DESIGN CALCULATIONS

Project: **RETAINING WALL AT 14 BEECHWOOD DRIVE, MERTHYR TYDFIL**
Job reference: **AX236**
Date: **December 2021**

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*The Institution
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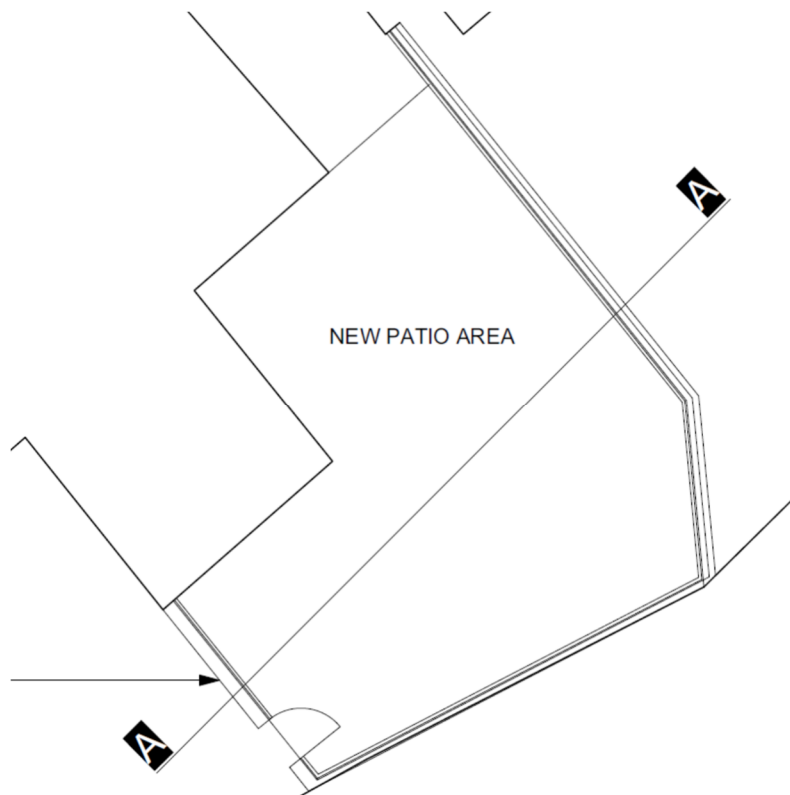
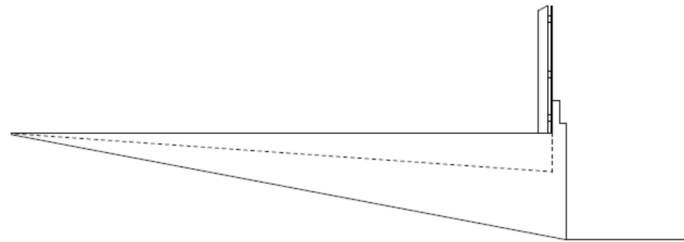


PROJECT NOTES

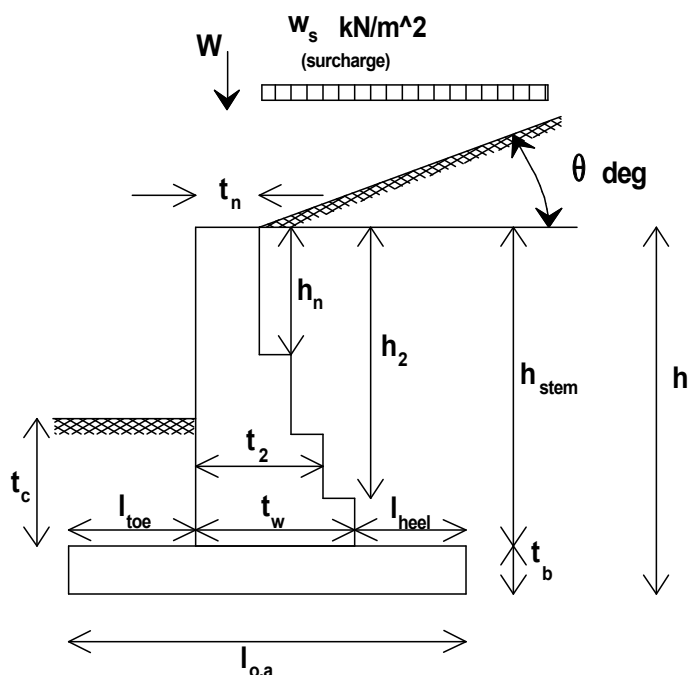
Brief

To provide a boundary retaining wall design for alterations to existing garden at 14 Beechwood Drive. The wall is to retain in approximatley 1.1m of loose fill, the land usage above is a residential garden therefore a surcharge load of 1.5kN/m^2 must be taken.

The wall is founded on firm clay and therefore a bearing capacity of 100kN/m^2 .



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CANTILEVER MASONRY RETAINING WALL DESIGN (BS8110&BS5628) MASONRY CANTILEVER RETAINING WALL DESIGN TO CP2 & BS5628 (PART 1)

RETAINING WALL PRESSURES - GRANULAR FILL - NO WALL FRICTION – ASSUMED FULLY DRAINED

General Soil Data

Density of retained soil	$\gamma_s = 18.0 \text{ kN/m}^3$
Angle of internal friction	$\phi = 28.0^\circ$
Angle of soil surface	$\theta = 0.0^\circ$
Ground cover over base at front of wall – if > 0mm, assumed permanent	$t_c = 200 \text{ mm}$

Loads on wall and ground

Surcharge load (horizontal plan area)	$w_s = 1.5 \text{ kN/m}^2$
Design vertical dead load on wall (unfactored)	$W_v = 0.00 \text{ kN/m}$
Design vertical live load on wall (unfactored)	$W_l = 0.00 \text{ kN/m}$

Stem details

Density of wall stem brickwork	$\gamma_w = 19.0 \text{ kN/m}^3$
Wall base section thickness	$t_w = 440.0 \text{ mm}$
Height retained	$h = 1200 \text{ mm}$

Base details

Density of wall base	$\gamma_b = 23.6 \text{ kN/m}^3$
Length of heel	$l_{heel} = 250 \text{ mm}$

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Length of toe $l_{toe} = 200$ mm

Base thickness $t_b = 200$ mm

Length of base $l_{o_a} = l_{toe} + t_w + l_{heel} = 890$ mm

Height of active soil (at back of stem and heel)

Height of wall stem $h_{stem} = h - t_b = 1000$ mm

$h_{soil} = h + l_{heel} \times \tan(\theta) = 1200$ mm

Load factors

Dead Load Factor $\gamma_{f_d} = 1.40$

Imposed Load Factor $\gamma_{f_i} = 1.60$

Coefficients using Rankine

Active coefficient (Sloping Surface) - no friction

$$k_{a_s} = (\cos(\theta) - \sqrt{((\cos(\theta))^2 - (\cos(\phi))^2)}) / (\cos(\theta) + \sqrt{((\cos(\theta))^2 - (\cos(\phi))^2)}) = 0.361$$

Active coefficient (level surface) $k_a = (1 - \sin(\phi)) / (1 + \sin(\phi)) = 0.361$

Passive coefficient (level surface) $k_p = (1 + \sin(\phi)) / (1 - \sin(\phi)) = 2.770$

At - rest coefficient $k_o = (1 - \sin(\phi)) = 0.531$

For a one metre width - (Horizontal Components - Active Earth Pressures)

At the virtual back of the wall (back of heel)

Surcharge

pressure $p_s = k_{a_s} \times w_s = 0.5$ kN/m²

force – horizontal $F_s = (p_s \times h_{soil}) \times (\cos(\theta))^2 = 0.6$ kN/m

overturning moment about toe $M_s = F_s \times h_{soil} / 2 = 0.4$ kNm/m

Backfill

pressure $p_a = k_{a_s} \times \gamma_s \times h_{soil} = 7.8$ kN/m²

force – horizontal $F_a = (p_a \times h_{soil} / 2) \times (\cos(\theta))^2 = 4.7$ kN/m

overturning moment about the toe $M_a = F_a \times h_{soil} / 3 = 1.9$ kNm/m

Total horizontal force (unfactored) $F_t = F_s + F_a = 5.3$ kN/m

Total horizontal force (factored) $F_{t_ult} = \gamma_{f_i} \times F_s + \gamma_{f_d} \times F_a = 7.6$ kN/m

Total overturning moment (unfactored) $M_t = M_s + M_a = 2.3$ kNm/m

Total overturning moment (factored) $M_{t_ult} = \gamma_{f_i} \times M_s + \gamma_{f_d} \times M_a = 3.2$ kNm/m

Average load factor $\gamma_{f_av} = M_{t_ult} / M_t = 1.43$

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STABILITY CHECKS

(Unfactored Loads - Active Soil Pressures)

1) SLIDING

Coefficient of friction $\mu = \tan(\phi) \times \text{factor} = \mathbf{0.452}$ factor = **0.85**

Passive pressures in front of wall

Top of base $pp_1 = k_p \times t_c \times \gamma_s = \mathbf{10.0}$ kN/m²

Underside of base $pp_2 = k_p \times (t_c + t_b) \times \gamma_s = \mathbf{19.9}$ kN/m²

Total resistance

Base $PP_{\text{base}} = (pp_1 + pp_2) \times t_b / 2 = \mathbf{3.0}$ kN/m

Passive resistance **Soil in front of wall assumed to resist sliding**

$P = PP_{\text{base}} \times \text{soil_resists} = \mathbf{3.0}$ kN/m

Factor of safety against sliding

Factor of safety required $FOS_{\text{reqd sliding}} = \mathbf{1.50}$

Length of heel provided $l_{\text{heel}} = \mathbf{250}$ mm

Conservatively, it is assumed that the surcharge load does not provide downward pressure on the heel in the sliding calculation.

$FOS_{\text{sliding}} = (((l_{\text{heel}} \times (\gamma_s \times (h_{\text{stem}} + l_{\text{heel}} \times \tan(\theta)/2) + \gamma_b \times t_b)) + l_{\text{toe}} \times \gamma_b \times t_b + W_v + (t_w \times (\gamma_w \times h_{\text{stem}} + \gamma_b \times t_b))) \times \mu) + P) / F_t$

$FOS_{\text{sliding}} = \mathbf{2.008}$

Factor of safety against sliding = 2.0 i.e. > 1.5 - OK

2) OVERTURNING

Factor of safety against overturning

Factor of safety required $FOS_{\text{reqd o_turn}} = \mathbf{1.50}$

Length of toe provided $l_{\text{toe}} = \mathbf{200}$ mm

Conservatively, it is assumed that the surcharge load does not provide downward pressure on the heel in the overturning calculation.

Taking Moments about front of the toe

$M_{r1} = (W_v + h_{\text{stem}} \times t_w \times \gamma_w) \times (l_{\text{toe}} + t_w / 2) = \mathbf{3.5}$ kNm/m

$M_{r2} = l_{\text{heel}} \times h_{\text{stem}} \times \gamma_s \times (l_{\text{toe}} + t_w + l_{\text{heel}} / 2) = \mathbf{3.4}$ kNm/m

$M_{r3} = (l_{\text{toe}} + t_w + l_{\text{heel}})^2 \times t_b \times \gamma_b / 2 = \mathbf{1.9}$ kNm/m

$M_{r4} = l_{\text{heel}} \times l_{\text{heel}} \times \tan(\theta) / 2 \times \gamma_s \times (l_{\text{toe}} + t_w + l_{\text{heel}} \times 2/3) = \mathbf{0.0}$ kNm/m

Resisting moment $M_r = M_{r1} + M_{r2} + M_{r3} + M_{r4} = \mathbf{8.8}$ kNm/m

Factor of safety against overturning $FOS_{\text{o_turn}} = M_r / \text{abs}(M_t) = \mathbf{3.90}$

Factor of safety against overturning = 3.9 i.e. > 1.5 - OK

Overall length of base $l_{\text{o_a}} = l_{\text{toe}} + t_w + l_{\text{heel}} = \mathbf{0.890}$ m

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3) BEARING PRESSURE (INCLUDING LIVE LOADS AND TOE COVER)

Total overturning moment for bearing calculation $M_t = 2.3 \text{ kNm/m}$

Total resisting moment for bearing calculation $M_r = 8.8 \text{ kNm/m}$

Total vertical load on base

$$N = t_w \times h_{\text{stem}} \times \gamma_w + (h_{\text{stem}} + l_{\text{heel}} \times \tan(\theta)/2) \times l_{\text{heel}} \times \gamma_s + t_c \times l_{\text{toe}} \times \gamma_s + l_{o_a} \times t_b \times \gamma_b + W_v + w_s \times l_{\text{heel}} + W_l$$

$$N = 18.2 \text{ kN/m}$$

Eccentricity of vertical load

$$e_1 = (M_r - \text{abs}(M_t) + t_c \times l_{\text{toe}}^2 \times \gamma_s/2 + w_s \times l_{\text{heel}} \times (l_{\text{toe}} + t_w + l_{\text{heel}}/2) + W_l \times (l_{\text{toe}} + t_w/2)) / N = 0.381 \text{ m}$$

$$e = l_{o_a} / 2 - e_1 = 0.064 \text{ m}$$

Resultant lies inside middle third

Maximum bearing pressure $p_{\text{max}} = \text{if}(\text{abs}(e) < (l_{o_a}/6), \sigma_{\text{max}2}, \sigma_{\text{max}1}) = 29.2 \text{ kN/m}^2$

Permissible bearing pressure $p_{\text{bearing}} = 100 \text{ kN/m}^2$

Maximum bearing pressure is 29 kN/m² i.e. < Allowable - OK

DESIGN BASE PRESSURES BASED UPON AT REST EARTH PRESSURES

For a one metre width - (Horizontal Components - At Rest Earth Pressures)

Surcharge

pressure $p_{so} = k_o \times w_s = 0.8 \text{ kN/m}^2$

force $F_{so} = p_{so} \times h = 1.0 \text{ kN/m}$

moment $M_{so} = F_{so} \times h / 2 = 0.6 \text{ kNm/m}$

Backfill

pressure $p_o = k_o \times \gamma_s \times h = 11.5 \text{ kN/m}^2$

force $F_o = p_o \times h / 2 = 6.9 \text{ kN/m}$

moment $M_o = F_o \times h / 3 = 2.8 \text{ kNm/m}$

Total horizontal force (unfactored) $F_{t_o} = F_{so} + F_o = 7.8 \text{ kN/m}$

Total horizontal force (factored) $F_{t_{ult_o}} = \gamma_{f_i} \times F_{so} + \gamma_{f_d} \times F_o = 11.2 \text{ kN/m}$

Total moment (unfactored) $M_{t_o} = M_{so} + M_o = 3.3 \text{ kNm/m}$

Total horizontal force (factored) $M_{t_{ult_o}} = \gamma_{f_i} \times M_{so} + \gamma_{f_d} \times M_o = 4.8 \text{ kNm/m}$

Average load factor $\gamma_{f_{av}} = M_{t_{ult_o}} / M_{t_o} = 1.43$

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Total vertical load on base

$$N = t_w \times h_{stem} \times \gamma_s + (h_{stem} + l_{heel} \times \tan(\theta) / 2) \times l_{heel} \times \gamma_s + t_c \times l_{toe} \times \gamma_s + l_{o_a} \times t_b \times \gamma_b + W_v + W_s \times l_{heel} + W_i$$

$$N = 18.2 \text{ kN/m}$$

Total resistance moment (no live loads included or toe cover)

$$M_r = 8.823 \text{ kNm/m}$$

Eccentricity of vertical load

$$e_1 = (M_r - M_{t_o} + t_c \times l_{toe}^2 \times \gamma_s / 2 + W_s \times l_{heel} \times (l_{toe} + t_w + l_{heel} / 2) + W_i \times (l_{toe} + t_w / 2)) / N = 0.323 \text{ m}$$

$$e = l_{o_a} / 2 - e_1 = 0.122 \text{ m}$$

Resultant lies inside middle third

1) Resultant outside middle third **This Section is Invalid as Resultant is within Middle Third**

$$\sigma_{max1} = (2 \times N) / (3 \times (l_{o_a} / 2 - \text{abs}(e))) = 38 \text{ kN/m}^2$$

$$l_{b1} = (N \times 2 / \sigma_{max1}) = 0.968 \text{ m}$$

2) Resultant inside middle third

$$\sigma_{max2} = N / l_{o_a} + 6 \times N \times \text{abs}(e) / l_{o_a}^2 = 37 \text{ kN/m}^2$$

$$\sigma_{min2} = N / l_{o_a} - 6 \times N \times \text{abs}(e) / l_{o_a}^2 = 4 \text{ kN/m}^2$$

$$l_{b2} = l_{o_a} = 0.890 \text{ m}$$

Pressures under the base

$$\sigma_{max} = \text{if}(\text{abs}(e) < l_{o_a} / 6, \sigma_{max2}, \sigma_{max1}) = 37.2 \text{ kN/m}^2$$

$$\sigma_{min} = \text{if}(\text{abs}(e) < l_{o_a} / 6, \sigma_{min2}, 0 \text{ kN/m}^2) = 3.6 \text{ kN/m}^2$$

$$\text{Bearing length } l_p = \text{if}(\text{abs}(e) < (l_{o_a} / 6), l_{b2}, l_{b1}) = 0.890 \text{ m}$$

Pressures under the heel/stem interface

$$l_{p_heel} = l_p - l_{toe} - t_w = 0.250 \text{ m}$$

$$\sigma_{heel} = \max(((\sigma_{max} - \sigma_{min}) \times l_{p_heel} / l_p) + \sigma_{min}, 0 \text{ kN/m}^2) = 13.0 \text{ kN/m}^2$$

Pressures under the toe/stem interface

$$\sigma_{toe} = ((\sigma_{max} - \sigma_{min}) \times (l_{p_heel} + t_w) / l_p) + \sigma_{min} = 29.7 \text{ kN/m}^2$$

BASE DESIGN - HEEL

Shears and Moments

$$\text{Vertical load downward } W_{ult_heel} = (h_{stem} \times \gamma_s + \gamma_b \times t_b) \times \gamma_{f_d} + W_s \times \gamma_{f_i} = 34.2 \text{ kN/m}^2$$

$$W_{ult_heel1} = (l_{heel} \times \tan(\theta) / 2 \times \gamma_s) \times \gamma_{f_d} = 0.0 \text{ kN/m}^2$$

Ultimate Shear (at wall face)

$$\text{downward } V_{ult_pos_heel} = (W_{ult_heel} + W_{ult_heel1}) \times l_{heel} = 8.6 \text{ kN/m}$$

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upward

$$V_{ult_neg_heel} = (\sigma_{min} \times \max(l_{p_heel}, 0 \text{ mm}) + (\sigma_{heel} - \sigma_{min}) \times (\max(l_{p_heel}, 0 \text{ mm}))^2 / (2 \times l_{p_heel})) \times \gamma_{f_av}$$

$$V_{ult_neg_heel} = \mathbf{3.0 \text{ kN/m}}$$

Nett Ultimate Shear

$$V_{ult_heel} = \text{abs}(V_{ult_pos_heel} - V_{ult_neg_heel}) = \mathbf{5.6 \text{ kN/m}}$$

Ultimate Moment (at centre of wall)

$$\text{clockwise } M_{ult_pos_heel} = W_{ult_heel} \times l_{heel} \times (l_{heel} + t_w) / 2 + W_{ult_heel1} \times l_{heel} \times (2 \times l_{heel} / 3 + t_w / 2) = \mathbf{3.0 \text{ kNm/m}}$$

anticlockwise

$$M_{ult_neg_heel} = ((\sigma_{min} \times l_{p_heel} \times (l_{p_heel} + t_w) / 2) + (\sigma_{heel} - \sigma_{min}) / 2 \times l_{p_heel} \times (l_{p_heel} / 3 + t_w / 2)) \times \gamma_{f_av}$$

$$M_{ult_neg_heel} = \mathbf{1.0 \text{ kNm/m}}$$

Nett Ultimate Moment

$$M_{ult_heel} = \text{abs}(M_{ult_pos_heel} - M_{ult_neg_heel}) = \mathbf{2.0 \text{ kNm/m}}$$

HEEL REINFORCEMENT - MESH

Tension Reinforcement

Cover to bars in the top of the heel

$$C_{r_heel} = \mathbf{35 \text{ mm}}$$

Effective depth to bars

$$d_{heel} = t_b - C_{r_heel} - (6 \text{ mm}) = \mathbf{159 \text{ mm}}$$

Assume the base is a cantilevered slab

Characteristic strength of reinforcement

$$f_y = \mathbf{460 \text{ N/mm}^2}$$

Characteristic strength of concrete

$$f_{cu} = \mathbf{35 \text{ N/mm}^2}$$

Area of reinforcement required

$$K_{heel} = \text{abs}(M_{ult_heel}) / (d_{heel}^2 \times f_{cu}) = \mathbf{0.002} \quad K' = 0.156$$

Compression steel not required

Lever arm

$$Z_{heel} = \min((0.95 \times d_{heel}), (d_{heel} \times (0.5 + \sqrt{(0.25 - K_{heel} / 0.9)}))) = \mathbf{151 \text{ mm}}$$

Reinforcement required

$$A_{s_heel} = \text{abs}(M_{ult_heel}) / (1/\gamma_{ms} \times f_y \times Z_{heel}) = \mathbf{30 \text{ mm}^2/\text{m}}$$

Minimum reinforcement $A_{s_min_heel} = \text{if}(f_y == 460 \text{ N/mm}^2, 0.0013 \times t_b, 0.0024 \times t_b) = \mathbf{260 \text{ mm}^2/\text{m}}$

$$A_{s_req_heel} = \max(A_{s_heel}, A_{s_min_heel}) = \mathbf{260 \text{ mm}^2/\text{m}}$$

Tension steel provided

$$\text{Use A393 Mesh } A_{s_prov_heel} = A_{sl_heel} = \mathbf{393 \text{ mm}^2/\text{m}}$$

Area of main tension steel provided in heel sufficient

Heel - Check min and max areas of steel

Total area of concrete

$$A_c = t_b = \mathbf{200000 \text{ mm}^2/\text{m}}$$

Minimum percentage area of reinforcement $k = \mathbf{0.13 \%}$

Minimum area of steel required

$$A_{s_min} = k \times A_c = \mathbf{260 \text{ mm}^2/\text{m}}$$

Maximum area of steel allowed

$$A_{s_max} = 4 \% \times A_c = \mathbf{8000 \text{ mm}^2/\text{m}}$$

Area of main steel provided OK

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Heel Distribution Steel

Minimum percentage of distribution reinforcement $k_1 = 0.13 \%$

Minimum Area Required $A_{s_dist_req} = k_1 \times A_c = 260 \text{ mm}^2/\text{m}$

Area Provided $A_{s_dist_base} = A_{st_heel} = 393 \text{ mm}^2/\text{m}$

Area of distribution steel provided OK

CHECK OF NOMINAL COVER

Cover to outer tension reinforcement

$$C_{heel} = t_b - d_{heel} - d_{sl_heel} / 2 = 36.0 \text{ mm}$$

Permissible minimum nominal cover to all reinforcement (Table 3.4)

$$C_{min_heel} = 35 \text{ mm}$$

Cover over outer steel OK (top of heel)

HEEL SHEAR RESISTANCE – AT WALL FACE

Applied shear stress at wall face

$$V_{heel} = V_{ult_heel} / d_{heel} = 0.04 \text{ N/mm}^2$$

Check shear stress to clause 3.4.5.2 (BS8110:Pt 1)

$$V_{allowable} = \min ((0.8 \text{ N}^{1/2}/\text{mm}) \times \sqrt{f_{cu}}, 5 \text{ N/mm}^2) = 4.73 \text{ N/mm}^2$$

Shear stress < maximum - OK

Shear stresses to clause 3.4.5.4 (BS8110:Pt1)

Allowable shear stress

$$V_{c_heel} = 0.56 \text{ N/mm}^2$$

No shear reinforcement required

BASE DESIGN - TOE

Shears and Moments

Conservatively all soil overburden on the toe is ignored

Ultimate Shear (conservatively - at face of wall)

$$V_{ult_toe} = ((\sigma_{toe} \times l_{toe}) + (((\sigma_{max} - \sigma_{toe}) / 2) \times l_{toe})) \times \gamma_{f_av} - l_{toe} \times t_b \times \gamma_b \times \gamma_{f_d} = 8.3 \text{ kN/m}$$

Ultimate Moment (at centre of wall)

$$M_{ult_toe} = ((\sigma_{toe} \times l_{toe} \times (l_{toe} + t_w)/2) + ((\sigma_{max} - \sigma_{toe}) / 2 \times l_{toe} \times (2 \times l_{toe}/3 + t_w/2))) \times \gamma_{f_av} - l_{toe} \times t_b \times \gamma_b \times \gamma_{f_d} \times (l_{toe}/2 + t_w/2)$$

$$M_{ult_toe} = 2.7 \text{ kNm/m}$$

TOE REINFORCEMENT - MESH

Tension Reinforcement

Cover to bars in the bottom of the toe $C_{r_toe} = 35 \text{ mm}$

Effective depth to bars $d_{toe} = t_b - C_{r_toe} - (6\text{mm}) = 159 \text{ mm}$

Assume the base is a cantilevered slab

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Characteristic strength of reinforcement $f_y = 460 \text{ N/mm}^2$

Characteristic strength of concrete $f_{cu} = 35 \text{ N/mm}^2$

Area of reinforcement required

$$K_{toe} = \text{abs}(M_{ult_toe}) / (d_{toe}^2 \times f_{cu}) = 0.003 \quad K' = 0.156$$

Compression steel not required

Lever arm $z_{toe} = \min((0.95 \times d_{toe}), (d_{toe} \times (0.5 + \sqrt{(0.25 - K_{toe}/0.9)}))) = 151 \text{ mm}$

Reinforcement required $A_{s_toe} = \text{abs}(M_{ult_toe}) / (1/\gamma_{ms} \times f_y \times z_{toe}) = 41 \text{ mm}^2/\text{m}$

Minimum reinforcement $A_{s_min_toe} = \text{if}(f_y == 460 \text{ N/mm}^2, 0.0013 \times t_b, 0.0024 \times t_b) = 260 \text{ mm}^2/\text{m}$

$A_{s_req_toe} = \max(A_{s_toe}, A_{s_min_toe}) = 260 \text{ mm}^2/\text{m}$

Tension steel provided

Use A393 Mesh $A_{s_prov_toe} = A_{st_toe} = 393 \text{ mm}^2/\text{m}$

Area of main tension steel provided in toe sufficient

Toe - Check min and max areas of steel

Total area of concrete $A_c = t_b = 200000 \text{ mm}^2/\text{m}$

Minimum percentage area of reinforcement $k = 0.13 \%$

Minimum area of steel required $A_{s_min} = k \times A_c = 260 \text{ mm}^2/\text{m}$

Maximum area of steel allowed $A_{s_max} = 4 \% \times A_c = 8000 \text{ mm}^2/\text{m}$

Area of main steel provided OK

Toe Distribution Steel

Minimum percentage of distribution reinforcement $k_1 = 0.13 \%$

Minimum Area Required $A_{s_dist_req} = k_1 \times A_c = 260 \text{ mm}^2/\text{m}$

Area Provided $A_{s_dist_base} = A_{st_toe} = 393 \text{ mm}^2/\text{m}$

Area of distribution steel provided OK

CHECK OF NOMINAL COVER

Cover to outer tension reinforcement

$$c_{toe} = t_b - d_{toe} - d_{sl_toe} / 2 = 36.0 \text{ mm}$$

Permissible minimum nominal cover to all reinforcement (Table 3.4)

$$c_{min_toe} = 35 \text{ mm}$$

Cover over outer steel OK (bottom of toe)

TOE SHEAR RESISTANCE

Applied shear stress

$$V_{toe} = V_{ult_toe} / d_{toe} = 0.05 \text{ N/mm}^2$$

Check shear stress to clause 3.4.5.2 (BS8110:Pt 1)

$$V_{allowable} = \min((0.8 \text{ N}^{1/2}/\text{mm}) \times \sqrt{f_{cu}}, 5 \text{ N/mm}^2) = 4.73 \text{ N/mm}^2$$

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Shear stress < maximum - OK

Shear stresses to clause 3.4.5.4 (BS8110:Pt 1)

Allowable shear stress

$$V_{c_toe} = 0.56 \text{ N/mm}^2$$

No shear reinforcement required

STEM DESIGN

Width of base of wall $t_w = 440.0 \text{ mm}$

Height of stem of wall $h_{stem} = 1000 \text{ mm}$

DESIGN OF WALL SECTION 1 (AT REST PRESSURES)

Wall base section thickness $t_w = 440.0 \text{ mm}$

Depth from top of wall to base

$h_{stem} = 1000 \text{ mm}$ **Warning the height of the wall is not a complete number of bricks**

Applied moment at base of section

$$M_{base} = (k_o \times w_s \times h_{stem}^2 / 2) \times \gamma_{f_i} + (k_o \times \gamma_s \times h_{stem}^3 / 6) \times \gamma_{f_d} = 2.9 \text{ kNm/m}$$

Applied shear force at base of section

$$F_{base} = (k_o \times w_s \times h_{stem}) \times \gamma_{f_i} + (k_o \times \gamma_s \times h_{stem}^2 / 2) \times \gamma_{f_d} = 8.0 \text{ kN/m}$$

CHECK RESISTANCE TO MOMENT WITH FLEXURAL STRENGTH (BS5628:PT 1:CL 36.5.3)

Flexural strength ($\parallel$ to bed joints)(Table 3) $f_{kx} = 0.38 \text{ N/mm}^2$

Design dead load at the base of the wall $V_{base} = W_v + t_w \times h_{stem} \times \gamma_w = 8.36 \text{ kN/m}$

Dead load per unit area $g_{d_base} = V_{base} \times \gamma_{fd} / t_w = 0.02 \text{ N/mm}^2$

Section modulus $Z_{base} = t_w^2 / 6 = 32.27 \times 10^6 \text{ mm}^3/\text{m}$

Restoring moment $M_{R_base} = (f_{kx} / \gamma_m + g_{d_base}) \times Z_{base} = 4.1 \text{ kNm/m}$

Wall bending - OK

STEM SHEAR (BS5628:PT 1:CL 33)

Mortar designation Mortar = "iii"

Design dead load at the base of the wall $V_{base} = W_v + t_w \times h_{stem} \times \gamma_w = 8.36 \text{ kN/m}$

Design vertical dead load per unit area $g_{A_base} = V_{base} \times \gamma_{fd} / t_w = 0.02 \text{ N/mm}^2$

Characteristic shear strength of masonry

$$f_{v_i} = \min(1.75 \text{ N/mm}^2, 0.35 \text{ N/mm}^2 + (0.6 \times g_{A_base})) = 0.36 \text{ N/mm}^2$$

$$f_{v_iii} = \min(1.4 \text{ N/mm}^2, 0.15 \text{ N/mm}^2 + (0.6 \times g_{A_base})) = 0.16 \text{ N/mm}^2$$

$$f_v = \text{if}((\text{Mortar} == \text{"i"}) || (\text{Mortar} == \text{"ii"}), f_{v_i}, f_{v_iii}) = 0.16 \text{ N/mm}^2$$

Ref BS 5628 Pt 1: Clause 25

Shear stress $V_{base} = F_{base} / t_w = 0.02 \text{ N/mm}^2$

Partial safety factor for shear $\gamma_{mv} = 2.5$

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Wall base shear OK

DESIGN OF WALL SECTION 2 (AT REST PRESSURES)

Wall section thickness $t_{wall_2} = 215.0$ mm

Depth from top of wall to base of section

$h_{wall_2} = 440$ mm **Warning the height of the section is not a complete number of bricks**

Applied moment at base of section

$$M_{wall_2} = (k_o \times w_s \times h_{wall_2}^2 / 2) \times \gamma_{f_i} + (k_o \times \gamma_s \times h_{wall_2}^3 / 6) \times \gamma_{f_d} = 0.3 \text{ kNm/m}$$

Applied shear force at base of section

$$F_{wall_2} = (k_o \times w_s \times h_{wall_2}) \times \gamma_{f_i} + (k_o \times \gamma_s \times h_{wall_2}^2 / 2) \times \gamma_{f_d} = 1.9 \text{ kN/m}$$

CHECK RESISTANCE TO MOMENT WITH FLEXURAL STRENGTH (BS5628:PT 1:CL 36.5.3)

Flexural strength (|| to bed joints)(Table 3) $f_{kx} = 0.38$ N/mm²

Design dead load at the base of the wall $V_{wall_2} = W_v + t_{wall_2} \times h_{wall_2} \times \gamma_w = 1.80$ kN/m

Dead load per unit area $g_{d_wall_2} = V_{wall_2} \times \gamma_{fd} / t_{wall_2} = 0.01$ N/mm²

Section modulus $Z_{wall_2} = t_{wall_2}^2 / 6 = 7.704 \times 10^6$ mm³/m

Restoring moment $M_{R_wall_2} = (f_{kx} / \gamma_m + g_{d_wall_2}) \times Z_{wall_2} = 0.9$ kNm/m

Wall bending - OK

STEM SHEAR (BS5628:PT 1:CL 33)

Mortar designation Mortar = "iii"

Design dead load at the base of the wall $V_{wall_2} = W_v + t_{wall_2} \times h_{wall_2} \times \gamma_w = 1.80$ kN/m

Design vertical dead load per unit area $g_{A_wall_2} = V_{wall_2} \times \gamma_{fd} / t_{wall_2} = 0.01$ N/mm²

Characteristic shear strength of masonry

$$f_{v_i} = \min(1.75 \text{ N/mm}^2, 0.35 \text{ N/mm}^2 + (0.6 \times g_{A_wall_2})) = 0.35 \text{ N/mm}^2$$

$$f_{v_iii} = \min(1.4 \text{ N/mm}^2, 0.15 \text{ N/mm}^2 + (0.6 \times g_{A_wall_2})) = 0.15 \text{ N/mm}^2$$

$$f_v = \text{if}((\text{Mortar} == "i")) | ((\text{Mortar} == "ii"), f_{v_i}, f_{v_iii}) = 0.15 \text{ N/mm}^2$$

Ref BS 5628 Pt 1: Clause 25

Shear stress $v_{wall_2} = F_{wall_2} / t_{wall_2} = 0.01$ N/mm²

Partial safety factor for shear $\gamma_{mv} = 2.5$

Wall section base shear OK

SUMMARY OF RESULTS

Wall Dimensions

Masonry Flexural Strength **Masonry Flexural Strength - 0.4 N/mm²**

Stem Base section **440mm thick and 1000mm from base to the top of the wall**

Section 2 **215mm thick and 440mm from base of section 2 to the top of the wall**

Base Top Reinforcement - Mesh

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Heel (Top) Reinforcement

Provide A393 Mesh (Top)

Base Bottom Reinforcement - Mesh

Toe (Bottom) Reinforcement

Provide A393 Mesh (Bottom)