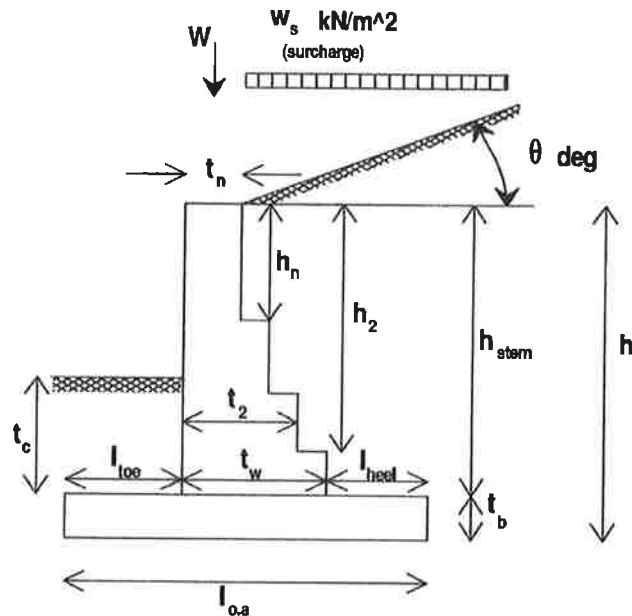


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CANTILEVER MASONRY RETAINING WALL DESIGN (BS8110&BS5628); MASONRY CANTILEVER RETAINING WALL DESIGN TO CP2 & BS5628 (PART 1)

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; $\phi = 35.0^\circ$
- ; 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; $t_w = 700.0 \text{ mm}$
- ; Height retained; $h = 1700 \text{ mm}$

Base details

- ; Density of wall base; $\gamma_b = 23.6 \text{ kN/m}^3$
- ; Length of heel; $l_{\text{heel}} = 25 \text{ mm}$
- ; Length of toe; $l_{\text{toe}} = 25 \text{ mm}$
- ; Base thickness; $t_b = 300 \text{ mm}$
- ; Length of base; $l_{o.a} = l_{\text{toe}} + t_w + l_{\text{heel}} = 750 \text{ mm}$

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

Height of wall stem;

$$h_{\text{stem}} = h - t_b = 1400 \text{ mm}$$

$$h_{\text{soil}} = h + h_{\text{heel}} \times \tan(\theta) = 1700 \text{ mm}$$

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

$$k_{a,s} = (\cos(\theta) - \sqrt{((\cos(\theta))^2 - (\cos(\phi))^2)}) / (\cos(\theta) + \sqrt{((\cos(\theta))^2 - (\cos(\phi))^2)}) = 0.271$$

Active coefficient (level surface);

$$k_a = (1 - \sin(\phi)) / (1 + \sin(\phi)) = 0.271$$

Passive coefficient (level surface);

$$k_p = (1 + \sin(\phi)) / (1 - \sin(\phi)) = 3.690$$

At - rest coefficient;

$$k_o = (1 - \sin(\phi)) = 0.426$$

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

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

Surcharge

pressure;

$$p_s = k_{a,s} \times w_s = 0.4 \text{ kN/m}^2$$

force – horizontal;

$$F_s = (p_s \times h_{\text{soil}}) \times (\cos(\theta))^2 = 0.7 \text{ kN/m}$$

overturning moment about toe; $M_s = F_s \times h_{\text{soil}} / 2 = 0.6 \text{ kNm/m}$

Backfill

pressure;

$$p_a = k_{a,s} \times \gamma_s \times h_{\text{soil}} = 8.3 \text{ kN/m}^2$$

force – horizontal;

$$F_a = (p_a \times h_{\text{soil}} / 2) \times (\cos(\theta))^2 = 7.0 \text{ kN/m}$$

overturning moment about the toe;

$$M_a = F_a \times h_{\text{soil}} / 3 = 4.0 \text{ kNm/m}$$

Total horizontal force (unfactored);

$$F_t = F_s + F_a = 7.7 \text{ kN/m}$$

Total horizontal force (factored);

$$F_{t,ult} = \gamma_{f,i} \times F_s + \gamma_{f,d} \times F_a = 11.0 \text{ kN/m}$$

Total overturning moment (unfactored);

$$M_t = M_s + M_a = 4.6 \text{ kNm/m}$$

Total overturning moment (factored);

$$M_{t,ult} = \gamma_{f,i} \times M_s + \gamma_{f,d} \times M_a = 6.5 \text{ kNm/m}$$

Average load factor;

$$\gamma_{f,av} = M_{t,ult} / M_t = 1.43$$

STABILITY CHECKS

(Unfactored Loads - Active Soil Pressures)

1) SLIDING

; Coefficient of friction;

$$\mu = \tan(\phi) \times \text{factor} = 0.525 ; \text{factor} = 0.75$$

Passive pressures in front of wall

Top of base;

$$pp_1 = k_p \times t_c \times \gamma_s = 13.3 \text{ kN/m}^2$$

Underside of base;

$$pp_2 = k_p \times (t_c + t_b) \times \gamma_s = 33.2 \text{ kN/m}^2$$

Total resistance

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Base; $PP_{base} = (pp_1 + pp_2) \times t_b / 2 = 7.0 \text{ kN/m}$

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

$P = PP_{base} \times \text{soil_resists} = 7.0 \text{ kN/m}$

Factor of safety against sliding

; Factor of safety required; $FOS_{reqd_{sliding}} = 2.00$

Length of heel provided; $l_{heel} = 25 \text{ mm}$

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

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

$FOS_{sliding} = 2.568$

Factor of safety against sliding = 2.6 i.e. > 2.0 - OK

2) OVERTURNING

Factor of safety against overturning

; Factor of safety required; $FOS_{reqd_{o_{um}}} = 2.00$

Length of toe provided; $l_{toe} = 25 \text{ mm}$

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

$$M_{r1} = (W_v + h_{stem} \times t_w \times \gamma_w) \times (l_{toe} + t_w / 2) = 7.0 \text{ kNm/m}$$

$$M_{r2} = l_{heel} \times h_{stem} \times \gamma_s \times (l_{toe} + t_w + l_{heel} / 2) = 0.5 \text{ kNm/m}$$

$$M_{r3} = (l_{toe} + t_w + l_{heel})^2 \times t_b \times \gamma_b / 2 = 2.0 \text{ kNm/m}$$

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

Resisting moment; $M_r = M_{r1} + M_{r2} + M_{r3} + M_{r4} = 9.4 \text{ kNm/m}$

Factor of safety against overturning ; $FOS_{o_{um}} = M_r / \text{abs}(M_i) = 2.06$

Factor of safety against overturning = 2.1 i.e. > 2.0 - OK

Overall length of base; $l_{o_a} = l_{toe} + t_w + l_{heel} = 0.750 \text{ m}$

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

Total overturning moment for bearing calculation; $M_i = 4.6 \text{ kNm/m}$

Total resisting moment for bearing calculation; $M_r = 9.4 \text{ kNm/m}$

Total vertical load on base

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

$N = 24.7 \text{ kN/m}$

Eccentricity of vertical load

$$e_1 = (M_r - \text{abs}(M_i) + t_c \times l_{toe}^2 \times \gamma_s / 2 + W_s \times l_{heel} \times (l_{toe} + t_w + l_{heel} / 2) + W_i \times (l_{toe} + t_w / 2)) / N = 0.198 \text{ m}$$

$e = l_{o_a} / 2 - e_1 = 0.177 \text{ m}$

Resultant lies outside middle third;

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Maximum bearing pressure; $p_{max} = \text{if}(\text{abs}(e) < (I_{o_a} / 6), \sigma_{max2}, \sigma_{max1}) = 83.2 \text{ kN/m}^2$

; Permissible bearing pressure; $p_{bearing} = 150 \text{ kN/m}^2$

Maximum bearing pressure is 83 kN/m² i.e. < Allowable - OK

STEM DESIGN

Width of base of wall;

$$t_w = 700.0 \text{ mm}$$

Height of stem of wall;

$$h_{stem} = 1400 \text{ mm}$$

DESIGN OF BASE WALL SECTION (ACTIVE PRESSURES)

; Wall base section thickness; $t_w = 700.0 \text{ mm}$

Depth from top of wall to base

; $h_{stem} = 1400 \text{ mm}$; **Warning the height of the wall is not a complete number of bricks**

Applied moment at base of wall

$$M_{base} = (k_{a_s} \times (\cos(\theta))^2 \times w_s \times h_{stem}^2 / 2) \times \gamma_{f_d} + (k_{a_s} \times (\cos(\theta))^2 \times \gamma_s \times h_{stem}^3 / 6) \times \gamma_{f_d} = 3.8 \text{ kNm/m}$$

Applied shear force at base of wall

$$F_{base} = (k_{a_s} \times (\cos(\theta))^2 \times w_s \times h_{stem}) \times \gamma_{f_d} + (k_{a_s} \times (\cos(\theta))^2 \times \gamma_s \times h_{stem}^2 / 2) \times \gamma_{f_d} = 7.6 \text{ kN/m}$$

CHECK RESISTANCE TO MOMENT WITHOUT FLEXURAL STRENGTH (BS5628:PT 1:CL 36.5.3)

; Compressive strength (Table 2); $f_k = 6.40 \text{ N/mm}^2$

; Design vertical load per unit length of wall; $n_{w_base} = \gamma_{f_d} \times (W_v + t_w \times h_{stem} \times \gamma_w) = 16.8 \text{ kN/m}$

; Moment of resistance; $M_{RC_base} = (n_{w_base} / 2) \times (t_w - (n_{w_base} \times \gamma_m / f_k)) = 5.8 \text{ kNm/m}$

Wall bending - OK

STEM SHEAR (BS5628:PT 1:CL 33)

; Mortar designation; Mortar = "iii"

Design dead load at the base of the wall; $V_{base} = W_v + t_w \times h_{stem} \times \gamma_w = 18.62 \text{ kN/m}$

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

Characteristic shear strength of masonry

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

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

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

Ref BS 5628 Pt 1: Clause 25

Shear stress;

$$v_{base} = F_{base} / t_w = 0.01 \text{ N/mm}^2$$

; Partial safety factor for shear;

$$\gamma_{mv} = 2.5$$

Wall base shear OK

DESIGN OF WALL SECTION 2 (ACTIVE PRESSURES)

; Wall section thickness; $t_{wall_2} = 552.5 \text{ mm}$

Depth from top of wall to base of section

; $h_{wall_2} = 900 \text{ mm}$;

Applied moment at base of section

$$M_{wall_2} = (k_{a_s} \times (\cos(\theta))^2 \times w_s \times h_{wall_2}^2 / 2) \times \gamma_{f_d} + (k_{a_s} \times (\cos(\theta))^2 \times \gamma_s \times h_{wall_2}^3 / 6) \times \gamma_{f_d} = 1.1 \text{ kNm/m}$$

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Applied shear force at base of section

$$F_{wall_2} = (k_{a_s} \times (\cos(\theta))^2 \times W_s \times h_{wall_2}) \times \gamma_{f_1} + (k_{a_s} \times (\cos(\theta))^2 \times \gamma_s \times h_{wall_2}^2 / 2) \times \gamma_{f_d} = 3.4 \text{ kN/m}$$

CHECK RESISTANCE TO MOMENT WITHOUT FLEXURAL STRENGTH (BS5628:PT 1:CL 36.5.3)

; Compressive strength (Table 2); $f_k = 6.40 \text{ N/mm}^2$

; Design vertical load per unit length of wall; $n_{w_wall_2} = \gamma_{fd} \times (W_v + t_{wall_2} \times h_{wall_2} \times \gamma_w) = 8.5 \text{ kN/m}$

; Moment of resistance; $M_{RC_wall_2} = (n_{w_wall_2} / 2) \times (t_{wall_2} - (n_{w_wall_2} \times \gamma_m / f_k)) = 2.3 \text{ kNm/m}$

Wall bending - OK

STEM SHEAR (BS5628:PT 1:CL 33)

; Mortar designation; Mortar = "iii"

Design dead load at the base of the wall; $V_{wall_2} = W_v + t_{wall_2} \times h_{wall_2} \times \gamma_w = 9.45 \text{ kN/m}$

g_{A_wall_2} = V_{wall_2} \times \gamma_{fd} / t_{wall_2} = 0.02 \text{ N/mm}^2

Characteristic shear strength of masonry

$$f_{v_1} = \min(1.75 \text{ N/mm}^2, 0.35 \text{ N/mm}^2 + (0.6 \times g_{A_wall_2})) = 0.36 \text{ N/mm}^2$$

$$f_{v_iii} = \min(1.4 \text{ N/mm}^2, 0.15 \text{ N/mm}^2 + (0.6 \times g_{A_wall_2})) = 0.16 \text{ N/mm}^2$$

$$f_v = \text{if}((\text{Mortar} == "i")) | (\text{Mortar} == "ii"), f_{v_1}, f_{v_iii} = 0.16 \text{ N/mm}^2$$

Ref BS 5628 Pt 1: Clause 25

Shear stress;

$$v_{wall_2} = F_{wall_2} / t_{wall_2} = 0.01 \text{ N/mm}^2$$

; Partial safety factor for shear;

$$\gamma_{mv} = 2.5$$

Wall section base shear OK

SUMMARY OF RESULTS

Wall Dimensions

Masonry Compressive Strength ; **Masonry Compressive Strength - 6.4 N/mm^2**

Stem Base section ; **700mm thick and 1400mm from base to the top of the wall**

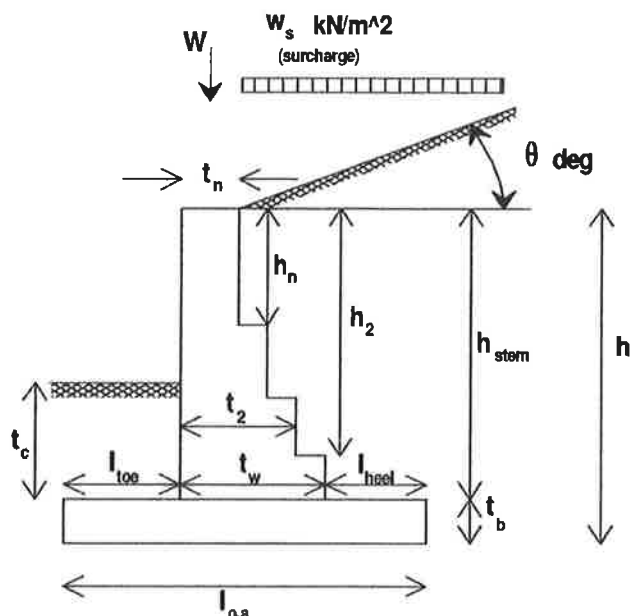
Section 2 ; **553mm thick and 900mm from base of section 2 to the top of the wall**

Base Mass Concrete Standard Mix ST4 750x300mm

;

;

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CHECK ON BASE OF WALL ADJACENT TO VESTRY FOUNDATION.

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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; $\phi = 35.0^\circ$
- ; 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); $w_s = 30.0 \text{ kN/m}^2$
- ; 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; $t_w = 1000.0 \text{ mm}$
- ; Height retained; $h = 750 \text{ mm}$

Base details

- ; Density of wall base; $\gamma_b = 23.6 \text{ kN/m}^3$
- ; Length of heel; $l_{heel} = 25 \text{ mm}$
- ; Length of toe; $l_{toe} = 25 \text{ mm}$
- ; Base thickness; $t_b = 300 \text{ mm}$

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Length of base;

$$l_{o,a} = l_{oe} + t_w + l_{heel} = 1050 \text{ mm}$$

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

Height of wall stem;

$$h_{stem} = h - t_b = 450 \text{ mm}$$

$$h_{soil} = h + l_{heel} \times \tan(\theta) = 750 \text{ mm}$$

Load factors

; Dead Load Factor;

$$\gamma_{f,d} = 1.40$$

; Imposed Load Factor;

$$\gamma_{f,l} = 1.60$$

Coefficients using Rankine

Active coefficient (Sloping Surface) - no friction

$$k_{a,s} = (\cos(\theta) - \sqrt{((\cos(\theta))^2 - (\cos(\phi))^2)}) / (\cos(\theta) + \sqrt{((\cos(\theta))^2 - (\cos(\phi))^2)}) = 0.271$$

Active coefficient (level surface);

$$k_a = (1 - \sin(\phi)) / (1 + \sin(\phi)) = 0.271$$

Passive coefficient (level surface);

$$k_p = (1 + \sin(\phi)) / (1 - \sin(\phi)) = 3.690$$

At - rest coefficient;

$$k_o = (1 - \sin(\phi)) = 0.426$$

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

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

Surcharge

pressure;

$$p_s = k_{a,s} \times w_s = 8.1 \text{ kN/m}^2$$

force – horizontal;

$$F_s = (p_s \times h_{soil}) \times (\cos(\theta))^2 = 6.1 \text{ kN/m}$$

overturning moment about toe; $M_s = F_s \times h_{soil} / 2 = 2.3 \text{ kNm/m}$

Backfill

pressure;

$$p_a = k_{a,s} \times \gamma_s \times h_{soil} = 3.7 \text{ kN/m}^2$$

force – horizontal;

$$F_a = (p_a \times h_{soil} / 2) \times (\cos(\theta))^2 = 1.4 \text{ kN/m}$$

overturning moment about the toe;

$$M_a = F_a \times h_{soil} / 3 = 0.3 \text{ kNm/m}$$

Total horizontal force (unfactored);

$$F_t = F_s + F_a = 7.5 \text{ kN/m}$$

Total horizontal force (factored);

$$F_{t,ult} = \gamma_{f,l} \times F_s + \gamma_{f,d} \times F_a = 11.7 \text{ kN/m}$$

Total overturning moment (unfactored);

$$M_t = M_s + M_a = 2.6 \text{ kNm/m}$$

Total overturning moment (factored);

$$M_{t,ult} = \gamma_{f,l} \times M_s + \gamma_{f,d} \times M_a = 4.1 \text{ kNm/m}$$

Average load factor;

$$\gamma_{f,av} = M_{t,ult} / M_t = 1.57$$

STABILITY CHECKS

(Unfactored Loads - Active Soil Pressures)

1) SLIDING

; Coefficient of friction;

$$\mu = \tan(\phi) \times \text{factor} = 0.525 ; \text{factor} = 0.75$$

Passive pressures in front of wall

Top of base;

$$pp_1 = k_p \times t_c \times \gamma_s = 13.3 \text{ kN/m}^2$$

Underside of base;

$$pp_2 = k_p \times (t_c + t_b) \times \gamma_s = 33.2 \text{ kN/m}^2$$

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Total resistance

Base; $PP_{base} = (pp_1 + pp_2) \times t_b / 2 = 7.0 \text{ kN/m}$

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

$P = PP_{base} \times \text{soil_resists} = 7.0 \text{ kN/m}$

Factor of safety against sliding

; Factor of safety required; $FOS_{reqd_{sliding}} = 2.00$

Length of heel provided; $l_{heel} = 25 \text{ mm}$

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

$FOS_{sliding} = (((l_{heel} \times (\gamma_s \times (h_{stem} + l_{heel} \times \tan(\theta)/2) + \gamma_b \times t_b)) + l_{toe} \times \gamma_b \times t_b + W_v + (t_w \times (\gamma_w \times h_{stem} + \gamma_b \times t_b))) \times \mu) + P) / F_1$

$FOS_{sliding} = 2.072$

Factor of safety against sliding = 2.1 i.e. > 2.0 - OK

2) OVERTURNING

Factor of safety against overturning

; Factor of safety required; $FOS_{reqd_{turn}} = 2.00$

Length of toe provided; $l_{toe} = 25 \text{ mm}$

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

$M_{r1} = (W_v + h_{stem} \times t_w \times \gamma_w) \times (l_{toe} + t_w / 2) = 4.5 \text{ kNm/m}$

$M_{r2} = l_{heel} \times h_{stem} \times \gamma_s \times (l_{toe} + t_w + l_{heel} / 2) = 0.2 \text{ kNm/m}$

$M_{r3} = (l_{toe} + t_w + l_{heel})^2 \times t_b \times \gamma_b / 2 = 3.9 \text{ kNm/m}$

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

Resisting moment; $M_r = M_{r1} + M_{r2} + M_{r3} + M_{r4} = 8.6 \text{ kNm/m}$

Factor of safety against overturning ; $FOS_{o_{turn}} = M_r / \text{abs}(M_t) = 3.27$

Factor of safety against overturning = 3.3 i.e. > 2.0 - OK

Overall length of base; $l_{o_a} = l_{toe} + t_w + l_{heel} = 1.050 \text{ m}$

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

Total overturning moment for bearing calculation; $M_t = 2.6 \text{ kNm/m}$

Total resisting moment for bearing calculation; $M_r = 8.6 \text{ kNm/m}$

Total vertical load on base

$N = t_w \times h_{stem} \times \gamma_w + (h_{stem} + l_{heel} \times \tan(\theta)/2) \times l_{heel} \times \gamma_s + t_c \times l_{toe} \times \gamma_s + l_{o_a} \times t_b \times \gamma_b + W_v + w_s \times l_{heel} + W_1$

$N = 17.0 \text{ kN/m}$

Eccentricity of vertical load

$e_1 = (M_r - \text{abs}(M_t) + t_c \times l_{toe}^2 \times \gamma_s / 2 + w_s \times l_{heel} \times (l_{toe} + t_w + l_{heel}/2) + W_1 \times (l_{toe} + t_w/2)) / N = 0.397 \text{ m}$

$e = l_{o_a} / 2 - e_1 = 0.128 \text{ m}$

Resultant lies inside middle third;

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Maximum bearing pressure; $p_{max} = \text{if}(\text{abs}(\theta) < (l_{o_a} / 6), \sigma_{max2}, \sigma_{max1}) = 28.1 \text{ kN/m}^2$

; Permissible bearing pressure; $p_{bearing} = 150 \text{ kN/m}^2$

Maximum bearing pressure is 28 kN/m² i.e. < Allowable - OK

STEM DESIGN

Width of base of wall;

$$t_w = 1000.0 \text{ mm}$$

Height of stem of wall;

$$h_{stem} = 450 \text{ mm}$$

DESIGN OF BASE WALL SECTION (ACTIVE PRESSURES)

; Wall base section thickness; $t_w = 1000.0 \text{ mm}$

Depth from top of wall to base

; $h_{stem} = 450 \text{ mm}$;

Applied moment at base of wall

$$M_{base} = (k_{a_s} \times (\cos(\theta))^2 \times w_s \times h_{stem}^2 / 2) \times \gamma_{f_i} + (k_{a_s} \times (\cos(\theta))^2 \times \gamma_s \times h_{stem}^3 / 6) \times \gamma_{f_d} = 1.4 \text{ kNm/m}$$

Applied shear force at base of wall

$$F_{base} = (k_{a_s} \times (\cos(\theta))^2 \times w_s \times h_{stem}) \times \gamma_{f_i} + (k_{a_s} \times (\cos(\theta))^2 \times \gamma_s \times h_{stem}^2 / 2) \times \gamma_{f_d} = 6.5 \text{ kN/m}$$

CHECK RESISTANCE TO MOMENT WITHOUT FLEXURAL STRENGTH (BS5628:PT 1:CL 36.5.3)

; Compressive strength (Table 2); $f_k = 6.40 \text{ N/mm}^2$

; Design vertical load per unit length of wall; $n_{w_base} = \gamma_{f_d} \times (W_v + t_w \times h_{stem} \times \gamma_w) = 7.7 \text{ kN/m}$

; Moment of resistance; $M_{RC_base} = (n_{w_base} / 2) \times (t_w - (n_{w_base} \times \gamma_m / f_k)) = 3.8 \text{ kNm/m}$

Wall bending - OK

STEM SHEAR (BS5628:PT 1:CL 33)

; Mortar designation; Mortar = "iii"

Design dead load at the base of the wall; $V_{base} = W_v + t_w \times h_{stem} \times \gamma_w = 8.55 \text{ kN/m}$

; Design vertical dead load per unit area; $g_{A_base} = V_{base} \times \gamma_{f_d} / t_w = 0.01 \text{ N/mm}^2$

Characteristic shear strength of masonry

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

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

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

Ref BS 5628 Pt 1: Clause 25

Shear stress;

$$v_{base} = F_{base} / t_w = 0.01 \text{ N/mm}^2$$

; Partial safety factor for shear;

$$\gamma_{mv} = 2.5$$

Wall base shear OK

SUMMARY OF RESULTS

Wall Dimensions

Masonry Compressive Strength

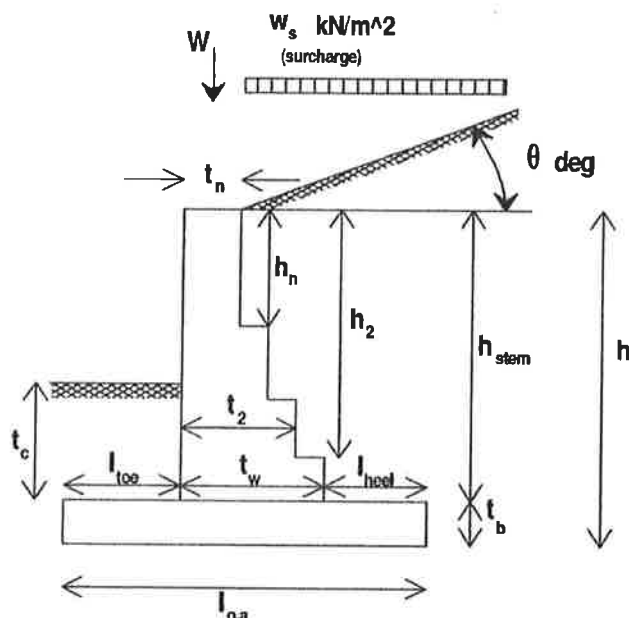
; Masonry Compressive Strength - 6.4 N/mm^2

Stem Base section

; 1000mm thick and 450mm from base to the top of the wall

Base Mass Concrete Standard Mix ST4 1050x300mm;

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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; $\phi = 35.0^\circ$
- ; 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; $t_w = 700.0 \text{ mm}$
- ; Height retained; $h = 1700 \text{ mm}$

Base details

- ; Density of wall base; $\gamma_b = 23.6 \text{ kN/m}^3$
- ; Length of heel; $l_{heel} = 25 \text{ mm}$
- ; Length of toe; $l_{toe} = 25 \text{ mm}$
- ; Base thickness; $t_b = 300 \text{ mm}$
- ; Length of base; $l_{o.a} = l_{toe} + t_w + l_{heel} = 750 \text{ mm}$

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

Height of wall stem;

$$h_{stem} = h - t_b = 1400 \text{ mm}$$

$$h_{soil} = h + h_{heel} \times \tan(\theta) = 1700 \text{ mm}$$

Load factors

; Dead Load Factor;

$$\gamma_{t,d} = 1.40$$

; Imposed Load Factor;

$$\gamma_{t,i} = 1.60$$

Coefficients using Rankine

Active coefficient (Sloping Surface) - no friction

$$k_{a,s} = (\cos(\theta) - \sqrt{((\cos(\theta))^2 - (\cos(\phi))^2)}) / (\cos(\theta) + \sqrt{((\cos(\theta))^2 - (\cos(\phi))^2)}) = 0.271$$

Active coefficient (level surface);

$$k_a = (1 - \sin(\phi)) / (1 + \sin(\phi)) = 0.271$$

Passive coefficient (level surface);

$$k_p = (1 + \sin(\phi)) / (1 - \sin(\phi)) = 3.690$$

At - rest coefficient;

$$k_o = (1 - \sin(\phi)) = 0.426$$

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

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

Surcharge

pressure;

$$p_s = k_{a,s} \times w_s = 0.4 \text{ kN/m}^2$$

force – horizontal;

$$F_s = (p_s \times h_{soil}) \times (\cos(\theta))^2 = 0.7 \text{ kN/m}$$

overturning moment about toe; $M_s = F_s \times h_{soil} / 2 = 0.6 \text{ kNm/m}$

Backfill

pressure;

$$p_a = k_{a,s} \times \gamma_s \times h_{soil} = 8.3 \text{ kN/m}^2$$

force – horizontal;

$$F_a = (p_a \times h_{soil} / 2) \times (\cos(\theta))^2 = 7.0 \text{ kN/m}$$

overturning moment about the toe;

$$M_a = F_a \times h_{soil} / 3 = 4.0 \text{ kNm/m}$$

Total horizontal force (unfactored);

$$F_t = F_s + F_a = 7.7 \text{ kN/m}$$

Total horizontal force (factored);

$$F_{t,ult} = \gamma_{t,i} \times F_s + \gamma_{t,d} \times F_a = 11.0 \text{ kN/m}$$

Total overturning moment (unfactored);

$$M_t = M_s + M_a = 4.6 \text{ kNm/m}$$

Total overturning moment (factored);

$$M_{t,ult} = \gamma_{t,i} \times M_s + \gamma_{t,d} \times M_a = 6.5 \text{ kNm/m}$$

Average load factor;

$$\gamma_{t,av} = M_{t,ult} / M_t = 1.43$$

STABILITY CHECKS

(Unfactored Loads - Active Soil Pressures)

1) SLIDING

; Coefficient of friction;

$$\mu = \tan(\phi) \times \text{factor} = 0.525 ; \text{factor} = 0.75$$

Passive pressures in front of wall

Top of base;

$$pp_1 = k_p \times t_c \times \gamma_s = 13.3 \text{ kN/m}^2$$

Underside of base;

$$pp_2 = k_p \times (t_c + t_b) \times \gamma_s = 33.2 \text{ kN/m}^2$$

Total resistance

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Base; $PP_{base} = (pp_1 + pp_2) \times t_b / 2 = 7.0 \text{ kN/m}$

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

$P = PP_{base} \times \text{soil_resists} = 7.0 \text{ kN/m}$

Factor of safety against sliding

; Factor of safety required; $FOS_{reqd_sliding} = 2.00$

Length of heel provided; $l_{heel} = 25 \text{ mm}$

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

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

$FOS_{sliding} = 2.568$

Factor of safety against sliding = 2.6 i.e. > 2.0 - OK

2) OVERTURNING

Factor of safety against overturning

; Factor of safety required; $FOS_{reqd_o_tum} = 2.00$

Length of toe provided; $l_{toe} = 25 \text{ mm}$

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

$M_{r1} = (W_v + h_{stem} \times t_w \times \gamma_w) \times (l_{toe} + t_w / 2) = 7.0 \text{ kNm/m}$

$M_{r2} = l_{heel} \times h_{stem} \times \gamma_s \times (l_{toe} + t_w + l_{heel} / 2) = 0.5 \text{ kNm/m}$

$M_{r3} = (l_{toe} + t_w + l_{heel})^2 \times t_b \times \gamma_b / 2 = 2.0 \text{ kNm/m}$

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

Resisting moment; $M_r = M_{r1} + M_{r2} + M_{r3} + M_{r4} = 9.4 \text{ kNm/m}$

Factor of safety against overturning; $FOS_{o_tum} = M_r / \text{abs}(M_t) = 2.06$

Factor of safety against overturning = 2.1 i.e. > 2.0 - OK

Overall length of base; $l_{o_a} = l_{toe} + t_w + l_{heel} = 0.750 \text{ m}$

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

Total overturning moment for bearing calculation; $M_t = 4.6 \text{ kNm/m}$

Total resisting moment for bearing calculation; $M_r = 9.4 \text{ kNm/m}$

Total vertical load on base

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

$N = 24.7 \text{ kN/m}$

Eccentricity of vertical load

$e_1 = (M_r - \text{abs}(M_t) + t_b \times l_{toe}^2 \times \gamma_s / 2 + W_s \times l_{heel} \times (l_{toe} + t_w + l_{heel}/2) + W_l \times (l_{toe} + t_w/2)) / N = 0.198 \text{ m}$

$e = l_{o_a} / 2 - e_1 = 0.177 \text{ m}$

Resultant lies outside middle third;

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Maximum bearing pressure; $p_{max} = \text{if}(\text{abs}(e) < (I_{o_a} / 6), \sigma_{max2}, \sigma_{max1}) = 83.2 \text{ kN/m}^2$

; Permissible bearing pressure; $p_{bearing} = 150 \text{ kN/m}^2$

Maximum bearing pressure is 83 kN/m² i.e. < Allowable - OK

STEM DESIGN

Width of base of wall;

$$t_w = 700.0 \text{ mm}$$

Height of stem of wall;

$$h_{stem} = 1400 \text{ mm}$$

DESIGN OF BASE WALL SECTION (ACTIVE PRESSURES)

; Wall base section thickness; $t_w = 700.0 \text{ mm}$

Depth from top of wall to base

; $h_{stem} = 1400 \text{ mm}$; **Warning the height of the wall is not a complete number of bricks**

Applied moment at base of wall

$$M_{base} = (k_{a_s} \times (\cos(\theta))^2 \times w_s \times h_{stem}^2 / 2) \times \gamma_{f_l} + (k_{a_s} \times (\cos(\theta))^2 \times \gamma_s \times h_{stem}^3 / 6) \times \gamma_{f_d} = 3.8 \text{ kNm/m}$$

Applied shear force at base of wall

$$F_{base} = (k_{a_s} \times (\cos(\theta))^2 \times w_s \times h_{stem}) \times \gamma_{f_l} + (k_{a_s} \times (\cos(\theta))^2 \times \gamma_s \times h_{stem}^2 / 2) \times \gamma_{f_d} = 7.6 \text{ kN/m}$$

CHECK RESISTANCE TO MOMENT WITHOUT FLEXURAL STRENGTH (BS5628:PT 1:CL 36.5.3)

; Compressive strength (Table 2); $f_k = 6.40 \text{ N/mm}^2$

; Design vertical load per unit length of wall; $n_{w_base} = \gamma_{fd} \times (W_v + t_w \times h_{stem} \times \gamma_w) = 16.8 \text{ kN/m}$

; Moment of resistance; $M_{RC_base} = (n_{w_base} / 2) \times (t_w - (n_{w_base} \times \gamma_m / f_k)) = 5.8 \text{ kNm/m}$

Wall bending - OK

STEM SHEAR (BS5628:PT 1:CL 33)

; Mortar designation; Mortar = "III"

Design dead load at the base of the wall; $V_{base} = W_v + t_w \times h_{stem} \times \gamma_w = 18.62 \text{ kN/m}$

; 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

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

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

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

Ref BS 5628 Pt 1: Clause 25

Shear stress;

$$v_{base} = F_{base} / t_w = 0.01 \text{ N/mm}^2$$

; Partial safety factor for shear;

$$\gamma_{mv} = 2.5$$

Wall base shear OK

DESIGN OF WALL SECTION 2 (ACTIVE PRESSURES)

; Wall section thickness; $t_{wall_2} = 552.5 \text{ mm}$

Depth from top of wall to base of section

; $h_{wall_2} = 900 \text{ mm}$;

Applied moment at base of section

$$M_{wall_2} = (k_{a_s} \times (\cos(\theta))^2 \times w_s \times h_{wall_2}^2 / 2) \times \gamma_{f_l} + (k_{a_s} \times (\cos(\theta))^2 \times \gamma_s \times h_{wall_2}^3 / 6) \times \gamma_{f_d} = 1.1 \text{ kNm/m}$$

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Applied shear force at base of section

$$F_{wall_2} = (k_{a_s} \times (\cos(\theta))^2 \times W_6 \times h_{wall_2}) \times \gamma_{t_1} + (k_{a_s} \times (\cos(\theta))^2 \times \gamma_s \times h_{wall_2}^2 / 2) \times \gamma_{t_d} = 3.4 \text{ kN/m}$$

CHECK RESISTANCE TO MOMENT WITHOUT FLEXURAL STRENGTH (BS5628:PT 1:CL 36.5.3)

; Compressive strength (Table 2); $f_k = 6.40 \text{ N/mm}^2$

; Design vertical load per unit length of wall; $n_{w_wall_2} = \gamma_{td} \times (W_v + t_{wall_2} \times h_{wall_2} \times \gamma_w) = 8.5 \text{ kN/m}$

; Moment of resistance; $M_{RC_wall_2} = (n_{w_wall_2} / 2) \times (t_{wall_2} - (n_{w_wall_2} \times \gamma_m / f_k)) = 2.3 \text{ kNm/m}$

Wall bending - OK

STEM SHEAR (BS5628:PT 1:CL 33)

; Mortar designation; Mortar = "iii"

Design dead load at the base of the wall; $V_{wall_2} = W_v + t_{wall_2} \times h_{wall_2} \times \gamma_w = 9.45 \text{ kN/m}$

; Design vertical dead load per unit area; $g_{A_wall_2} = V_{wall_2} \times \gamma_{td} / t_{wall_2} = 0.02 \text{ N/mm}^2$

Characteristic shear strength of masonry

$$f_{v_i} = \min(1.75 \text{ N/mm}^2, 0.35 \text{ N/mm}^2 + (0.6 \times g_{A_wall_2})) = 0.36 \text{ N/mm}^2$$

$$f_{v_ii} = \min(1.4 \text{ N/mm}^2, 0.15 \text{ N/mm}^2 + (0.6 \times g_{A_wall_2})) = 0.16 \text{ N/mm}^2$$

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

Ref BS 5628 Pt 1: Clause 25

Shear stress;

$$v_{wall_2} = F_{wall_2} / t_{wall_2} = 0.01 \text{ N/mm}^2$$

; Partial safety factor for shear;

$$\gamma_{mv} = 2.5$$

Wall section base shear OK

SUMMARY OF RESULTS

Wall Dimensions

Masonry Compressive Strength ; Masonry Compressive Strength - 6.4 N/mm^2

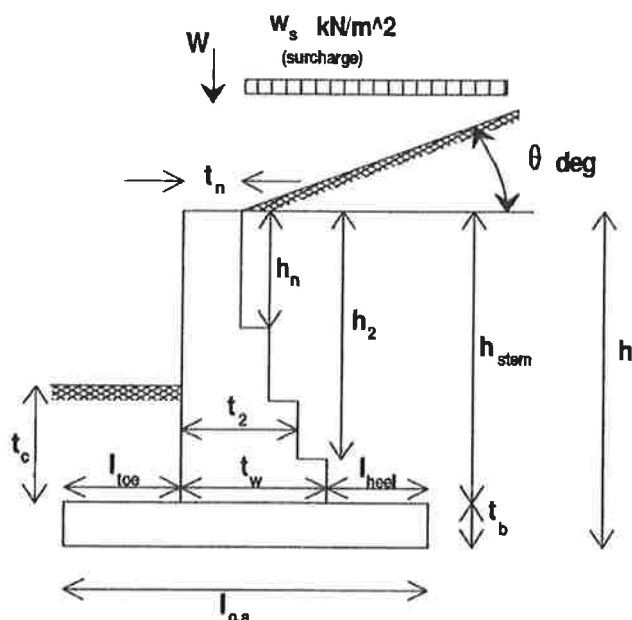
Stem Base section ; 700mm thick and 1400mm from base to the top of the wall

Section 2 ; 553mm thick and 900mm from base of section 2 to the top of the wall

Base Mass Concrete Standard Mix ST4 750x300mm

;

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CHECK ON BASE OF WALL ADJACENT TO VESTRY FOUNDATION.

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; $\phi = 35.0^\circ$
- ; 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); $w_s = 30.0 \text{ kN/m}^2$
- ; 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; $t_w = 1000.0 \text{ mm}$
- ; Height retained; $h = 750 \text{ mm}$

Base details

- ; Density of wall base; $\gamma_b = 23.6 \text{ kN/m}^3$
- ; Length of heel; $l_{heel} = 25 \text{ mm}$
- ; Length of toe; $l_{toe} = 25 \text{ mm}$
- ; Base thickness; $t_b = 300 \text{ mm}$

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Length of base;

$$l_{o-a} = l_{toe} + l_w + l_{heel} = 1050 \text{ mm}$$

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

Height of wall stem;

$$h_{stem} = h - t_b = 450 \text{ mm}$$

$$h_{soil} = h + l_{heel} \times \tan(\theta) = 750 \text{ mm}$$

Load factors

; Dead Load Factor;

$$\gamma_{L_d} = 1.40$$

; Imposed Load Factor;

$$\gamma_{L_i} = 1.60$$

Coefficients using Rankine

Active coefficient (Sloping Surface) - no friction

$$k_{a_s} = (\cos(\theta) - \sqrt{((\cos(\theta))^2 - (\cos(\phi))^2)}) / (\cos(\theta) + \sqrt{((\cos(\theta))^2 - (\cos(\phi))^2)}) = 0.271$$

Active coefficient (level surface);

$$k_a = (1 - \sin(\phi)) / (1 + \sin(\phi)) = 0.271$$

Passive coefficient (level surface);

$$k_p = (1 + \sin(\phi)) / (1 - \sin(\phi)) = 3.690$$

At - rest coefficient;

$$k_o = (1 - \sin(\phi)) = 0.426$$

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

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

Surcharge

pressure;

$$p_s = k_{a_s} \times w_s = 8.1 \text{ kN/m}^2$$

force - horizontal;

$$F_s = (p_s \times h_{soil}) \times (\cos(\theta))^2 = 6.1 \text{ kN/m}$$

overturning moment about toe; $M_s = F_s \times h_{soil} / 2 = 2.3 \text{ kNm/m}$

Backfill

pressure;

$$p_a = k_{a_a} \times \gamma_a \times h_{soil} = 3.7 \text{ kN/m}^2$$

force - horizontal;

$$F_a = (p_a \times h_{soil} / 2) \times (\cos(\theta))^2 = 1.4 \text{ kN/m}$$

overturning moment about the toe;

$$M_a = F_a \times h_{soil} / 3 = 0.3 \text{ kNm/m}$$

Total horizontal force (unfactored);

$$F_t = F_s + F_a = 7.5 \text{ kN/m}$$

Total horizontal force (factored);

$$F_{t_{ult}} = \gamma_{L_i} \times F_s + \gamma_{L_d} \times F_a = 11.7 \text{ kN/m}$$

Total overturning moment (unfactored);

$$M_t = M_s + M_a = 2.6 \text{ kNm/m}$$

Total overturning moment (factored);

$$M_{t_{ult}} = \gamma_{L_i} \times M_s + \gamma_{L_d} \times M_a = 4.1 \text{ kNm/m}$$

Average load factor;

$$\gamma_{t_{av}} = M_{t_{ult}} / M_t = 1.57$$

STABILITY CHECKS

(Unfactored Loads - Active Soil Pressures)

1) SLIDING

; Coefficient of friction;

$$\mu = \tan(\phi) \times \text{factor} = 0.525 ; \text{factor} = 0.75$$

Passive pressures in front of wall

Top of base;

$$pp_1 = k_p \times t_c \times \gamma_s = 13.3 \text{ kN/m}^2$$

Underside of base;

$$pp_2 = k_p \times (t_c + t_b) \times \gamma_s = 33.2 \text{ kN/m}^2$$

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Total resistance

Base; $PP_{base} = (pp_1 + pp_2) \times t_b / 2 = 7.0 \text{ kN/m}$

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

$P = PP_{base} \times \text{soil_resists} = 7.0 \text{ kN/m}$

Factor of safety against sliding

; Factor of safety required; $FOS_{reqd_sliding} = 2.00$

Length of heel provided; $l_{heel} = 25 \text{ mm}$

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

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

$FOS_{sliding} = 2.072$

Factor of safety against sliding = 2.1 i.e. > 2.0 - OK

2) OVERTURNING

Factor of safety against overturning

; Factor of safety required; $FOS_{reqd_turn} = 2.00$

Length of toe provided; $l_{toe} = 25 \text{ mm}$

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

$$M_{r1} = (W_v + h_{stem} \times t_w \times \gamma_w) \times (l_{toe} + t_w / 2) = 4.5 \text{ kNm/m}$$

$$M_{r2} = l_{heel} \times h_{stem} \times \gamma_s \times (l_{toe} + t_w + l_{heel} / 2) = 0.2 \text{ kNm/m}$$

$$M_{r3} = (l_{toe} + t_w + l_{heel})^2 \times t_b \times \gamma_b / 2 = 3.9 \text{ kNm/m}$$

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

Resisting moment; $M_r = M_{r1} + M_{r2} + M_{r3} + M_{r4} = 8.6 \text{ kNm/m}$

Factor of safety against overturning ; $FOS_{o_turn} = M_r / \text{abs}(M_i) = 3.27$

Factor of safety against overturning = 3.3 i.e. > 2.0 - OK

Overall length of base; $l_{o_a} = l_{toe} + t_w + l_{heel} = 1.050 \text{ m}$

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

Total overturning moment for bearing calculation; $M_i = 2.6 \text{ kNm/m}$

Total resisting moment for bearing calculation; $M_r = 8.6 \text{ kNm/m}$

Total vertical load on base

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

$N = 17.0 \text{ kN/m}$

Eccentricity of vertical load

$$e_1 = (M_r - \text{abs}(M_i) + t_c \times l_{toe}^2 \times \gamma_s / 2 + w_s \times l_{heel} \times (l_{toe} + t_w + l_{heel} / 2) + W_i \times (l_{toe} + t_w / 2)) / N = 0.397 \text{ m}$$

$e = l_{o_a} / 2 - e_1 = 0.128 \text{ m}$

Resultant lies inside middle third;

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Maximum bearing pressure; $p_{max} = \text{if}(\text{abs}(e) < (I_{o_g} / 6), \sigma_{max2}, \sigma_{max1}) = 28.1 \text{ kN/m}^2$

; Permissible bearing pressure; $p_{bearing} = 150 \text{ kN/m}^2$

Maximum bearing pressure is 28 kN/m² i.e. < Allowable - OK

STEM DESIGN

Width of base of wall;

$$t_w = 1000.0 \text{ mm}$$

Height of stem of wall;

$$h_{stem} = 450 \text{ mm}$$

DESIGN OF BASE WALL SECTION (ACTIVE PRESSURES)

; Wall base section thickness; $t_w = 1000.0 \text{ mm}$

Depth from top of wall to base

; $h_{stem} = 450 \text{ mm}$;

Applied moment at base of wall

$$M_{base} = (k_{a_s} \times (\cos(\theta))^2 \times w_s \times h_{stem}^2 / 2) \times \gamma_{l_i} + (k_{a_s} \times (\cos(\theta))^2 \times \gamma_s \times h_{stem}^3 / 6) \times \gamma_{l_d} = 1.4 \text{ kNm/m}$$

Applied shear force at base of wall

$$F_{base} = (k_{a_s} \times (\cos(\theta))^2 \times w_s \times h_{stem}) \times \gamma_{l_i} + (k_{a_s} \times (\cos(\theta))^2 \times \gamma_s \times h_{stem}^2 / 2) \times \gamma_{l_d} = 6.5 \text{ kN/m}$$

CHECK RESISTANCE TO MOMENT WITHOUT FLEXURAL STRENGTH (BS5628:PT 1:CL 36.5.3)

; Compressive strength (Table 2); $f_k = 6.40 \text{ N/mm}^2$

; Design vertical load per unit length of wall; $n_{w_base} = \gamma_{fd} \times (W_v + t_w \times h_{stem} \times \gamma_w) = 7.7 \text{ kN/m}$

; Moment of resistance; $M_{RC_base} = (n_{w_base} / 2) \times (t_w - (n_{w_base} \times \gamma_m / f_k)) = 3.8 \text{ kNm/m}$

Wall bending - OK

STEM SHEAR (BS5628:PT 1:CL 33)

; Mortar designation; Mortar = "iii"

Design dead load at the base of the wall; $V_{base} = W_v + t_w \times h_{stem} \times \gamma_w = 8.55 \text{ kN/m}$

; Design vertical dead load per unit area; $g_{A_base} = V_{base} \times \gamma_{fd} / t_w = 0.01 \text{ N/mm}^2$

Characteristic shear strength of masonry

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

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

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

Ref BS 5628 Pt 1: Clause 25

Shear stress;

$$v_{base} = F_{base} / t_w = 0.01 \text{ N/mm}^2$$

; Partial safety factor for shear;

$$\gamma_{mv} = 2.5$$

Wall base shear OK

SUMMARY OF RESULTS

Wall Dimensions

Masonry Compressive Strength

; **Masonry Compressive Strength - 6.4 N/mm²**

Stem Base section

; **1000mm thick and 450mm from base to the top of the wall**

Base Mass Concrete Standard Mix ST4 1050x300mm;