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H& H Building Solutions Ltd	Project: Jungle Trade Supplies Ltd Staden Lane Buxton				Job Ref	
H&H Building Solutions Ltd 52 Tavern Rd Hadfield SK13 2RB	Section: Solid stone car park retaining wall 700 high				Sheet no./rev: 1	
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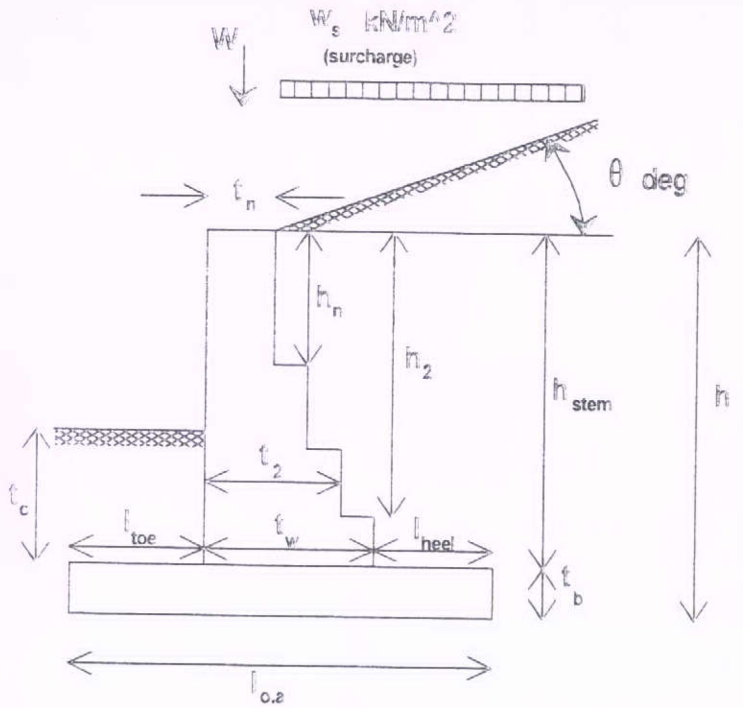

CANTILEVER MASONRY RETAINING WALL DESIGN (BS8110&BS5628) MASONRY CANTILEVER RETAINING WALL DESIGN TO CP2 & BS5628 (PART 1)

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

General Soil Data

Density of retained soil	γ_s = 18.0 kN/m^3
Angle of internal friction	ϕ = 30.0 °
Angle of soil surface	θ = 0.0 °
Ground cover over base at front of wall – if > 0mm, assumed permanent	t_c = 150 mm

Loads on wall and ground

Surcharge load (horizontal plan area)	w_s = 2.5 kN/m^2
Design vertical dead load on wall (unfactored)	W_d = 0.00 kN/m
Design vertical live load on wall (unfactored)	W_l = 0.00 kN/m

Stem details

Density of wall stem brickwork	γ_w = 22.0 kN/m^3
Wall base section thickness	t_w = 500.0 mm
Height retained	h = 700 mm

Base details

Density of wall base $\gamma_b = 23.6$ kN/m^3

Length of heel $l_{heel} = 0$ mm

Length of toe $l_{toe} = 0$ mm

Base thickness $t_b = 200$ mm

Length of base $l_{o\_a} = l_{toe} + t_w + l_{heel} = 500$ mm

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

Height of wall stem $h_{stem} = h - t_b = 500$ mm

$h_{soil} = h + l_{heel} \times \tan(\theta) = 700$ 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

$$k_{a\_s} = (\cos(\theta) - \sqrt{((\cos(\theta))^2 - (\cos(\phi))^2)}) / (\cos(\theta) + \sqrt{((\cos(\theta))^2 - (\cos(\phi))^2)}) = 0.333$$

Active coefficient (level surface) $k_a = (1 - \sin(\phi)) / (1 + \sin(\phi)) = 0.333$

Passive coefficient (level surface) $k_p = (1 + \sin(\phi)) / (1 - \sin(\phi)) = 3.000$

At - rest coefficient $k_o = (1 - \sin(\phi)) = 0.500$

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

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

Surcharge

pressure $p_s = k_{a\_s} \times w_s = 0.8$ kN/m^2

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

overturning moment about toe $M_s = F_s \times h_{soil} /2 = 0.2$ kNm/m

Backfill

pressure $p_a = k_{a\_s} \times \gamma_s \times h_{soil} = 4.2$ kN/m^2

force – horizontal $F_a = (p_a \times h_{soil} / 2) \times (\cos(\theta))^2 = 1.5$ kN/m

overturning moment about the toe $M_a = F_a \times h_{soil} / 3 = 0.3$ kNm/m

Total horizontal force (unfactored) $F_t = F_s + F_a = 2.1$ kN/m

Total horizontal force (factored) $F_{t\_ult} = \gamma_{f\_l} \times F_s + \gamma_{f\_d} \times F_a = 3.0$ kN/m

Total overturning moment (unfactored) $M_t = M_s + M_a = 0.5$ kNm/m

Total overturning moment (factored) $M_{t\_ult} = \gamma_{f\_l} \times M_s + \gamma_{f\_d} \times M_a = 0.8$ kNm/m

Average load factor $\gamma_{f\_av} = M_{t\_ult} / M_t = 1.47$

STABILITY CHECKS

(Unfactored Loads - Active Soil Pressures)

1) SLIDING

Coefficient of friction $\mu = \tan(\phi) \times \text{factor} = 0.577$ factor = 1.00

Passive pressures in front of wall

Top of base $pp_1 = k_p \times t_c \times \gamma_s = 8.1$ kN/m^2

Underside of base $pp_2 = k_p \times (t_c + t_b) \times \gamma_s = 18.9$ kN/m^2

Total resistance

Base $PP_{base} = (pp_1 + pp_2) \times t_b / 2 = 2.7$ kN/m

Passive resistance **Soil in front of wall NOT assumed to resist sliding**

$P = PP_{base} \times \text{soil\_resists} = 0.0$ kN/m

Factor of safety against sliding

Factor of safety required $FOS\_reqd_{sliding} = 2.00$

Length of heel provided $l_{heel} = 0$ mm

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

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

$FOS_{sliding} = 2.210$

Factor of safety against sliding = 2.2 i.e. > 2.0 - OK

2) OVERTURNING

Factor of safety against overturning

Factor of safety required $FOS\_reqd_{o\_turn} = 2.00$

Length of toe provided $l_{toe} = 0$ 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

$M_{r1} = (W_v + h_{stem} \times t_w \times \gamma_w) \times (l_{toe} + t_w / 2) = 1.4$ kNm/m

$M_{r2} = l_{heel} \times h_{stem} \times \gamma_s \times (l_{toe} + t_w + l_{heel} / 2) = 0.0$ kNm/m

$M_{r3} = (l_{toe} + t_w + l_{heel})^2 \times t_b \times \gamma_b / 2 = 0.6$ kNm/m

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

Resisting moment $M_r = M_{r1} + M_{r2} + M_{r3} + M_{r4} = 2.0$ kNm/m

Factor of safety against overturning $FOS_{o\_turn} = M_r / abs(M_t) = 3.59$

Factor of safety against overturning = 3.6 i.e. > 2.0 - OK

Overall length of base $l_{c\_a} = l_{toe} + t_w + l_{heel} = 0.500$ m

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

Total overturning moment for bearing calculation $M_t = 0.5$ kNm/m

Total resisting moment for bearing calculation $M_r = 2.0$ kNm/m

Total vertical load on base

$N = t_w \times h_{stem} \times \gamma_w + (h_{stem}+l_{heel}\times\tan(0)/2) \times l_{heel} \times \gamma_s + t_c \times l_{toe} \times \gamma_s + l_{o\_a} \times t_b \times \gamma_b + W_v + w_s \times l_{heel} + W_l$

$N = 7.9$ kN/m

Eccentricity of vertical load

$e_1 = (M_r - abs(M_t) + t_c \times l_{toe}^2 \times \gamma_s/2 + w_s \times l_{heel} \times (l_{toe} + t_w + l_{heel}/2) + W_l \times (l_{toe} + t_w/2)) / N = 0.180$ m

$e = l_{o\_a} / 2 - e_1 = 0.070$ m

Resultant lies inside middle third

Maximum bearing pressure $p_{max} = if(abs(e)<(l_{o\_a}/6), \sigma_{max2}, \sigma_{max1}) = 28.9$ kN/m^2

Permissible bearing pressure $p_{bearing} = 150$ 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 $p_{so} = k_o \times w_s = 1.3$ kN/m^2

force $F_{so} = p_{so} \times h = 0.9$ kN/m

moment $M_{so} = F_{so} \times h / 2 = 0.3$ kNm/m

Backfill

pressure $p_o = k_o \times \gamma_s \times h = 6.3$ kN/m^2

force $F_o = p_o \times h / 2 = 2.2$ kN/m

moment $M_o = F_o \times h / 3 = 0.5$ kNm/m

Total horizontal force (unfactored) $F_{t\_o} = F_{so} + F_o = 3.1$ kN/m

Total horizontal force (factored) $F_{t\_ult\_o} = \gamma_{f\_l} \times F_{so} + \gamma_{f\_d} \times F_o = 4.5$ kN/m

Total moment (unfactored) $M_{t\_o} = M_{so} + M_o = 0.8$ kNm/m

Total horizontal force (factored) $M_{t\_ult\_o} = \gamma_{f\_l} \times M_{so} + \gamma_{f\_d} \times M_o = 1.2$ kNm/m

Average load factor $\gamma_{f\_av} = M_{t\_ult\_o} / M_{t\_o} = 1.47$

Total vertical load on base

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

$N = 7.9$ kN/m

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

$M_r = 1.965$ kNm/m

Eccentricity of vertical load

$e_1 = (M_r - M_{t\_o} + t_c \times l_{toe}^2 \times \gamma_s/2 + w_s \times l_{heel} \times (l_{toe} + t_w + l_{heel}/2) + W_l \times (l_{toe} + t_w/2)) / N = 0.146$ m

$e = l_{o\_a} / 2 - e_1 = 0.104$ m

Resultant lies outside middle third

1) Resultant outside middle third

$\sigma_{max1} = (2 \times N) / (3 \times (l_{o\_a} / 2 - abs(e))) = 36$ kN/m^2

$l_{b1} = (N \times 2 / \sigma_{max1}) = 0.437$ m

2) Resultant inside middle third **This Section is Invalid as Resultant is outside Middle Third**

$\sigma_{max2} = N / l_{o\_a} + 6 \times N \times abs(e) / l_{o\_a}^2 = 35$ kN/m^2

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

$l_{b2} = l_{o_a} = 0.500$m

Pressures under the base

$\sigma_{max} = if(abs(e) < l_{o\_a} / 6, \sigma_{max2}, \sigma_{max1}) = 36.0$ kN/m^2

$\sigma_{min} = if(abs(e) < l_{o\_a} / 6, \sigma_{min2}, 0 \text{ kN/m}^2) = 0.0$ kN/m^2

Bearing length $l_p = if(abs(e) < (l_{o\_a} / 6), l_{b2}, l_{b1}) = 0.437$ m

Pressures under the heel/stem interface

$l_{p\_heel} = l_p - l_{toe} - t_w = -0.063$ m

$\sigma_{heel} = max(((\sigma_{max} - \sigma_{min}) \times l_{p\_heel} / l_p) + \sigma_{min}, 0 \text{ kN/m}^2) = 0.0$ kN/m^2

Pressures under the toe/stem interface

$\sigma_{toe} = ((\sigma_{max} - \sigma_{min}) \times (l_{p\_heel} + t_w) / l_p) + \sigma_{min} = 36.0$ kN/m^2

STEM DESIGN

Width of base of wall $t_w = 500.0$ mm

Height of stem of wall $h_{stem} = 500$ mm

DESIGN OF WALL SECTION 1 (AT REST PRESSURES)

Wall base section thickness t_w = **500.0** mm

Depth from top of wall to base

h_{stem} = **500** mm **Warning the height of the wall is not a complete number of bricks**

Applied moment at base of section

$M_{base} = (k_o \times w_s \times h_{stem}^2 / 2) \times \gamma_{f\_l} + (k_o \times \gamma_s \times h_{stem}^3 / 6) \times \gamma_{f\_d}$ = **0.5** kNm/m

Applied shear force at base of section

$F_{base} = (k_o \times w_s \times h_{stem}) \times \gamma_{f\_l} + (k_o \times \gamma_s \times h_{stem}^2 / 2) \times \gamma_{f\_d}$ = **2.6** kN/m

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

Compressive strength (Table 2) f_k = **7.50** N/mm²

Design vertical load per unit length of wall $n_{w\_base} = \gamma_{fd} \times (W_v + t_w \times h_{stem} \times \gamma_w)$ = **5.0** kN/m

Moment of resistance $M_{RC\_base} = (n_{w\_base} / 2) \times (t_w - (n_{w\_base} \times \gamma_m / f_k))$ = **1.2** 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 $V_{base} = W_v + t_w \times h_{stem} \times \gamma_w$ = **5.50** kN/m

Design vertical dead load per unit area $g_{A\_base} = V_{base} \times \gamma_{fd} / t_w$ = **0.01** N/mm²

Characteristic shear strength of masonry

f_{v_i} = min(1.75 N/mm², 0.35 N/mm² + (0.6 × g_{A_base})) = **0.36** N/mm²

f_{v_iii} = min(1.4 N/mm², 0.15 N/mm² + (0.6 × g_{A_base})) = **0.16** N/mm²

f_v = if((Mortar == "i")||(Mortar == "ii"), f_{v_i}, f_{v_iii}) = **0.16** N/mm²

Ref BS 5628 Pt 1 Clause 25

Shear stress $v_{base} = F_{base} / t_w$ = **0.01** N/mm²

Partial safety factor for shear γ_{mv} = **2.5**

Wall base shear OK

DESIGN OF WALL SECTION 2 (AT REST PRESSURES)

Wall section thickness t_{wall_2} = **300.0** mm

Depth from top of wall to base of section

h_{wall_2} = **200** mm **Warning the height of the section is not a complete number of bricks**

Applied moment at base of section

$M_{wall\_2} = (k_o \times w_s \times h_{wall\_2}^2 / 2) \times \gamma_{f\_l} + (k_o \times \gamma_s \times h_{wall\_2}^3 / 6) \times \gamma_{f\_d}$ = **0.1** kNm/m

Applied shear force at base of section

$F_{wall\_2} = (k_o \times w_s \times h_{wall\_2}) \times \gamma_{f\_l} + (k_o \times \gamma_s \times h_{wall\_2}^2 / 2) \times \gamma_{f\_d}$ = **0.7** kN/m

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

Compressive strength (Table 2) f_k = 7.50 N/mm^2

Design vertical load per unit length of wall $n_{w\_wall\_2} = \gamma_{fd} \times (W_v + t_{wall\_2} \times h_{wall\_2} \times \gamma_w)$ = 1.2 kN/m

Moment of resistance $M_{RC\_wall\_2} = (n_{w\_wall\_2} / 2) \times (t_{wall\_2} - (n_{w\_wall\_2} \times \gamma_m / f_k))$ = 0.2 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 $V_{wall\_2} = W_v + t_{wall\_2} \times h_{wall\_2} \times \gamma_w$ = 1.32 kN/m

Design vertical dead load per unit area $g_{A\_wall\_2} = V_{wall\_2} \times \gamma_{fd} / t_{wall\_2}$ = 0.00 N/mm^2

Characteristic shear strength of masonry

f_{v_i} = min(1.75 N/mm^2, 0.35 N/mm^2 + (0.6 × $g_{A\_wall\_2}$)) = 0.35 N/mm^2

f_{v_iii} = min(1.4 N/mm^2, 0.15 N/mm^2 + (0.6 × $g_{A\_wall\_2}$)) = 0.15 N/mm^2

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

Ref BS 5628 Pt 1 Clause 25

Shear stress $v_{wall\_2} = F_{wall\_2} / t_{wall\_2}$ = 0.00 N/mm^2

Partial safety factor for shear γ_{mv} = 2.5

Wall section base shear OK

SUMMARY OF RESULTS

Wall Dimensions

Masonry Compressive Strength **Masonry Compressive Strength - 7.5 N/mm^2**

Stem Base section **500mm thick and 500mm from base to the top of the wall**

Section 2 **300mm thick and 200mm from base of section 2 to the top of the wall**