

Structural Calculations

Design Stage Dec 2018

FOR

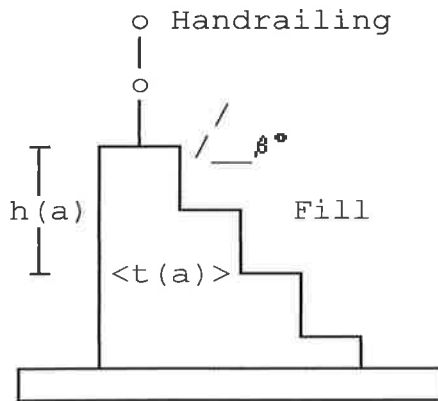
RETAINING WALL

AT

PLOT 22 VARTEG FAWR
BRYN, PORT TALBOT

Masonry gravity wall

Designed in accordance with BS5628:Part 1: 1992.
Location: Wall on grid line A/1-2



Steps are numbered down from the top.

h(a) is height at step a (from top)

t(a) is thickness at step a

Soil details

Weight/unit volume of soil & wall $w_e = 18 \text{ kN/m}^3$
Internal angle of friction $\phi = 40^\circ$
Angle of backfill $\beta = 0^\circ$
Active soil pressure is applicable.
Sine angle of internal friction $sp = \sin(\text{RAD}(\phi)) = 0.6428$
Active pressure coefficient $ce = (1 - sp) / (1 + sp)$
 $= (1 - 0.6428) / (1 + 0.6428)$
 $= 0.2174$

Masonry details

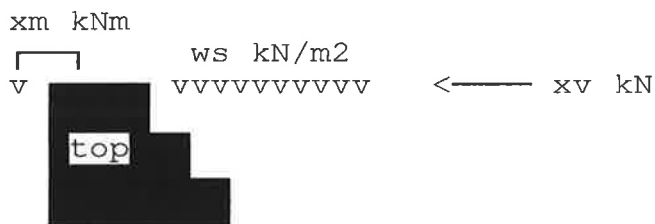
Mortar designation to Table 1 $\text{mortar} = 1$
Masonry type (1=clay 2=cal silicate 3=conc brick 4=block) $\text{typ}(1) = 4$
Concrete Blocks Dimensions
Height $hb = 215 \text{ mm}$
Least horiz dimension $lhd = 100 \text{ mm}$
ratio height/least horiz dim $rb = hb / lhd = 215 / 100 = 2.15$

Proposed Retaining Wall at:
 Plot 22 Varteg Fawr
 Bryn
 Port Talbot

Page: 2
 Made by:
 Date: 12.12.18
 Ref No:

Compressive strength of blocks $p_o = 7 \text{ N/mm}^2$
 Characteristic flexural strength for bed failure and leaf greater than
 250mm thick - Table 3 $f_b(a) = \text{TABLE 3.71 for } p_o = 7, \text{ mortar} = 1$
 $= 0.15 \text{ N/mm}^2$
 Partial safety factor material $\gamma_{mam} = 3.1$

External loading



Applied moment at top of wall $x_m = 0 \text{ kNm}$
 Applied shear at top of wall $x_v = 0 \text{ kN}$
 Weight/unit area of surcharge $w_s = 5 \text{ kN/m}^2$
 Load factor external loads at top $\gamma_{max} = 1.6$
 Load factor surcharge $\gamma_{mas} = 1.6$
 Load factor earth pressure $\gamma_{mae} = 1.4$
 Load factor self weight $\gamma_{maf} = 0.9$

Wall design

Number of steps proposed in wall $\text{steps} = 4$

Step 1 Typical Analysis which is repeated for each step

Proposed height at step $h(1) = 0.45 \text{ m}$
 Proposed thickness at step $t(1) = 0.225 \text{ m}$
 Moment at height h earth $m_e = c_e * w_e * h(a)^3 / 6 = 0.2174 * 18 * 0.45^3 / 6$
 $= 0.05944 \text{ kNm}$
 surcharge $m_s = c_e * w_s * h(a)^2 / 2 = 0.2174 * 5 * 0.45^2 / 2$
 $= 0.1101 \text{ kNm}$
 Ultimate moment at height h $\mu = m_e * \gamma_{mae} + m_s * \gamma_{mas} + (x_m + x_v * h(a))$
 $* \gamma_{max}$
 $= 0.05944 * 1.4 + 0.1101 * 1.6 + (0 + 0 * 0.45)$
 $* 1.6$
 $= 0.2593$

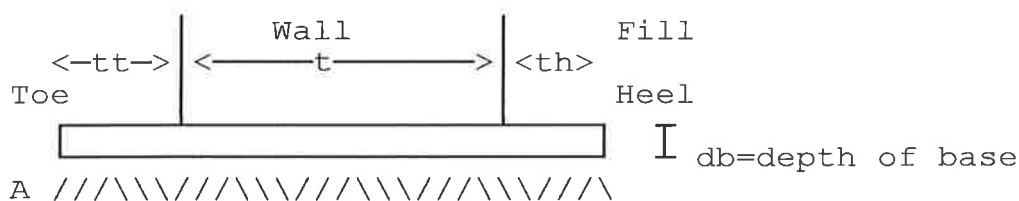
Proposed Retaining Wall at:
 Plot 22 Varteg Fawr
 Bryn
 Port Talbot

Page: 3
 Made by:
 Date: 12.12.18
 Ref No:

Section modulus at thickness t $z = t(a)^2/6 = 0.225^2/6 = 0.008438 \text{ m}^3$
 Weight/unit area at depth h $gd = (ws + we \cdot h(a)) \cdot \gamma_{maf}/1000$
 $= (5 + 18 \cdot 0.45) \cdot 0.9/1000$
 $= 0.01179 \text{ N/mm}^2$
 Moment of resistance $mr = (fb(1)/\gamma_{mam} + gd) \cdot z \cdot 1000$
 $= (0.15/3.1 + 0.01179) \cdot 0.008438 \cdot 1000$
 $= 0.5077 \text{ kNm}$
 Applied moment less than moment of resistance ($0.2593 \leq 0.5077$)
 therefore section is satisfactory.
 Step 1 width 0.225 m
 height 0.45 m

Step height (m)	Step thicknes (m)	Ultimate Moments (kNm)	
		Resistance	Applied
0.45	0.225	0.5077	0.2593
0.9	0.45	2.277	1.37
1.45	0.675	5.8	4.613
2	0.9	11.51	10.79

Stability and bearing check



Width of toe $tt = 0.25 \text{ m}$
 Width of heel $th = 0.15 \text{ m}$
 Thickness of wall $t = 0.9 \text{ m}$
 Height of wall $h = 2 \text{ m}$
 Width of base $tb = t + tt + th = 0.9 + 0.25 + 0.15$
 $= 1.3$
 Depth of base $db = 0.30 \text{ m}$
 Overall depth $od = h + db = 2 + 0.3 = 2.3 \text{ m}$
 Weight of fill and wall $wf = we \cdot (t + th) \cdot h = 18 \cdot (0.9 + 0.15) \cdot 2$
 $= 37.8 \text{ kN}$

Eccentricity from A $ef = tt + (t + th) / 2 = 0.25 + (0.9 + 0.15) / 2$
 $= 0.775 \text{ m}$

Weight of base $wb = tb * db * 24 = 1.3 * 0.3 * 24 = 9.36 \text{ kN}$

Earth horizontal force $sfe = ce * we * od^2 / 2 = 0.2174 * 18 * 2.3^2 / 2$
 $= 10.35 \text{ kN}$

Moment due to earth pressure $me = sfe * od / 3 = 10.35 * 2.3 / 3 = 7.937 \text{ kNm}$

Surcharge horizontal force $sfs = ws * ce * od = 5 * 0.2174 * 2.3$
 $= 2.501 \text{ kN}$

Moment due to surcharge $ms = sfs * od / 2 = 2.501 * 2.3 / 2 = 2.876 \text{ kNm}$

Wall shear

Horizontal shear force $usf = (sfe * gammae) + (sfs * gammas)$
 $= (10.35 * 1.4) + (2.501 * 1.6)$
 $= 18.49 \text{ kN}$

Shear stress at bottom of wall $uss = usf / (t * (steps) * 1000)$
 $= 18.49 / (0.9 * 1000)$
 $= 0.02055 \text{ N/mm}^2$

Weight at bottom of step 1 $uwt = t(a) * we * h(a) * gammaf$
 $= 0.225 * 18 * 0.45 * 0.9$
 $= 1.64 \text{ kN}$

Weight at bottom of step 2 $uwt = uwt + (t(a) * we * h(a) * gammaf)$
 $= 1.64 + (0.45 * 18 * 0.9 * 0.9)$
 $= 8.201 \text{ kN}$

Weight at bottom of step 3 $uwt = uwt + (t(a) * we * h(a) * gammaf)$
 $= 8.201 + (0.675 * 18 * 1.45 * 0.9)$
 $= 24.06 \text{ kN}$

Weight at bottom of step 4 $uwt = uwt + (t(a) * we * h(a) * gammaf)$
 $= 24.06 + (0.9 * 18 * 2 * 0.9)$
 $= 53.22 \text{ kN}$

Weight per. unit area $ga = uwt / (t * (steps) * 1000)$
 $= 53.22 / (0.9 * 1000)$
 $= 0.05913 \text{ N/mm}^2$

Permissible shear stress $fv = 0.35 + 0.6 * ga = 0.35 + 0.6 * 0.05913$
 $= 0.3855 \text{ N/mm}^2$

Applied shear less than shear resistance ($0.02055 \leq 0.3855$)
therefore section is satisfactory.

Proposed Retaining Wall at:
Plot 22 Varteg Fawr
Bryn
Port Talbot

Page: 5
Made by:
Date: 12.12.18
Ref No:

Overturning

Overturning moment about A $om = me + ms + (xm + xv * od)$
 $= 7.937 + 2.876 + (0 + 0 * 2.3)$
 $= 10.81 \text{ kNm}$

Restoring moment abt A fill/wall $rmf = wf * ef = 37.8 * 0.775 = 29.3 \text{ kNm}$
base $rmb = wb * tb / 2 = 9.36 * 1.3 / 2 = 6.084 \text{ kNm}$
surcharge $rms = ws * (t + th) * ef = 5 * (0.9 + 0.15) * 0.775$
 $= 4.069$
total $rm = rmf + rmb + rms = 29.3 + 6.084 + 4.069$
 $= 39.45$

Factor of safety $fso = rm / om = 39.45 / 10.81 = 3.648$

Sliding (passive resistance ignored)

Sliding force $sf = sfe + sfs + xv = 10.35 + 2.501 + 0$
 $= 12.85$

Details of bearing stratas
angle of friction $phib = 40^\circ$
cohesion $cu = 0 \text{ kN/m}^2$

Coefficient of friction $cf = \text{TAN}(\text{RAD}(phib * 2 / 3))$
 $= \text{TAN}(\text{RAD}(40 * 2 / 3))$
 $= 0.5022$

Resisting force fill $rff = wf * cf = 37.8 * 0.5022 = 18.98 \text{ kN}$
base $rfb = wb * cf + tb * cu / 2 = 9.36 * 0.5022 + 1.3 * 0 / 2$
 $= 4.701 \text{ kN}$
surcharge $rfs = ws * (t + th) * cf = 5 * (0.9 + 0.15) * 0.5022$
 $= 2.637 \text{ kN}$
total $rf = rff + rfb + rfs = 18.98 + 4.701 + 2.637$
 $= 26.32 \text{ kN}$

Factor of safety $fss = rf / sf = 26.32 / 12.85 = 2.048$

Bearing pressure

Weight of surcharge $sw = ws * (t + th) = 5 * (0.9 + 0.15)$
 $= 5.25 \text{ kN}$

Moments about centre of base $m = om + (wf + sw) * (tb / 2 - ef)$
 $= 10.81 + (37.8 + 5.25) * (1.3 / 2 - 0.775)$
 $= 5.431 \text{ kNm}$

Section modulus of base $zb = tb^2 / 6 = 1.3^2 / 6 = 0.2817 \text{ m}^3$

Proposed Retaining Wall at:
 Plot 22 Varteg Fawr
 Bryn
 Port Talbot

Page: 6
 Made by:
 Date: 12.12.18
 Ref No:

Total weight	$tw=wf+sw+wb=37.8+5.25+9.36$ $=52.41 \text{ kN}$
Pressure due to weight	$pw=tw/tb=52.41/1.3=40.32 \text{ kN/m}^2$
Pressure due to moment (+/-)	$pm=m/zb=5.431/0.2817=19.28 \text{ kN/m}^2$
Maximum pressure	$pmax=pw+pm=40.32+19.28=59.6 \text{ kN/m}^2$
Minimum pressure	$pmin=pw-pm=40.32-19.28=21.03 \text{ kN/m}^2$

Summary of stability check

Factor of safety overturning	3.648
Factor of safety sliding	2.048
Maximum base pressure	59.6 kN/m ²

DESIGN SUMMARY		Wall height	2 m
		Wall design	
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		Resistance	Applied
0.45	0.225	0.5077	0.2593
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