

Structural Calculations

Design Stage July 2023

FOR

MASONRY RETAINING WALL

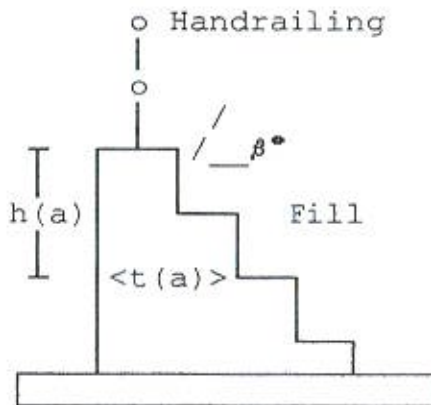
AT

GOYTRE CHURCH
EAST STREET, GOYTRE

Mr. Sam Alkarnaz BEng. C.BuildE, MCABE

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 $\phi=35^\circ$
Angle of backfill $\beta=0^\circ$
Active soil pressure is applicable.
Sine angle of internal friction $sp=\sin(\text{RAD}(\phi))=0.5736$
Active pressure coefficient $ce=(1-sp)/(1+sp)$
 $= (1-0.5736)/(1+0.5736)$
 $=0.271$

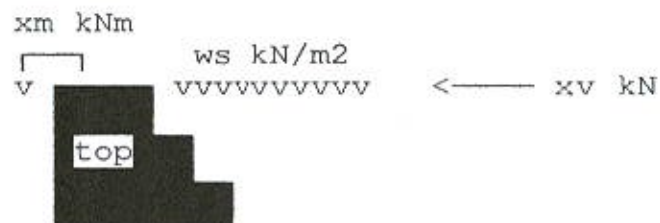
Masonry details

Mortar designation to Table 1 $\text{mortar}=3$
Masonry type (1=clay 2=calc 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 $rb=hb/lhd=215/100=2.15$
Compressive strength of blocks $po=7.3 \text{ N/mm}^2$

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Partial safety factor material $\gamma_{mm}=3.5$

External loading



Applied moment at top of wall	xm=0 kNm
Applied shear at top of wall	xv=0 kN
Weight/unit area of surcharge	ws=5 kN/m ²
Load factor external loads at top	gammax=1.6
Load factor surcharge	gammas=1.6
Load factor earth pressure	gammae=1.4
Load factor self weight	gammaf=0.9

Wall design

Number of steps proposed in wall steps=3

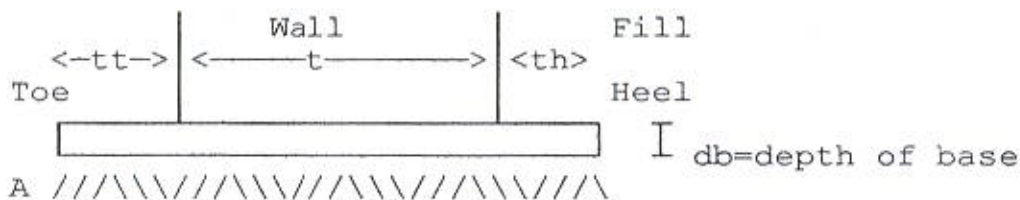
Step 1 Typical Analysis which is repeated for each step

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Proposed height at step      h(1)=0.45 m  
Proposed thickness at step   t(1)=0.325 m  
Moment at height h          earth    me=ce*we*h(a)^3/6=0.271*18*0.45^3/6  
                               =0.07408 kNm  
                             surcharge ms=ce*ws*h(a)^2/2=0.271*5*0.45^2/2  
                               =0.1372 kNm  
Ultimate moment at height h mu=me*gammae+ms*gammass+(xm+xv*h(a))  
                               *gammamax  
                               =0.07408*1.4+0.1372*1.6+(0+0*0.45)  
                               *1.6  
                               =0.3232
```

Section modulus at thickness t $z = t(a)^2/6 = 0.325^2/6 = 0.0176 \text{ m}^3$
 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 $mr = (fb(1)/\gamma_{mam} + gd) \cdot z \cdot 1000$
 $= (0.1586/3.5 + 0.01179) \cdot 0.0176 \cdot 1000$
 $= 1.005 \text{ kNm}$
 Applied moment less than moment of resistance ($0.3232 \leq 1.005$)
 therefore section is satisfactory.
 Step 1 width 0.325 m
 height 0.45 m

Step height (m)	Step thickness (m)	Ultimate Moments (kNm)	
		Resistance	Applied
0.45	0.325	1.005	0.3232
0.9	0.45	2.173	1.708
1.35	0.675	5.443	4.776

Stability and bearing check



Width of toe $tt = 0.15 \text{ m}$
 Width of heel $th = 0.15 \text{ m}$
 Thickness of wall $t = 0.675 \text{ m}$
 Height of wall $h = 1.35 \text{ m}$
 Width of base $tb = t + tt + th = 0.675 + 0.15 + 0.15$
 $= 0.975$
 Depth of base $db = 0.3 \text{ m}$
 Overall depth $od = h + db = 1.35 + 0.3 = 1.65 \text{ m}$
 Weight of fill and wall $wf = we \cdot (t + th) \cdot h = 18 \cdot (0.675 + 0.15) \cdot 1.35$
 $= 20.05 \text{ kN}$
 Eccentricity from A $ef = tt + (t + th)/2 = 0.15 + (0.675 + 0.15)/2$
 $= 0.5625 \text{ m}$

Weight of base $wb = tb * db * 24 = 0.975 * 0.3 * 24$
 $= 7.02 \text{ kN}$
Earth horizontal force $sfe = ce * we * od^2 / 2 = 0.271 * 18 * 1.65^2 / 2$
 $= 6.64 \text{ kN}$
Moment due to earth pressure $me = sfe * od / 3 = 6.64 * 1.65 / 3 = 3.652 \text{ kNm}$
Surcharge horizontal force $sfs = ws * ce * od = 5 * 0.271 * 1.65$
 $= 2.236 \text{ kN}$
Moment due to surcharge $ms = sfs * od / 2 = 2.236 * 1.65 / 2$
 $= 1.844 \text{ kNm}$

Wall shear

Horizontal shear force $usf = (sfe * gammae) + (sfs * gammas)$
 $= (6.64 * 1.4) + (2.236 * 1.6)$
 $= 12.87 \text{ kN}$
Shear stress at bottom of wall $uss = usf / (t(\text{steps}) * 1000)$
 $= 12.87 / (0.675 * 1000)$
 $= 0.01907 \text{ N/mm}^2$
Weight at bottom of step 1 $uwt = t(a) * we * h(a) * gammaf$
 $= 0.325 * 18 * 0.45 * 0.9$
 $= 2.369 \text{ kN}$
Weight at bottom of step 2 $uwt = uwt + (t(a) * we * h(a) * gammaf)$
 $= 2.369 + (0.45 * 18 * 0.9 * 0.9)$
 $= 8.93 \text{ kN}$
Weight at bottom of step 3 $uwt = uwt + (t(a) * we * h(a) * gammaf)$
 $= 8.93 + (0.675 * 18 * 1.35 * 0.9)$
 $= 23.69 \text{ kN}$
Weight per. unit area $ga = uwt / (t(\text{steps}) * 1000)$
 $= 23.69 / (0.675 * 1000)$
 $= 0.0351 \text{ N/mm}^2$
Permissible shear stress $fv = 0.15 + 0.6 * ga = 0.15 + 0.6 * 0.0351$
 $= 0.1711 \text{ N/mm}^2$

Applied shear less than shear resistance ($0.01907 \leq 0.1711$)
therefore section is satisfactory.

Overturning

Overturning moment about A	$om = me + ms + (xm + xv * od)$ $= 3.652 + 1.844 + (0 + 0 * 1.65)$ $= 5.496 \text{ kNm}$
Restoring moment abt A fill/wall	$rmf = wf * ef = 20.05 * 0.5625 = 11.28 \text{ kNm}$
base	$rmb = wb * tb / 2 = 7.02 * 0.975 / 2$ $= 3.422 \text{ kNm}$
surcharge	$rms = ws * (t + th) * ef$ $= 5 * (0.675 + 0.15) * 0.5625$ $= 2.32$
total	$rm = rmf + rmb + rms = 11.28 + 3.422 + 2.32$ $= 17.02$
Factor of safety	$fso = rm / om = 17.02 / 5.496 = 3.096$

Sliding (passive resistance ignored)

Sliding force	$sf = sfe + sfs + xv = 6.64 + 2.236 + 0$ $= 8.876$
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	$rff = wf * cf = 20.05 * 0.5022 = 10.07 \text{ kN}$
base	$rfb = wb * cf + tb * cu / 2$ $= 7.02 * 0.5022 + 0.975 * 0 / 2$ $= 3.526 \text{ kN}$
surcharge	$rfs = ws * (t + th) * cf$ $= 5 * (0.675 + 0.15) * 0.5022$ $= 2.072 \text{ kN}$
total	$rf = rff + rfb + rfs = 10.07 + 3.526 + 2.072$ $= 15.67 \text{ kN}$
Factor of safety	$fss = rf / sf = 15.67 / 8.876 = 1.765$

Proposed Masonry Retaining Wall:
 Goytre Church
 East Street
 Goytre, Port Talbot

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Bearing pressure

Weight of surcharge	$sw = ws * (t + th) = 5 * (0.675 + 0.15)$ = 4.125 kN
Moments about centre of base	$m = om + (wf + sw) * (tb / 2 - ef)$ = 5.496 + (20.05 + 4.125) * (0.975 / 2 - 0.5625) = 3.683 kNm
Section modulus of base	$zb = tb^2 / 6 = 0.975^2 / 6 = 0.1584 \text{ m}^3$
Total weight	$tw = wf + sw + wb = 20.05 + 4.125 + 7.02$ = 31.19 kN
Pressure due to weight	$pw = tw / tb = 31.19 / 0.975 = 31.99 \text{ kN/m}^2$
Pressure due to moment (+/-)	$pm = m / zb = 3.683 / 0.1584 = 23.25 \text{ kN/m}^2$
Maximum pressure	$pmax = pw + pm = 31.99 + 23.25 = 55.24 \text{ kN/m}^2$
Minimum pressure	$pmin = pw - pm = 31.99 - 23.25 = 8.744 \text{ kN/m}^2$

Summary of stability check

Factor of safety overturning	3.096
Factor of safety sliding	1.765
Maximum base pressure	55.24 kN/m ²

DESIGN SUMMARY	Wall height	1.35 m	
	Wall design		
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		Resistance	Applied
0.45	0.325	1.005	0.3232
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