

Project Mass Masonry Retaining Wall Design Bryniau Road					
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Structural Design for the design of various size mass masonry Retaining Walls

1 Introduction

Calculations by Pierre Grigorian BEng(Hons) CEng MStructE FICE

These calculations have been prepared for the design of mass masonry retaining walls for various heights up to a maximum retained height of 1.5m. The design is for typical garden type retaining walls.

2 Design Parameters

(i) Retaining wall dimensions and details are shown on Standard detail retaining wall drawing.

(ii) Maximum slope of retained material is 1 in 8. $\Theta = 7$ degrees

(iii) Retained granular material angle of internal friction $\vartheta = 35$ degrees

(iv) Density of retained material $\varphi = 18$ kN/m³

(v) Blockwork Density $\varphi = 18$ kN/m³

(vi) Blockwork compressive strength $= 7.3$ N/mm²

(vii) Brickwork Density $\varphi = 20$ kN/m³

(viii) Brickwork Strength $= 20$ N/mm²

(ix) Mortar Class (cement:lime:sand) $= (i) = (1:0 \text{ to } 1/4:3)$ Only use (i), (ii) or (iii)

(x) Concrete foundations
Mass concrete = C16/20
Reinforced foundations = C28/35

(xi) Surcharge loading $= 5$ kN/m²

(xii) Allowable Bearing Pressure $= 100$ kN/m²

(xiii) Concrete Density $= 24$ kN/m³

(xiv) Characteristic Initial Shear Strength of Masonry $f_{vko} = 0.35$ N/mm²
(BS 5628-1:2005 - Cl 21.1.2 - c) 0.15 for mortar (iii) (iv)
0.35 for mortar (i) (ii)

(xv) Basic flexural strength of blockwork, $f_{kx} = 0.35$ N/mm²
(From Table 3, BS5628:Pt 1:2005)

(xvi) Dead load factor of safety (for blockwork flexural checks) $\gamma_f = 0.9$

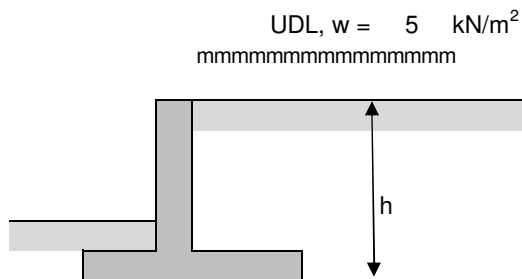
(xvii) Level of Blockwork Manufacturing Control $\gamma_m = 3.5$

(xviii) Dead load factor of safety for general applied loads $\gamma_G = 1.4$

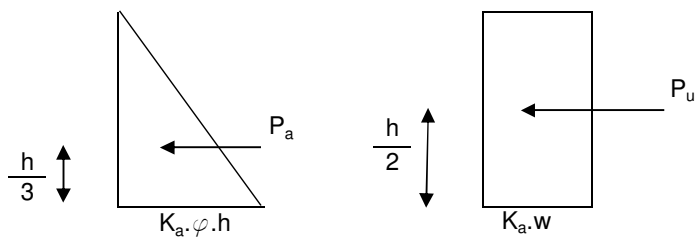
(ixx) Imposed (surcharge) load factor of safety for loads $\gamma_Q = 1.6$

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3 Lateral Pressure on Retaining Walls



Pressures acting on wall are modelled as shown below:



Horizontal thrust on wall = $P_a + P_u$

where $P_a = 0.5 \cdot K_a \cdot \phi \cdot h^2$ (Earth Pressure)

$P_u = K_a \cdot w \cdot h$ (Surcharge Pressure)

Active Earth pressure coefficient calculation

For $\Theta = 7$ degrees and for $\vartheta = 35$ degrees

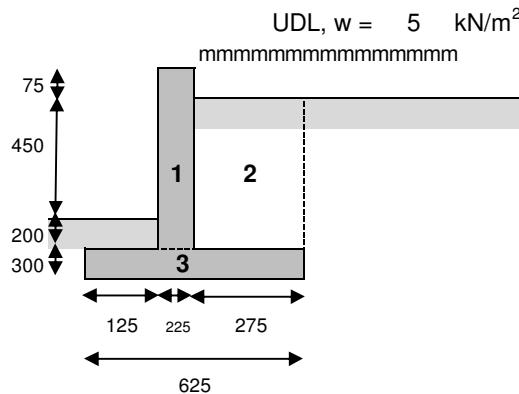
$$K_a = \cos \Theta \times \frac{\cos \Theta - (\cos^2 \Theta - \cos^2 \vartheta)^{0.5}}{\cos \Theta + (\cos^2 \Theta - \cos^2 \vartheta)^{0.5}} \quad (\text{Rankine Coeffs with inclined backfills})$$

$K_a = 0.276$

$K_a = 0.276$

These values and formulas have been used in the calculations on the following pages

4 Wall Type "A" (Max retained height = 0.45 m)



$$P_a = 0.5 \cdot K_a \cdot \phi \cdot h^2 = 0.5 \times 0.276 \times 18 \times 0.95^2 = 2.24 \text{ kN/m}$$

$$P_u = K_a \cdot w \cdot h = 0.276 \times 5.0 \times 0.95 = 1.31 \text{ kN/m}$$

Table of Forces and Moments taken about point at bottom left of footing

Wall Element	Force (kN)	Lever Arm (m)	Moment (kNm)	
			Clockwise	Anticlockwise
1	0.725 x 0.225 x 20.0 = 3.263	0.238	0.775	
2	0.650 x 0.275 x 18.0 = 3.218	0.488	1.569	
3	0.625 x 0.300 x 24.0 = 4.500	0.313	1.406	
P _a	As calculated above = 2.243	0.317		0.710
P _u	As calculated above = 1.312	0.475		0.623
Totals	Horiz. = 3.555 kN Vert = 10.980 kN		3.750	1.333
Overturning Moment Sum =			2.416 kNm	

Check Overturning F.O.S = $\frac{3.750}{1.333} = 2.81 > 2.0$ **Therefore OK**

Therefore OK

Check Sliding F.O.S = $\frac{\text{Vert Load} \times \tan \theta}{\text{Horiz Load}} = \frac{10.98 \times 0.70}{3.555} = 2.163 > 2$ **Therefore OK**

Therefore OK

Check Ground Pressure

Reaction Lever Arm, y = $\frac{\text{Sum of Moments}}{\text{Vertical Reaction}} = \frac{2.416}{10.980} = 0.22 \text{ m}$ (dist from bottom left)

Distance from reaction to centre of foundation, e = $\frac{\text{Length of footing}}{2} - y = \frac{0.625}{2} - 0.22$

$$e = 0.092 \text{ m}$$

Check Middle Third Rule: $\frac{L}{6} = \frac{0.625}{6} = 0.104 \text{ m} > 0.092 \text{ m}$ Therefore reaction lies in middle third

Maximum Ground Bearing Pressure, p_{max} = $\frac{\text{Vert Reaction}}{\text{Footing Length}} \times [1 + \frac{6 \times e}{\text{Footing Length}}]$

Maximum Ground Bearing Pressure, p_{max} = $\frac{10.980}{0.625} \times (1 + \frac{6 \times 0.092}{0.625}) = 33.16 \text{ kN/m}^2$
 $< 100 \text{ kN/m}^2$
 $< \text{Allowable, therefore OK}$

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Check Blockwork

$$\text{At base of wall } Z = \frac{b \times d^2}{6} = \frac{1000 \times 225^2}{6} = 8437500 \text{ mm}^3$$

$$\text{Self weight pressure (g}_d\text{)} = \frac{\gamma_f \times \text{Density} \times \text{Thickness} \times \text{Height}}{\text{Thickness}} = \gamma_f \times \text{Density} \times \text{Height}$$

$$\gamma_f = 0.9 \quad (\text{It should be noted that this value of } \gamma_f \text{ should be used in calculating the design vertical load})$$

$$g_d = 0.9 \times 0.725 \text{ m} \times 18 \text{ kN/m}^3 = 11.75 \text{ kN/m}^2 = 0.012 \text{ N/mm}^2$$

$$\text{Basic flexural strength of blockwork, } f_{kx} = 0.35 \text{ N/mm}^2 \quad (\text{From Table 3, BS5628:Pt 1:2005})$$

Blockwork moment Resistance with modified Blockwork flexural strength enhanced by dead weight:

$$M_R = \left[\frac{f_{kx}}{\gamma_m} + g_d \right] \times Z$$

$$M_R = \left[\frac{0.35}{3.5} + 0.012 \right] \times 8437500 = 942848.44 \text{ N.mm} = \mathbf{0.943 \text{ kNm}}$$

Applied moment with appropriate load factors for dead and imposed loads

(Note that height h is height of masonry and excludes the depth of the footing, h = 0.65 m)

$$M_o = 1.4 \left[P_a \times \frac{h}{3} \right] + 1.6 \left[P_u \times \frac{h}{2} \right]$$

where the P_a and P_u for the blockwork height of 0.65 m only, and not the height from base

$$P_a = 0.5 K_a \cdot \varphi \cdot h^2 = 0.5 \times 0.276 \times 18 \times 0.65^2 = 1.05 \text{ kN/m}$$

$$P_u = K_a \cdot w \cdot h = 0.276 \times 5.0 \times 0.65 = 0.90 \text{ kN/m}$$

$$M_o = 1.4 \left[1.05 \times \frac{0.65}{3} \right] + 1.6 \left[0.90 \times \frac{0.65}{2} \right] = \mathbf{0.785 \text{ kNm}}$$

Therefore since $0.943 (M_R) > 0.785 (M_o)$ OK

OK

Check Shear at the Base of Blockwork Wall

$$\text{Applied Shear, } F_v = (1.4 \times P_a) + (1.6 \times P_u)$$

$$\text{Applied Shear, } F_v = (1.4 \times 1.05) + (1.6 \times 0.90) = \mathbf{2.906 \text{ kN (ult)}}$$

$$\text{Contact area at base of blockwork} = 225 \text{ mm} \quad (\times 1000 \text{ mm width})$$

$$\text{Therefore average applied shear stress} = \frac{2.906 \times 1000}{225 \times 1000} = 0.013 \text{ N/mm}^2$$

Shear resistance of blockwork in horizontal direction (cl. 21.1.1 BS 5628:pt1:2005)

$$f_v = f_{vko} + 0.6g_A \quad \text{where} \quad f_{vko} = 0.35 \text{ N/mm}^2$$

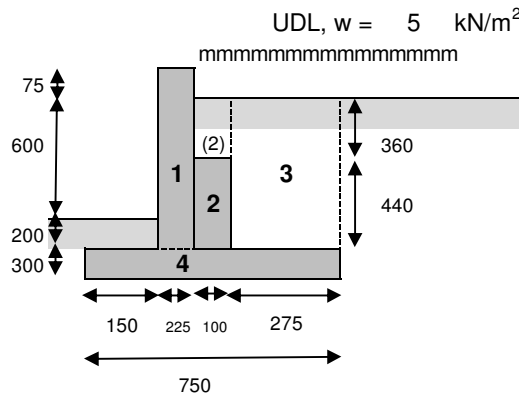
$$g_A = g_d = 0.012 \text{ N/mm}^2$$

$$f_v = 0.350 + (0.600 \times 0.012) = 0.357 \text{ N/mm}^2$$

Therefore since $0.357 (f_v) > 0.013 (F_v)$ OK

OK

5 Wall Type "B" (Max retained height = 0.6 m)



$$P_a = 0.5 \cdot K_a \cdot \phi \cdot h^2 = 0.5 \times 0.276 \times 18 \times 1.1^2 = 3.01 \text{ kN/m}$$

$$P_u = K_a \cdot w \cdot h = 0.276 \times 5.0 \times 1.1 = 1.52 \text{ kN/m}$$

Table of Forces and Moments taken about point at bottom left of footing

Wall Element	Force (kN)	Lever Arm (m)	Moment (kNm)	
			Clockwise	Anticlockwise
1	$0.875 \times 0.225 \times 20.0 = 3.938$	0.263	1.034	
2	$0.800 \times 0.100 \times 18.0 = 1.440$	0.425	0.612	
3	$0.800 \times 0.275 \times 18.0 = 3.960$	0.613	2.426	
4	$0.750 \times 0.300 \times 24.0 = 5.400$	0.375	2.025	
P_a	As calculated above = 3.007	0.367		1.103
P_u	As calculated above = 1.519	0.55		0.835
Totals	Horiz. = 4.526 kN Vert = 14.738 kN		6.096	1.938

Overturning Moment Sum = 4.158 kNm

Check Overturning F.O.S = $\frac{6.096}{1.938} = 3.15 > 2.0$ **Therefore OK**

Therefore OK

Check Sliding F.O.S = $\frac{\text{Vert Load} \times \tan \theta}{\text{Horiz Load}} = \frac{14.74 \times 0.70}{4.526} = 2.28 > 2$ **Therefore OK**

Therefore OK

Check Ground Pressure

Reaction Lever Arm, $y = \frac{\text{Sum of Moments}}{\text{Vertical Reaction}} = \frac{4.158}{14.738} = 0.282 \text{ m}$ (dist from bottom left)

Distance from reaction to centre of foundation, $e = \frac{\text{Length of footing}}{2} - y = \frac{0.75}{2} - 0.282$

$e = 0.093 \text{ m}$

Check Middle Third Rule: $\frac{L}{6} = \frac{0.75}{6} = 0.125 \text{ m} > 0.093 \text{ m}$ Therefore reaction lies in middle third

Maximum Ground Bearing Pressure, $p_{\max} = \frac{\text{Vert Reaction}}{\text{Footing Length}} \times \left[1 + \frac{6 \times e}{\text{Footing Length}} \right]$

Maximum Ground Bearing Pressure, $p_{\max} = \frac{14.738}{0.75} \times \left(1 + \frac{6 \times 0.093}{0.75} \right) = 34.25 \text{ kN/m}^2$
 $< 100 \text{ kN/m}^2$
 $< \text{Allowable, therefore OK}$

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Check Blockwork

$$\text{At base of wall } Z = \frac{b \times d^2}{6} = \frac{1000 \times 325^2}{6} = 17604167 \text{ mm}^3$$

$$\text{Self weight pressure (g}_d\text{)} = \frac{\gamma_f \times \text{Density} \times \text{Thickness} \times \text{Height}}{\text{Thickness}} = \gamma_f \times \text{Density} \times \text{Height}$$

$$\gamma_f = 0.9 \quad (\text{It should be noted that this value of } \gamma_f \text{ should be used in calculating the design vertical load})$$

$$g_d = 0.9 \times 0.8 \text{ m} \times 18 \text{ kN/m}^3 = 12.96 \text{ kN/m}^2 = 0.013 \text{ N/mm}^2$$

$$\text{Basic flexural strength of blockwork, } f_{kx} = 0.35 \text{ N/mm}^2 \quad (\text{From Table 3, BS5628:Pt 1:2005})$$

Blockwork moment Resistance with modified Blockwork flexural strength enhanced by dead weight:

$$M_R = \left[\frac{f_{kx}}{\gamma_m} + g_d \right] \times Z$$

$$M_R = \left[\frac{0.35}{3.5} + 0.013 \right] \times 17604167 = 1988566.7 \text{ N.mm} = \mathbf{1.989 \text{ kNm}}$$

Applied moment with appropriate load factors for dead and imposed loads

(Note that height h is height of masonry and excludes the depth of the footing, h = 0.8 m)

$$M_o = 1.4 \left[P_a \times \frac{h}{3} \right] + 1.6 \left[P_u \times \frac{h}{2} \right]$$

where the P_a and P_u for the blockwork height of 0.8 m only, and not the height from base

$$P_a = 0.5 K_a \cdot \varphi \cdot h^2 = 0.5 \times 0.276 \times 18 \times 0.8^2 = 1.59 \text{ kN/m}$$

$$P_u = K_a \cdot w \cdot h = 0.276 \times 5.0 \times 0.8 = 1.10 \text{ kN/m}$$

$$M_o = 1.4 \left[1.59 \times \frac{0.8}{3} \right] + 1.6 \left[1.10 \times \frac{0.8}{2} \right] = \mathbf{1.301 \text{ kNm}}$$

Therefore since $1.989 (M_R) > 1.301 (M_o)$ OK

OK

Check Shear at the Base of Blockwork Wall

$$\text{Applied Shear, } F_v = (1.4 \times P_a) + (1.6 \times P_u)$$

$$\text{Applied Shear, } F_v = (1.4 \times 1.59) + (1.6 \times 1.10) = \mathbf{3.994 \text{ kN (ult)}}$$

$$\text{Contact area at base of blockwork} = 225 \text{ mm} \quad (\times 1000 \text{ mm width})$$

$$\text{Therefore average applied shear stress} = \frac{3.994 \times 1000}{225 \times 1000} = 0.018 \text{ N/mm}^2$$

Shear resistance of blockwork in horizontal direction (cl. 21.1.1 BS 5628:pt1:2005)

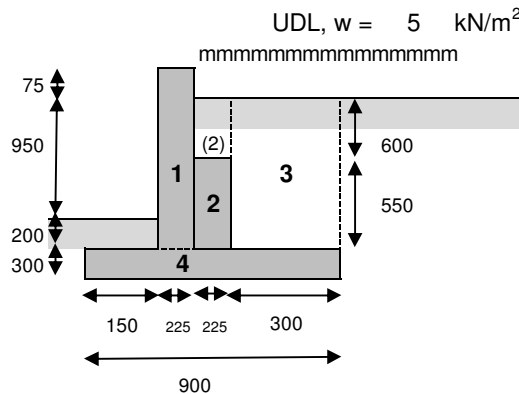
$$f_v = f_{vko} + 0.6g_A \quad \text{where} \quad f_{vko} = 0.35 \text{ N/mm}^2$$

$$g_A = g_d = 0.013 \text{ N/mm}^2$$

$$f_v = 0.350 + (0.600 \times 0.013) = 0.358 \text{ N/mm}^2$$

Therefore since $0.358 (f_v) > 0.018 (F_v)$ OK

6 Wall Type "C" (Max retained height = 0.9 m)



$$P_a = 0.5 \cdot K_a \cdot \phi \cdot h^2 = 0.5 \times 0.276 \times 18 \times 1.45^2 = 5.23 \text{ kN/m}$$

$$P_u = K_a \cdot w \cdot h = 0.276 \times 5.0 \times 1.45 = 2.00 \text{ kN/m}$$

Table of Forces and Moments taken about point at bottom left of footing

Wall Element	Force (kN)	Lever Arm (m)	Moment (kNm)	
			Clockwise	Anticlockwise
1	1.225 x 0.225 x 20.0 = 5.513	0.263	1.447	
2	1.150 x 0.225 x 18.0 = 4.658	0.488	2.271	
3	1.150 x 0.300 x 18.0 = 6.210	0.750	4.658	
4	0.900 x 0.300 x 24.0 = 6.480	0.450	2.916	
P _a	As calculated above = 5.225	0.483		2.526
P _u	As calculated above = 2.002	0.725		1.451
Totals	Horiz. = 7.227 kN Vert = 22.860 kN		11.291	3.977

Overturning Moment Sum = 7.314 kNm

Check Overturning F.O.S = $\frac{11.291}{3.977} = 2.84 > 2.0$ **Therefore OK**

Therefore OK

Check Sliding F.O.S = $\frac{\text{Vert Load} \times \tan \theta}{\text{Horiz Load}} = \frac{22.86 \times 0.70}{7.227} = 2.215 > 2$ **Therefore OK**

Therefore OK

Check Ground Pressure

Reaction Lever Arm, y = $\frac{\text{Sum of Moments}}{\text{Vertical Reaction}} = \frac{7.314}{22.860} = 0.32 \text{ m}$ (dist from bottom left)

Distance from reaction to centre of foundation, e = $\frac{\text{Length of footing}}{2} - y = \frac{0.9}{2} - 0.32$

e = 0.13 m

Check Middle Third Rule: $\frac{L}{6} = \frac{0.9}{6} = 0.15 \text{ m} > 0.13 \text{ m}$ Therefore reaction lies in middle third

Maximum Ground Bearing Pressure, p_{max} = $\frac{\text{Vert Reaction}}{\text{Footing Length}} \times \left[1 + \frac{6 \times e}{\text{Footing Length}} \right]$

Maximum Ground Bearing Pressure, p_{max} = $\frac{22.860}{0.9} \times \left(1 + \frac{6 \times 0.13}{0.9} \right) = 47.42 \text{ kN/m}^2$
 < 100 kN/m²
 < Allowable, therefore OK

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Check Blockwork

$$\text{At base of wall } Z = \frac{b \times d^2}{6} = \frac{1000 \times 450^2}{6} = 33750000 \text{ mm}^3$$

$$\text{Self weight pressure (g}_d\text{)} = \frac{\gamma_f \times \text{Density} \times \text{Thickness} \times \text{Height}}{\text{Thickness}} = \gamma_f \times \text{Density} \times \text{Height}$$

$$\gamma_f = 0.9 \quad (\text{It should be noted that this value of } \gamma_f \text{ should be used in calculating the design vertical load})$$

$$g_d = 0.9 \times 1.15 \text{ m} \times 18 \text{ kN/m}^3 = 18.63 \text{ kN/m}^2 = 0.019 \text{ N/mm}^2$$

$$\text{Basic flexural strength of blockwork, } f_{kx} = 0.35 \text{ N/mm}^2 \quad (\text{From Table 3, BS5628:Pt 1:2005})$$

Blockwork moment Resistance with modified Blockwork flexural strength enhanced by dead weight:

$$M_R = \left[\frac{f_{kx}}{\gamma_m} + g_d \right] \times Z$$

$$M_R = \left[\frac{0.35}{3.5} + 0.019 \right] \times 33750000 = 4003762.5 \text{ N.mm} = \mathbf{4.004 \text{ kNm}}$$

Applied moment with appropriate load factors for dead and imposed loads

(Note that height h is height of masonry and excludes the depth of the footing, h = 1.15 m)

$$M_o = 1.4 \left[P_a \times \frac{h}{3} \right] + 1.6 \left[P_u \times \frac{h}{2} \right]$$

where the P_a and P_u for the blockwork height of 1.15 m only, and not the height from base

$$P_a = 0.5 K_a \cdot \varphi \cdot h^2 = 0.5 \times 0.276 \times 18 \times 1.15^2 = 3.29 \text{ kN/m}$$

$$P_u = K_a \cdot w \cdot h = 0.276 \times 5.0 \times 1.15 = 1.59 \text{ kN/m}$$

$$M_o = 1.4 \left[3.29 \times \frac{1.15}{3} \right] + 1.6 \left[1.59 \times \frac{1.15}{2} \right] = \mathbf{3.225 \text{ kNm}}$$

Therefore since $4.004 (M_R) > 3.225 (M_o)$ OK

OK

Check Shear at the Base of Blockwork Wall

$$\text{Applied Shear, } F_v = (1.4 \times P_a) + (1.6 \times P_u)$$

$$\text{Applied Shear, } F_v = (1.4 \times 3.29) + (1.6 \times 1.59) = \mathbf{7.142 \text{ kN (ult)}}$$

$$\text{Contact area at base of blockwork} = 225 \text{ mm} \quad (\times 1000 \text{ mm width})$$

$$\text{Therefore average applied shear stress} = \frac{7.142 \times 1000}{225 \times 1000} = 0.032 \text{ N/mm}^2$$

Shear resistance of blockwork in horizontal direction (cl. 21.1.1 BS 5628:pt1:2005)

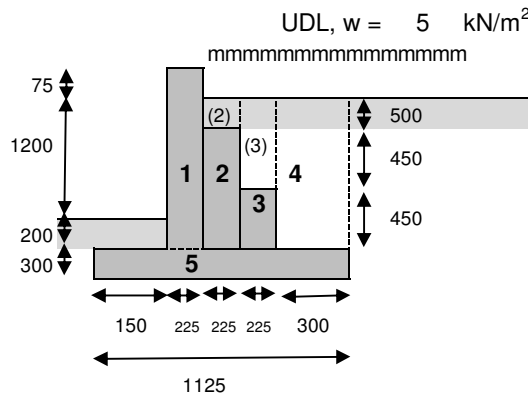
$$f_v = f_{vko} + 0.6g_A \quad \text{where} \quad f_{vko} = 0.35 \text{ N/mm}^2$$

$$g_A = g_d = 0.019 \text{ N/mm}^2$$

$$f_v = 0.350 + (0.600 \times 0.019) = 0.361 \text{ N/mm}^2$$

Therefore since $0.361 (f_v) > 0.032 (F_v)$ OK

7 Wall Type "D" (Max retained height = 1.2 m)



$$P_a = 0.5 \cdot K_a \cdot \phi \cdot h^2 = 0.5 \times 0.276 \times 18 \times 1.7^2 = 7.18 \text{ kN/m}$$

$$P_u = K_a \cdot w \cdot h = 0.276 \times 5.0 \times 1.7 = 2.35 \text{ kN/m}$$

Table of Forces and Moments taken about point at bottom left of footing

Wall Element	Force (kN)	Lever Arm (m)	Moment (kNm)	
			Clockwise	Anticlockwise
1	1.475 x 0.225 x 20.0 = 6.638	0.263	1.742	
2	1.400 x 0.225 x 18.0 = 5.670	0.488	2.764	
3	1.400 x 0.225 x 18.0 = 5.670	0.713	4.040	
4	1.400 x 0.300 x 18.0 = 7.560	0.975	7.371	
5	1.125 x 0.300 x 24.0 = 8.100	0.563	4.556	
P _a	As calculated above = 7.182	0.567		4.070
P _u	As calculated above = 2.347	0.85		1.995
Totals	Horiz. = 9.529 kN Vert = 33.638 kN		20.474	6.065
Overturning Moment Sum =			14.409 kNm	

Check Overturning F.O.S = $\frac{20.474}{6.065} = 3.38 > 2.0$ **Therefore OK** Therefore OK

Check Sliding F.O.S = $\frac{\text{Vert Load} \times \tan \theta}{\text{Horiz Load}} = \frac{33.64 \times 0.70}{9.529} = 2.472 > 2$ **Therefore OK** Therefore OK

Check Ground Pressure

Reaction Lever Arm, y = $\frac{\text{Sum of Moments}}{\text{Vertical Reaction}} = \frac{14.409}{33.638} = 0.428 \text{ m}$ (dist from bottom left)

Distance from reaction to centre of foundation, e = $\frac{\text{Length of footing}}{2} - y = \frac{1.125}{2} - 0.428$
 $e = 0.134 \text{ m}$

Check Middle Third Rule: $\frac{L}{6} = \frac{1.125}{6} = 0.188 \text{ m} > 0.134 \text{ m}$ Therefore reaction lies in middle third

Maximum Ground Bearing Pressure, p_{max} = $\frac{\text{Vert Reaction}}{\text{Footing Length}} \times [1 + \frac{6 \times e}{\text{Footing Length}}]$

Maximum Ground Bearing Pressure, p_{max} = $\frac{33.638}{1.125} \times (1 + \frac{6 \times 0.134}{1.125}) = 51.29 \text{ kN/m}^2$
 $< 100 \text{ kN/m}^2$
 < Allowable, therefore OK

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Check Blockwork

$$\text{At base of wall } Z = \frac{b \times d^2}{6} = \frac{1000 \times 675^2}{6} = 75937500 \text{ mm}^3$$

$$\text{Self weight pressure (g}_d\text{)} = \frac{\gamma_f \times \text{Density} \times \text{Thickness} \times \text{Height}}{\text{Thickness}} = \gamma_f \times \text{Density} \times \text{Height}$$

$$\gamma_f = 0.9 \quad (\text{It should be noted that this value of } \gamma_f \text{ should be used in calculating the design vertical load})$$

$$g_d = 0.9 \times 1.4 \text{ m} \times 18 \text{ kN/m}^3 = 22.68 \text{ kN/m}^2 = 0.023 \text{ N/mm}^2$$

$$\text{Basic flexural strength of blockwork, } f_{kx} = 0.35 \text{ N/mm}^2 \quad (\text{From Table 3, BS5628:Pt 1:2005})$$

Blockwork moment Resistance with modified Blockwork flexural strength enhanced by dead weight:

$$M_R = \left[\frac{f_{kx}}{\gamma_m} + g_d \right] \times Z$$

$$M_R = \left[\frac{0.35}{3.5} + 0.023 \right] \times 75937500 = 9316012.5 \text{ N.mm} = \mathbf{9.316 \text{ kNm}}$$

Applied moment with appropriate load factors for dead and imposed loads

(Note that height h is height of masonry and excludes the depth of the footing, h = 1.4 m)

$$M_o = 1.4 \left[P_a \times \frac{h}{3} \right] + 1.6 \left[P_u \times \frac{h}{2} \right]$$

where the P_a and P_u for the blockwork height of 1.4 m only, and not the height from base

$$P_a = 0.5 K_a \cdot \varphi \cdot h^2 = 0.5 \times 0.276 \times 18 \times 1.4^2 = 4.87 \text{ kN/m}$$

$$P_u = K_a \cdot w \cdot h = 0.276 \times 5.0 \times 1.4 = 1.93 \text{ kN/m}$$

$$M_o = 1.4 \left[4.87 \times \frac{1.4}{3} \right] + 1.6 \left[1.93 \times \frac{1.4}{2} \right] = \mathbf{5.347 \text{ kNm}}$$

Therefore since $9.316 (M_R) > 5.347 (M_o)$ OK

OK

Check Shear at the Base of Blockwork Wall

$$\text{Applied Shear, } F_v = (1.4 \times P_a) + (1.6 \times P_u)$$

$$\text{Applied Shear, } F_v = (1.4 \times 4.87) + (1.6 \times 1.93) = \mathbf{9.912 \text{ kN (ult)}}$$

$$\text{Contact area at base of blockwork} = 225 \text{ mm} \quad (\times 1000 \text{ mm width})$$

$$\text{Therefore average applied shear stress} = \frac{9.912 \times 1000}{225 \times 1000} = 0.044 \text{ N/mm}^2$$

Shear resistance of blockwork in horizontal direction (cl. 21.1.1 BS 5628:pt1:2005)

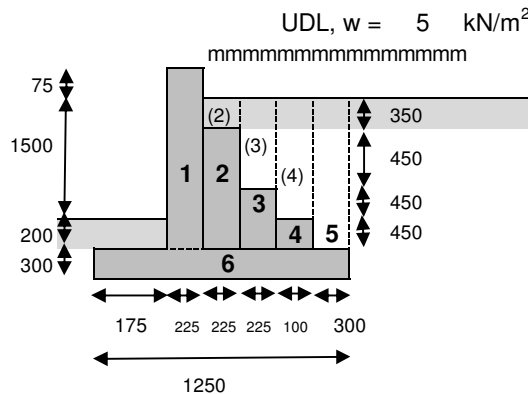
$$f_v = f_{vko} + 0.6g_A \quad \text{where} \quad f_{vko} = 0.35 \text{ N/mm}^2$$

$$g_A = g_d = 0.023 \text{ N/mm}^2$$

$$f_v = 0.350 + (0.600 \times 0.023) = 0.364 \text{ N/mm}^2$$

Therefore since $0.364 (f_v) > 0.044 (F_v)$ OK

8 Wall Type "E" (Max retained height = 1.5 m)



$$P_a = 0.5 \cdot K_a \cdot \phi \cdot h^2 = 0.5 \times 0.276 \times 18 \times 2^2 = 9.94 \text{ kN/m}$$

$$P_u = K_a \cdot w \cdot h = 0.276 \times 5.0 \times 2 = 2.76 \text{ kN/m}$$

Table of Forces and Moments taken about point at bottom left of footing

Wall Element	Force (kN)	Lever Arm (m)	Moment (kNm)	
			Clockwise	Anticlockwise
1	1.775 x 0.225 x 20.0 = 7.988	0.288	2.296	
2	1.700 x 0.225 x 18.0 = 6.885	0.513	3.529	
3	1.700 x 0.225 x 18.0 = 6.885	0.738	5.078	
4	1.700 x 0.100 x 18.0 = 3.060	0.900	2.754	
5	1.700 x 0.300 x 18.0 = 9.180	1.100	10.098	
6	1.250 x 0.300 x 24.0 = 9.000	0.625	5.625	
P _a	As calculated above = 9.941	0.667		6.627
P _u	As calculated above = 2.761	1		2.761
Totals	Horiz. = 12.702 kN Vert = 42.998 kN		29.380	9.389

Overturning Moment Sum = 19.991 kNm

Check Overturning F.O.S = $\frac{29.380}{9.389} = 3.13 > 2.0$ **Therefore OK**

Therefore OK

Check Sliding F.O.S = $\frac{\text{Vert Load} \times \tan \theta}{\text{Horiz Load}} = \frac{43.00 \times 0.70}{12.702} = 2.37 > 2$ **Therefore OK**

Therefore OK

Check Ground Pressure

Reaction Lever Arm, y = $\frac{\text{Sum of Moments}}{\text{Vertical Reaction}} = \frac{19.991}{42.998} = 0.465 \text{ m}$ (dist from bottom left)

Distance from reaction to centre of foundation, e = $\frac{\text{Length of footing}}{2} - y = \frac{1.25}{2} - 0.465$
e = 0.16 m

Check Middle Third Rule: $\frac{L}{6} = \frac{1.25}{6} = 0.208 \text{ m} > 0.16 \text{ m}$ Therefore reaction lies in middle third

Maximum Ground Bearing Pressure, p_{max} = $\frac{\text{Vert Reaction}}{\text{Footing Length}} \times \left[1 + \frac{6 \times e}{\text{Footing Length}} \right]$

Maximum Ground Bearing Pressure, p_{max} = $\frac{42.998}{1.25} \times \left(1 + \frac{6 \times 0.16}{1.25} \right) = 60.83 \text{ kN/m}^2$
< 100 kN/m²
< Allowable, therefore OK

Project					
Mass Masonry Retaining Wall Design Bryniau Road					
Date	Calc by	Checked	Job no.	Sheet no.	
Dec '19	PHG	AA	1982	12	

Check Blockwork

$$\text{At base of wall } Z = \frac{b \times d^2}{6} = \frac{1000 \times 675^2}{6} = 75937500 \text{ mm}^3$$

$$\text{Self weight pressure (g}_d\text{)} = \frac{\gamma_f \times \text{Density} \times \text{Thickness} \times \text{Height}}{\text{Thickness}} = \gamma_f \times \text{Density} \times \text{Height}$$

$$\gamma_f = 0.9 \quad (\text{It should be noted that this value of } \gamma_f \text{ should be used in calculating the design vertical load})$$

$$g_d = 0.9 \times 1.7 \text{ m} \times 18 \text{ kN/m}^3 = 27.54 \text{ kN/m}^2 = 0.028 \text{ N/mm}^2$$

$$\text{Basic flexural strength of blockwork, } f_{kx} = 0.35 \text{ N/mm}^2 \quad (\text{From Table 3, BS5628:Pt 1:2005})$$

Blockwork moment Resistance with modified Blockwork flexural strength enhanced by dead weight:

$$M_R = \left[\frac{f_{kx}}{\gamma_m} + g_d \right] \times Z$$

$$M_R = \left[\frac{0.35}{3.5} + 0.028 \right] \times 75937500 = 9685068.8 \text{ N.mm} = \mathbf{9.685 \text{ kNm}}$$

Applied moment with appropriate load factors for dead and imposed loads

(Note that height h is height of masonry and excludes the depth of the footing, h = 1.7 m)

$$M_o = 1.4 \left[P_a \times \frac{h}{3} \right] + 1.6 \left[P_u \times \frac{h}{2} \right]$$

where the P_a and P_u for the blockwork height of 1.7 m only, and not the height from base

$$P_a = 0.5 K_a \cdot \gamma \cdot h^2 = 0.5 \times 0.276 \times 18 \times 1.7^2 = 7.18 \text{ kN/m}$$

$$P_u = K_a \cdot w \cdot h = 0.276 \times 5.0 \times 1.7 = 2.35 \text{ kN/m}$$

$$M_o = 1.4 \left[7.18 \times \frac{1.7}{3} \right] + 1.6 \left[2.35 \times \frac{1.7}{2} \right] = \mathbf{8.89 \text{ kNm}}$$

Therefore since $9.685 (M_R) > 8.89 (M_o)$ OK

OK

Check Shear at the Base of Blockwork Wall

$$\text{Applied Shear, } F_v = (1.4 \times P_a) + (1.6 \times P_u)$$

$$\text{Applied Shear, } F_v = (1.4 \times 7.18) + (1.6 \times 2.35) = \mathbf{13.81 \text{ kN (ult)}}$$

$$\text{Contact area at base of blockwork} = 225 \text{ mm} \quad (\times 1000 \text{ mm width})$$

$$\text{Therefore average applied shear stress} = \frac{13.81 \times 1000}{225 \times 1000} = 0.061 \text{ N/mm}^2$$

Shear resistance of blockwork in horizontal direction (cl. 21.1.1 BS 5628:pt1:2005)

$$f_v = f_{vko} + 0.6g_A \quad \text{where} \quad f_{vko} = 0.35 \text{ N/mm}^2$$

$$g_A = g_d = 0.028 \text{ N/mm}^2$$

$$f_v = 0.350 + (0.600 \times 0.028) = 0.367 \text{ N/mm}^2$$

Therefore since $0.367 (f_v) > 0.061 (F_v)$ OK