

|                                                                                     |         |         |         |           |                                                                                    |
|-------------------------------------------------------------------------------------|---------|---------|---------|-----------|------------------------------------------------------------------------------------|
| Project                                                                             |         |         |         |           |  |
| <h1 style="text-align: center; color: red;">Mass Masonry Retaining Wall Design</h1> |         |         |         |           |                                                                                    |
| Date                                                                                | Calc by | Checked | Job no. | Sheet no. |                                                                                    |
| Mar '24                                                                             | WW      | PHG     | 2336    | 1         |                                                                                    |

## Structural Design for the design of various size mass masonry Retaining Walls

### 1 Introduction

The design of garden retaining walls up to a maximum height of 1.2m

### 2 Design Parameters

Wall Construction: Concrete Blocks

Wall Thickness: Walls of any thickness

(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/m<sup>3</sup>

(v) Blockwork Density  $\varphi =$  18 kN/m<sup>3</sup>

(vi) Blockwork compressive strength  $=$  10.4 N/mm<sup>2</sup>

(vii) Brickwork Density  $\varphi =$  20 kN/m<sup>3</sup>

(viii) Brickwork Strength  $=$  20 N/mm<sup>2</sup>

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

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

(xi) Surcharge loading  $=$  2.5 kN/m<sup>2</sup>

(xii) Allowable Bearing Pressure  $=$  50 kN/m<sup>2</sup>

(xiii) Concrete Density  $=$  24 kN/m<sup>3</sup>

(xiv) Characteristic Initial Shear Strength of Masonry  $f_{vk0} =$  0.35 N/mm<sup>2</sup>  
(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,  $f_{kx} =$  0.25 N/mm<sup>2</sup>  
(From Table 3, BS5628:Pt 1:2005)

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

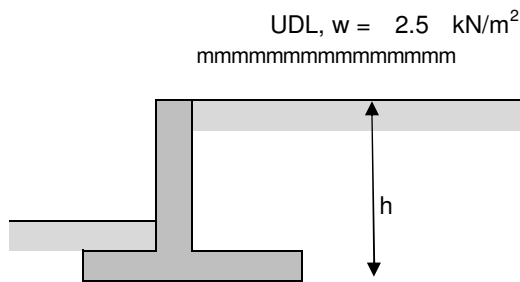
(xvii) Level of Blockwork Manufacturing Control  $\gamma_m =$  3.5

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

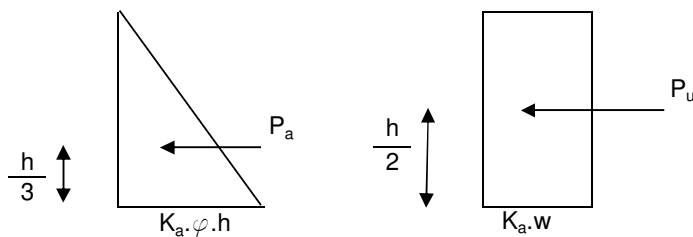
(ixx) Imposed (surcharge) load factor of safety for loads  $\gamma_Q =$  1.6

(xx) Overturning FOS 2.0 Sliding FOS 2.0

### **3 Lateral Pressure on Retaining Walls**



Pressures acting on wall are modelled as shown below:



$$\text{Horizontal thrust on wall} = P_a + P_u$$

where  $P_a = 0.5.K_a.\varphi.h^2$  (Earth Pressure)

$$P_u = K_a \cdot w \cdot h \quad (\text{Surcharge Pressure})$$

### Active Earth pressure coefficient calculation

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

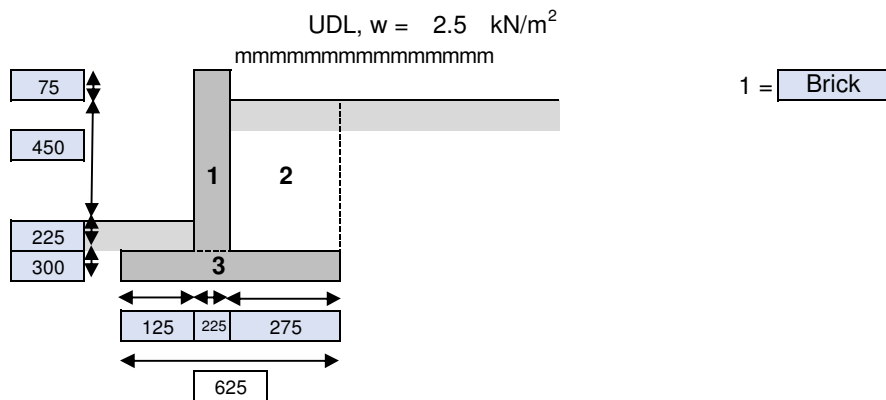
$$K_a = \frac{\cos(\theta) \times \cos(\theta - (\cos^2 \theta - \cos^2 \psi)^{0.5}}{\cos(\theta) + (\cos^2 \theta - \cos^2 \psi)^{0.5}} \quad (\text{Rankine Coeffs with inclined backfills})$$

$$K_a = 0.276$$

$$K_a = 0.276$$

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

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



$$P_a = 0.5 \cdot K_a \cdot \phi \cdot h^2 = 0.5 \times 0.276 \times 18 \times 0.98^2 = \mathbf{2.36 \text{ kN/m}}$$

$$P_u = K_a \cdot w \cdot h = 0.276 \times 2.5 \times 0.98 = \mathbf{0.67 \text{ kN/m}}$$

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

| Wall Element   | Force (kN/m)                          | Lever Arm (m) | Moment (kNm/m) |               |
|----------------|---------------------------------------|---------------|----------------|---------------|
|                |                                       |               | Clockwise      | Anticlockwise |
| 1              | 0.750 x 0.225 x 20.0 = <b>3.375</b>   | 0.238         | 0.802          |               |
| 2              | 0.675 x 0.275 x 18.0 = <b>3.341</b>   | 0.488         | 1.629          |               |
| 3              | 0.625 x 0.300 x 24.0 = <b>4.500</b>   | 0.313         | 1.406          |               |
| P <sub>a</sub> | As calculated above = <b>2.36</b>     | 0.325         |                | 0.768         |
| P <sub>u</sub> | As calculated above = <b>0.67</b>     | 0.488         |                | 0.328         |
| Totals         | Horiz. = 3.036 kN    Vert = 11.216 kN |               | <b>3.837</b>   | <b>1.096</b>  |

Overturning Moment Sum = 2.741 kNm

Check Overturning

$$\text{F.O.S} = \frac{3.837}{1.096} = \mathbf{3.50} > \mathbf{2.0} \quad \text{Therefore OK}$$

Therefore OK

Check Sliding

$$\text{F.O.S} = \frac{\text{Vert Load} \times \tan \Theta}{\text{Horiz Load}} = \frac{11.22 \times 0.70}{3.036} = \mathbf{2.587} > \mathbf{2.0}$$

**Therefore OK**

Therefore OK

Check Ground Pressure

Reaction Lever Arm, y =  $\frac{\text{Sum of Moments}}{\text{Vertical Reaction}} = \frac{2.741}{11.216} = 0.244 \text{ m}$  (dist from bottom left)

Distance from reaction to centre of foundation, e =  $\frac{\text{Length of footing}}{2} - y = \frac{0.625}{2} - 0.244$

e = 0.068 m

Check Middle Third Rule:  $\frac{L}{6} = \frac{0.625}{6} = 0.104 \text{ m} > 0.068 \text{ m}$     Therefore reaction lies in middle third

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

Maximum Ground Bearing Pressure, p<sub>max</sub> =  $\frac{11.216}{0.625} \times \frac{(1 + 6 \times 0.068)}{0.625} = \mathbf{29.69 \text{ kN/m}^2}$

< 50 kN/m<sup>2</sup>  
< Allowable, therefore OK

|                                    |         |         |         |           |                                                                                    |
|------------------------------------|---------|---------|---------|-----------|------------------------------------------------------------------------------------|
| Project                            |         |         |         |           |  |
| Mass Masonry Retaining Wall Design |         |         |         |           |                                                                                    |
| Date                               | Calc by | Checked | Job no. | Sheet no. |                                                                                    |
| Mar '24                            | WW      | PHG     | 2336    | 4         |                                                                                    |

### Check Blockwork

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

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

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

$$g_d = 0.9 \times 0.75 \text{ m} \times 18 \text{ kN/m}^3 = 12.15 \text{ kN/m}^2 = 0.012 \text{ N/mm}^2$$

$$\text{Basic flexural strength of blockwork, } f_{kx} = 0.25 \text{ N/mm}^2 \quad (\text{From Table 3, BS5628:Pt 1:2005})$$

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

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

$$M_R = \left[ \frac{0.25}{3.5} + 0.012 \right] \times 8437500 = 705194.2 \text{ N.mm} = \mathbf{0.705 \text{ kNm}}$$

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 = 0.675 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 Pa and Pu for the blockwork height of 0.675 m only, and not the height from base

$$P_a = 0.5 K_a \cdot \varphi \cdot h^2 = 0.5 \times 0.276 \times 18 \times 0.675^2 = 1.13 \text{ kN/m}$$

$$P_u = K_a \cdot w \cdot h = 0.276 \times 2.5 \times 0.675 = 0.47 \text{ kN/m}$$

$$M_o = 1.4 \left[ 1.13 \times \frac{0.675}{3} \right] + 1.6 \left[ 0.47 \times \frac{0.675}{2} \right] = \mathbf{0.608 \text{ kNm}}$$

Therefore since  $0.705 (M_R) > 0.608 (M_o)$  OK

OK

### Check Shear at the Base of Blockwork Wall

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

$$\text{Applied Shear, } F_v = (1.4 \times 1.13) + (1.6 \times 0.47) = \mathbf{2.331 \text{ kN (ult)}}$$

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

$$\text{Therefore average applied shear stress} = \frac{2.331 \times 1000}{225 \times 1000} = 0.01 \text{ N/mm}^2$$

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

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

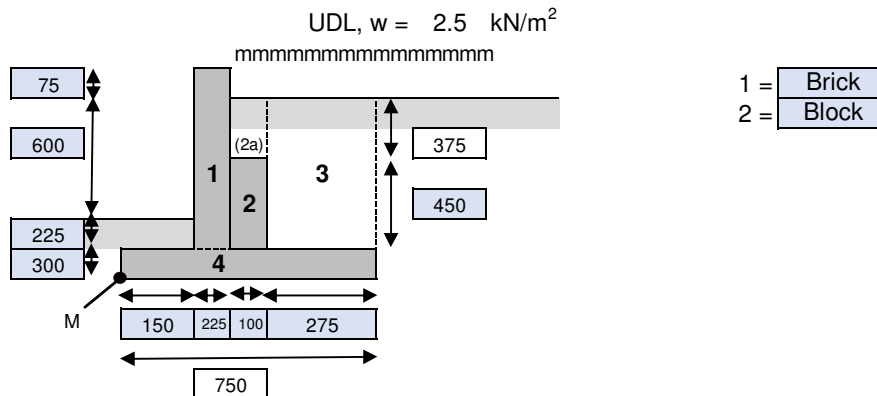
$$g_A = g_d = 0.012 \text{ N/mm}^2$$

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

Therefore since  $0.357 (f_v) > 0.01 (F_v)$  OK

OK

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



$$P_a = 0.5 \cdot K_a \cdot \phi \cdot h^2 = 0.5 \times 0.276 \times 18 \times 1.13^2 = \mathbf{3.15 \text{ kN/m}}$$

$$P_u = K_a \cdot w \cdot h = 0.276 \times 2.5 \times 1.13 = 0.78 \text{ kN/m}$$

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

| Wall Element             | Force (kN/m)                            | Lever Arm (m) | Moment (kNm/m) |               |
|--------------------------|-----------------------------------------|---------------|----------------|---------------|
|                          |                                         |               | Clockwise      | Anticlockwise |
| 1                        | 0.900 x 0.225 x 20.0 = <b>4.050</b>     | 0.263         | 1.063          | 1.180         |
| 2                        | 0.450 x 0.100 x 18.0 = <b>0.810</b>     | 0.425         | 0.344          |               |
| 2a                       | 0.375 x 0.100 x 18.0 = <b>0.675</b>     | 0.425         | 0.287          |               |
| 3                        | 0.825 x 0.275 x 18.0 = <b>4.084</b>     | 0.613         | 2.501          |               |
| 4                        | 0.750 x 0.300 x 24.0 = <b>5.400</b>     | 0.375         | 2.025          |               |
| P <sub>a</sub>           | As calculated above = <b>3.145</b>      | 0.375         |                |               |
| P <sub>u</sub>           | As calculated above = <b>0.777</b>      | 0.563         |                |               |
| Totals                   | Horiz. = 3.922 kN      Vert = 15.019 kN |               | <b>6.221</b>   | <b>1.616</b>  |
| Overturning Moment Sum = |                                         |               | 4.604 kNm      |               |

|                          |                                            |              |
|--------------------------|--------------------------------------------|--------------|
| <u>Check Overturning</u> | F.O.S = $\frac{6.221}{1.616} = 3.85 > 2.0$ | Therefore OK |
|--------------------------|--------------------------------------------|--------------|

|                      |         |                                                                                                               |                     |              |
|----------------------|---------|---------------------------------------------------------------------------------------------------------------|---------------------|--------------|
| <u>Check Sliding</u> | F.O.S = | $\frac{\text{Vert Load} \times \tan \Theta}{\text{Horiz Load}} = \frac{15.02 \times 0.70}{3.922} = 2.681 > 2$ | <b>Therefore OK</b> | Therefore OK |
|----------------------|---------|---------------------------------------------------------------------------------------------------------------|---------------------|--------------|

Check Ground Pressure

$$\text{Reaction Lever Arm, } y = \frac{\text{Sum of Moments}}{\text{Vertical Reaction}} = \frac{4.604}{15.019} = 0.307 \text{ m} \quad (\text{dist from bottom left})$$

$$\text{Distance from reaction to centre of foundation, } e = \frac{\text{Length of footing}}{2} - y = \frac{0.75}{2} - 0.307$$

$$e = 0.068 \text{ m}$$

Check Middle Third Rule:  $\frac{L}{6} = \frac{0.75}{6} = 0.125 \text{ m} > 0.068 \text{ m}$  Therefore reaction lies in middle third

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

$$\text{Maximum Ground Bearing Pressure, } p_{\max} = \frac{15.019}{0.75} \times \frac{(1 + 6 \times 0.068)}{0.75} = \frac{30.99}{0.75} \text{ kN/m}^2$$

< 50 kN/m<sup>2</sup>  
< Allowable, therefore OK

|                                    |         |         |         |           |                                                                                    |
|------------------------------------|---------|---------|---------|-----------|------------------------------------------------------------------------------------|
| Project                            |         |         |         |           |  |
| Mass Masonry Retaining Wall Design |         |         |         |           |                                                                                    |
| Date                               | Calc by | Checked | Job no. | Sheet no. |                                                                                    |
| Mar '24                            | WW      | PHG     | 2336    | 6         |                                                                                    |

### Check Blockwork

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

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

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

$$g_d = 0.9 \times 0.825 \text{ m} \times 18 \text{ kN/m}^3 = 13.37 \text{ kN/m}^2 = 0.013 \text{ N/mm}^2$$

$$\text{Basic flexural strength of blockwork, } f_{kx} = 0.25 \text{ N/mm}^2 \quad (\text{From Table 3, BS5628:Pt 1:2005})$$

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

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

$$M_R = \left[ \frac{0.25}{3.5} + 0.013 \right] \times 17604167 = 1492720.2 \text{ N.mm} = \mathbf{1.493 \text{ kNm}}$$

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 = 0.825 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 Pa and Pu for the blockwork height of 0.825 m only, and not the height from base

$$P_a = 0.5 K_a \cdot \varphi \cdot h^2 = 0.5 \times 0.276 \times 18 \times 0.825^2 = 1.69 \text{ kN/m}$$

$$P_u = K_a \cdot w \cdot h = 0.276 \times 2.5 \times 0.825 = 0.57 \text{ kN/m}$$

$$M_o = 1.4 \left[ 1.69 \times \frac{0.825}{3} \right] + 1.6 \left[ 0.57 \times \frac{0.825}{2} \right] = \mathbf{1.027 \text{ kNm}}$$

Therefore since  $1.493 (M_R) > 1.027 (M_o)$  **OK**

OK

### Check Shear at the Base of Blockwork Wall

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

$$\text{Applied Shear, } F_v = (1.4 \times 1.69) + (1.6 \times 0.57) = \mathbf{3.279 \text{ kN (ult)}}$$

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

$$\text{Therefore average applied shear stress} = \frac{3.279 \times 1000}{225 \times 1000} = 0.015 \text{ N/mm}^2$$

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  $0.358 (f_v) > 0.015 (F_v)$  **OK**

# Mass Masonry Retaining Wall Design

Mar '24

WW

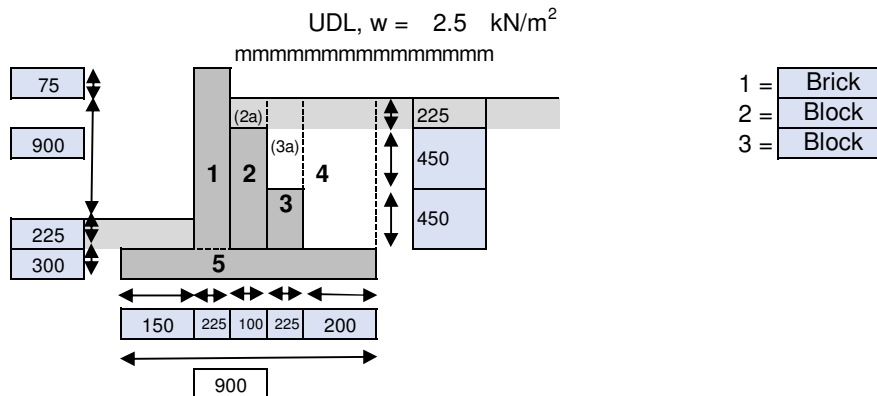
PHG

2336

7

## 6 Wall Type "C"

(Max retained height = 0.9 m )



$$P_a = 0.5 \cdot K_a \cdot \phi \cdot h^2 = 0.5 \times 0.276 \times 18 \times 1.43^2 = 5.05 \text{ kN/m}$$

$$P_u = K_a \cdot w \cdot h = 0.276 \times 2.5 \times 1.43 = 0.98 \text{ kN/m}$$

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

| Wall Element | Force (kN/m)                             | Lever Arm (m) | Moment (kNm/m)  |
|--------------|------------------------------------------|---------------|-----------------|
| 1            | $1.200 \times 0.225 \times 20.0 = 5.400$ | 0.263         | 1.418           |
| 2            | $0.900 \times 0.100 \times 18.0 = 1.620$ | 0.425         | 0.689           |
| 2a           | $0.225 \times 0.100 \times 18.0 = 0.405$ | 0.425         | 0.172           |
| 3            | $0.450 \times 0.225 \times 18.0 = 1.823$ | 0.588         | 1.071           |
| 3a           | $0.675 \times 0.225 \times 18.0 = 2.734$ | 0.900         | 2.460           |
| 4            | $1.125 \times 0.200 \times 18.0 = 4.050$ | 0.800         | 3.240           |
| 5            | $0.900 \times 0.300 \times 24.0 = 6.480$ | 0.450         | 2.916           |
| $P_a$        | As calculated above = 5.047              | 0.475         | 2.397           |
| $P_u$        | As calculated above = 0.984              | 0.713         | 0.701           |
| Totals       | Horiz. = 6.030 kN    Vert = 22.511 kN    |               | 11.965    3.098 |

Overturning Moment Sum = 8.867 kNm

### Check Overturning

$$\text{F.O.S} = \frac{11.965}{3.098} = 3.86 > 2.0 \quad \text{Therefore OK}$$

Therefore OK

### Check Sliding

$$\text{F.O.S} = \frac{\text{Vert Load} \times \tan \theta}{\text{Horiz Load}} = \frac{22.51 \times 0.70}{6.030} = 2.614 > 2 \quad \text{Therefore OK}$$

Therefore OK

### Check Ground Pressure

$$\text{Reaction Lever Arm, } y = \frac{\text{Sum of Moments}}{\text{Vertical Reaction}} = \frac{8.867}{22.511} = 0.394 \text{ m} \quad (\text{dist from bottom left})$$

$$\text{Distance from reaction to centre of foundation, } e = \frac{\text{Length of footing}}{2} - y = \frac{0.9}{2} - 0.394 = 0.056 \text{ m}$$

$$\text{Check Middle Third Rule: } \frac{L}{6} = \frac{0.9}{6} = 0.15 \text{ m} > 0.056 \text{ m} \quad \text{Therefore reaction lies in middle third}$$

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

$$\text{Maximum Ground Bearing Pressure, } p_{\max} = \frac{22.511}{0.9} \times \frac{(1 + 6 \times 0.056)}{0.9} = 34.367 \text{ kN/m}^2 < 50 \text{ kN/m}^2 < \text{Allowable, therefore OK}$$

|                                    |         |         |         |           |                                                                                    |
|------------------------------------|---------|---------|---------|-----------|------------------------------------------------------------------------------------|
| Project                            |         |         |         |           |  |
| Mass Masonry Retaining Wall Design |         |         |         |           |                                                                                    |
| Date                               | Calc by | Checked | Job no. | Sheet no. |                                                                                    |
| Mar '24                            | WW      | PHG     | 2336    | 8         |                                                                                    |

### Check Blockwork

$$\text{At base of wall } Z = \frac{b \times d^2}{6} = \frac{1000 \times 550^2}{6} = 50416667 \text{ mm}^3$$

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

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

$$g_d = 0.9 \times 1.125 \text{ m} \times 18 \text{ kN/m}^3 = 18.23 \text{ kN/m}^2 = 0.018 \text{ N/mm}^2$$

$$\text{Basic flexural strength of blockwork, } f_{kx} = 0.25 \text{ N/mm}^2 \quad (\text{From Table 3, BS5628:Pt 1:2005})$$

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

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

$$M_R = \left[ \frac{0.25}{3.5} + 0.018 \right] \times 50416667 = 4520034.2 \text{ N.mm} = \mathbf{4.520 \text{ kNm}}$$

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 = 1.125 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 Pa and Pu for the blockwork height of 1.125 m only, and not the height from base

$$P_a = 0.5 K_a \cdot \varphi \cdot h^2 = 0.5 \times 0.276 \times 18 \times 1.125^2 = 3.15 \text{ kN/m}$$

$$P_u = K_a \cdot w \cdot h = 0.276 \times 2.5 \times 1.125 = 0.78 \text{ kN/m}$$

$$M_o = 1.4 \left[ 3.15 \times \frac{1.125}{3} \right] + 1.6 \left[ 0.78 \times \frac{1.125}{2} \right] = \mathbf{2.35 \text{ kNm}}$$

Therefore since **4.520 (M<sub>R</sub>) > 2.35 (M<sub>o</sub>) OK**

OK

### Check Shear at the Base of Blockwork Wall

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

$$\text{Applied Shear, } F_v = (1.4 \times 3.15) + (1.6 \times 0.78) = \mathbf{5.646 \text{ kN (ult)}}$$

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

$$\text{Therefore average applied shear stress} = \frac{5.646 \times 1000}{225 \times 1000} = 0.025 \text{ N/mm}^2$$

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

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

$$g_A = g_d = 0.018 \text{ N/mm}^2$$

$$f_v = 0.350 + (0.600 \times 0.018) = 0.361 \text{ N/mm}^2$$

Therefore since **0.361 (f<sub>v</sub>) > 0.025 (F<sub>v</sub>) OK**

OK

# Mass Masonry Retaining Wall Design

Mar '24

WW

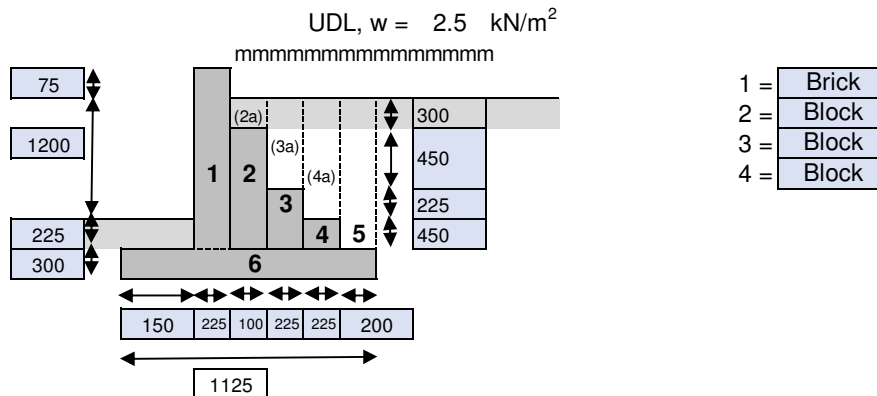
PHG

2336

9

## 7 Wall Type "D"

(Max retained height = 1.2 m )



$$P_a = 0.5 \cdot K_a \cdot \phi \cdot h^2 = 0.5 \times 0.276 \times 18 \times 1.73^2 = 7.40 \text{ kN/m}$$

$$P_u = K_a \cdot w \cdot h = 0.276 \times 2.5 \times 1.73 = 1.19 \text{ kN/m}$$

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

| Wall Element | Force (kN/m)                             | Lever Arm (m) | Moment (kNm/m) |               |
|--------------|------------------------------------------|---------------|----------------|---------------|
|              |                                          |               | Clockwise      | Anticlockwise |
| 1            | $1.500 \times 0.225 \times 20.0 = 6.750$ | 0.263         | 1.772          |               |
| 2            | $1.125 \times 0.100 \times 18.0 = 2.025$ | 0.425         | 0.861          |               |
| 3            | $0.675 \times 0.225 \times 18.0 = 2.734$ | 0.588         | 1.606          |               |
| 4            | $0.450 \times 0.225 \times 18.0 = 1.823$ | 0.813         | 1.481          |               |
| 5            | $1.425 \times 0.200 \times 18.0 = 5.130$ | 1.025         | 5.258          |               |
| 6            | $1.125 \times 0.300 \times 24.0 = 8.100$ | 0.563         | 4.556          |               |
| 2a 3a 4a     | As calculated                            |               | 5.222          |               |
| $P_a$        | As calculated above = 7.395              | 0.575         |                | 4.252         |
| $P_u$        | As calculated above = 1.191              | 0.863         |                | 1.027         |
| Totals       | Horiz. = 8.586 kN    Vert = 26.561 kN    |               | 20.756         | 5.279         |

Overturning Moment Sum = 15.477 kNm

### Check Overturning

$$\text{F.O.S} = \frac{20.756}{5.279} = 3.93 > 2.0 \quad \text{Therefore OK}$$

Therefore OK

### Check Sliding

$$\text{F.O.S} = \frac{\text{Vert Load} \times \tan \theta}{\text{Horiz Load}} = \frac{26.56 \times 0.70}{8.586} = 2.166 > 2 \quad \text{Therefore OK}$$

Therefore OK

### Check Ground Pressure

$$\text{Reaction Lever Arm, } y = \frac{\text{Sum of Moments}}{\text{Vertical Reaction}} = \frac{15.477}{26.561} = 0.583 \text{ m} \quad (\text{dist from bottom left})$$

$$\text{Distance from reaction to centre of foundation, } e = \frac{\text{Length of footing}}{2} - y = \frac{1.125}{2} - 0.583 = -0.02 \text{ m}$$

$$\text{Check Middle Third Rule: } \frac{L}{6} = \frac{1.125}{6} = 0.188 \text{ m} > -0.02 \text{ m} \quad \text{Therefore reaction lies in middle third}$$

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

$$\text{Maximum Ground Bearing Pressure, } p_{\max} = \frac{26.561}{1.125} \times \left( 1 + \frac{6 \times -0.02}{1.125} \right) = 21.07 \text{ kN/m}^2 < 50 \text{ kN/m}^2 < \text{Allowable, therefore OK}$$

# Mass Masonry Retaining Wall Design

Mar '24

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## Check Blockwork

$$\text{At base of wall } Z = \frac{b \times d^2}{6} = \frac{1000 \times 775^2}{6} = 100104167 \text{ mm}^3$$

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

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

$$g_d = 0.9 \times 1.425 \text{ m} \times 18 \text{ kN/m}^3 = 23.09 \text{ kN/m}^2 = 0.023 \text{ N/mm}^2$$

$$\text{Basic flexural strength of blockwork, } f_{kx} = 0.25 \text{ N/mm}^2 \quad (\text{From Table 3, BS5628:Pt 1:2005})$$

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

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

$$M_R = \left[ \frac{0.25}{3.5} + 0.023 \right] \times 100104167 = 9461202.3 \text{ N.mm} = \mathbf{9.461 \text{ kNm}}$$

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 = 1.425 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 1.425 m only, and not the height from base

$$P_a = 0.5 K_a \cdot \varphi \cdot h^2 = 0.5 \times 0.276 \times 18 \times 1.425^2 = 5.05 \text{ kN/m}$$

$$P_u = K_a \cdot w \cdot h = 0.276 \times 2.5 \times 1.425 = 0.98 \text{ kN/m}$$

$$M_o = 1.4 \left[ 5.05 \times \frac{1.425}{3} \right] + 1.6 \left[ 0.98 \times \frac{1.425}{2} \right] = \mathbf{4.477 \text{ kNm}}$$

Therefore since  $9.461 (M_R) > 4.477 (M_o)$  OK

OK

## Check Shear at the Base of Blockwork Wall

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

$$\text{Applied Shear, } F_v = (1.4 \times 5.05) + (1.6 \times 0.98) = \mathbf{8.639 \text{ kN (ult)}}$$

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

$$\text{Therefore average applied shear stress} = \frac{8.639 \times 1000}{225 \times 1000} = 0.038 \text{ N/mm}^2$$

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  $0.364 (f_v) > 0.038 (F_v)$  OK