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WDEEC  
PLANNING DEPARTMENT

- 5 OCT 2020

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**Structural Design Check**

**for**

**3.4m Retaining Wall**

**at**

**Trebethan Bungalow**

**Tydfil Terrace**

**CF47 8SY**

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# TREBETHAN BUNGALOW, TYDFIL TERRACE

CF47  
85Y

PROJECT 3.4m RETAINING WALL

PREPARED BY CM

DATE AUG 20

JOB No. AM/CM/02

DRG No.

PAGE No. 1 of 9

CHECKED BY

DATE

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CALCULATIONS

## DESIGN

Check reinforced blockwork retaining wall to garden area to accommodate new garage + driveway

### (1) STABILITY ANALYSIS

Use 'SCALE' software to check wall using a  $10 \text{ kN/m}^2$  surcharge as wall is  $> 3.0 \text{ m}$

BS 5628

BS 8110

BS 8002

$\phi = 32^\circ$  (granular fill)

$K_a = 0.24$

$\gamma_{\text{wall}} = 24 \text{ kN/m}^3$

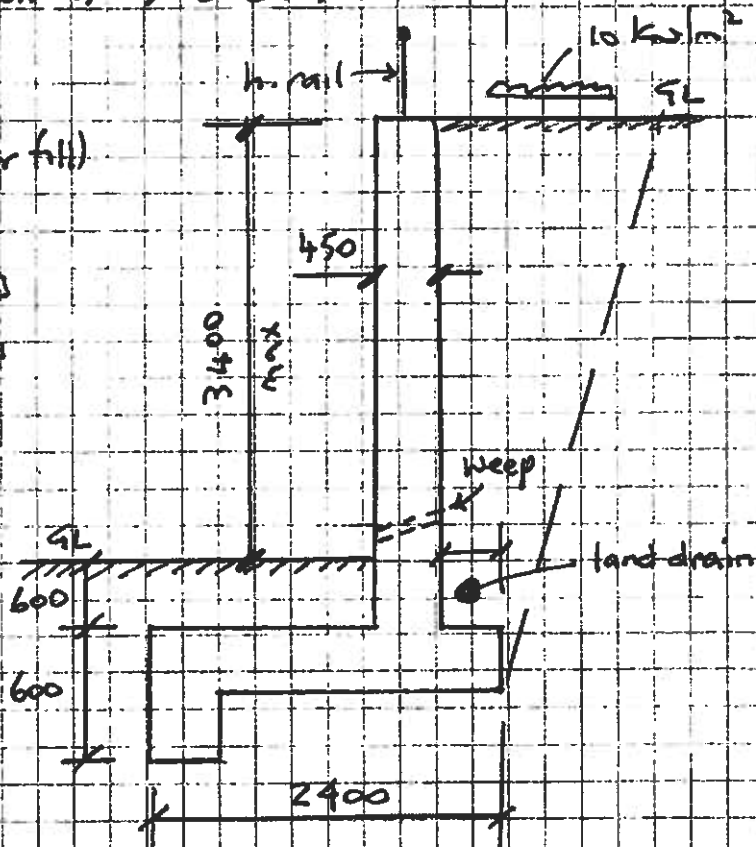
$\gamma_{\text{soil}} = 18 \text{ kN/m}^3$

Blockwork  $= 7 \text{ N/mm}^2$

Mortar  $= 1:6$

Bearing  $= 75 \text{ kN/m}^2$

Surcharge  $= 10 \text{ kN/m}^2$



WALL SECTION

$$FOS_{\text{sliding}} = \frac{2.18}{1} > 2$$

$$FOS_{\text{stability}} = \frac{2.33}{1} > 2$$

$$\text{Bearing pressure} = \frac{74.6}{1} \text{ kN/m}^2 < 75 \text{ kN/m}^2 \text{ (see report.)}$$

|                                 |                                   |      |
|---------------------------------|-----------------------------------|------|
| PROJECT                         | PREPARED BY                       | DATE |
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## CALCULATIONS

\* WALL STABLE IN O/TURNING, SLIDING AND BEARING

(2) STEM WALL DESIGN



$$M_A = 64.7 \times 1.5 = \underline{97.05 \text{ kNm/m}} \rightarrow$$

$$V_A = 13.77 \times 1.5 = \underline{65.66 \text{ kN/m}} \rightarrow$$

$$d_{eff} = 450 - 100 - 35 - \frac{16}{2} = \underline{307 \text{ mm}}$$

$$M_R = Qbd \text{ gives } Q = \frac{97.05 \times 10^6}{10^3 \times (307)^2} = \underline{1.03 \text{ N/mm}^2}$$

BS 5628 for  $f_k = 6.4 \text{ N/mm}^2$   $\gamma_c = 2.00$   $\gamma_{ed} = 1.15$

$$f_{k/p} = 6.4 / 2 = \underline{3.2} \text{ refer to BS 5628 design tables}$$

4.2.4.2.1 gives  $C = \underline{0.80}$   $f_y = 460$   $f_{cu} = 35$   $Z = 0.95d$

$$A_s \text{ reqd} = \frac{97.05 \times 10^6 \times 1.15}{460 \times 0.80 \times 307} = \underline{988 \text{ mm}^2/\text{m}}$$

\* PROVIDE 2 x B503 MESH (T8 @ 100mm vertical) TO REAR FACE OF WALL WITH 1 x A393 MESH TO FRONT FACE AND T16 STARTER BARS @ 200 CRS TO BASE (1005)

Shear  $V = \underline{65.66 \text{ kN/m}}$   $A_s = 1005$

$$\rho = \frac{A_s}{bd} = \frac{1005}{10^3 \times 307} = \underline{0.003 \text{ N/mm}^2}$$

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CALCULATIONS

$$f_u = 0.35 + 17.5(p) = \underline{0.41} \text{ N/mm}^2$$

$$v = \frac{65.66 \times 10^3}{10^3 \times 307} = \underline{0.21} \text{ N/mm}^2$$

$$\frac{f_u}{2} = \frac{0.41}{2} = 0.205 \pm 0.21$$

O.K

\* NO ADDITIONAL SHEAR REBAR REQUIRED

### (3) BASE DESIGN

$$M_A = 57.20 \times 1.5 = \underline{85.80} \text{ km/m}$$

$$V_A = 57.40 \times 1.5 = \underline{86.10} \text{ kN/m}$$

$$d_{eff} = 300 - 16 - \frac{16}{2} = \underline{252} \text{ mm}$$



$$K = \frac{85.80 \times 10^6}{35 \times 10^3 \times (252)^2} = 0.039 \text{ N/mm}^2$$

$$\text{given } k' = 0.156 \quad z \leq 0.95d$$

$$A_s = \frac{85.80 \times 10^6}{0.87 \times 460 \times (0.95 \times 252)} = \underline{896} \text{ mm}^2/\text{m}$$

\* PROVIDE 1 x B503 + 1 x A393 (T8 @ 160 from to mesh)

 $A_s = 896$ 

MESH TO BOTTOM FACE WITH 1 x A393 MESH TO TOP FACE (40mm COVER)

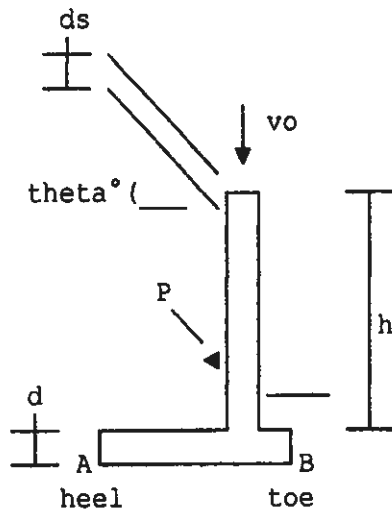
$$\text{Shear } V = \underline{86.10} \text{ kN/m}$$

$$v = \frac{86.10 \times 10^3}{10^3 \times 252} = \underline{0.34} < 0.49$$

$$\left. \begin{array}{l} d = 252 \\ \frac{v}{f_y} = 0.36 \\ \text{but } f_y = 460 \end{array} \right\} v_c = 0.49$$

NO ADDITIONAL SHEAR REINFORCEMENT REQUIRED

**Location: 3.4m Garden Retaining Wall**



**RC retaining wall to BS8002**

Using either Rankine or Coulomb theory, the following assumptions are made:

- surface of rupture is a plane
- point of resultant pressure P on back of wall is at one third of the distance up from the base of the wall.

Both Rankine and Coulomb give formula for resultant earth pressure on back of wall as  $P = C_e \cdot w \cdot h^2 / 2$  where  $C_e$  is a pressure coefficient.

Weight/unit vol. of retained soil  $w = 18 \text{ kN/m}^3$

Height of wall  $h = 4.0 \text{ m}$

Pressure due to surcharge  $\text{press} = 10 \text{ kN/m}^2$

Equivalent depth of surcharge  $ds = \text{press}/w = 10/18 = 0.55556 \text{ m}$

Load above wall supported on stem  $vo = 0 \text{ kN/m}$

Angle of slope of soil (if any)  $\theta = 0^\circ$

Internal friction angle of soil  $\phi = 38^\circ$

Angle of wall-to-soil friction  $\delta = 25.333^\circ$

Friction factor on underside base  $fb = 0.6$

Data 0.6 entered, exceeds maximum expected value 0.5

Thickness of wall  $t = 0.45 \text{ m}$

Density of wall (stem)  $dt = 24 \text{ kN/m}^3$

**Pressure from retained soil**

Cosine of surcharge angle ( $\theta$ )  $ct = \cos(\text{RAD}(\theta)) = 1$   
Sine of friction angle ( $\phi$ )  $sp = \sin(\text{RAD}(\phi)) = 0.61566$   
Cosine of friction angle ( $\phi$ )  $cp = \cos(\text{RAD}(\phi)) = 0.78801$   
Cosine of wall-soil friction ( $\delta$ )  $cd = \cos(\text{RAD}(\delta)) = 0.90384$   
Sine of ( $\phi + \delta$ )  $ss1 = \sin(\text{RAD}(\phi) + \text{RAD}(\delta))$

$= \sin(\text{RAD}(38) + \text{RAD}(25.333))$   
 $= 0.89363$

Sine of ( $\phi - \theta$ )  $ss2 = \sin(\text{RAD}(\phi) - \text{RAD}(\theta))$   
 $= \sin(\text{RAD}(38) - \text{RAD}(0))$   
 $= 0.61566$

Coulomb theory:

Factor  $f = cd * (1 + \text{SQR}(ss1 * ss2 / (cd * ct)))^2$   
 $= 0.90384 * (1 + \text{SQR}(0.89363 * 0.61566 / (0.90384 * 1)))^2$   
 $= 2.8644$

Pressure coefficient  $Cec = cp^2 / f = 0.78801^2 / 2.8644$   
 $= 0.21679$

Rankine theory:

Factor  $f = \text{SQR}(ct^2 - cp^2) = \text{SQR}(1^2 - 0.78801^2)$   
 $= 0.61566$

Pressure coefficient  $C_e = c_t * (c_t - f) / (c_t + f)$   
 $= 1 * (1 - 0.61566) / (1 + 0.61566)$   
 $= 0.23788$

Rankine pressure coefficient is chosen.

Resultant earth force (active)  $P = C_e * w * h^2 / 2 = 0.23788 * 18 * 4^2 / 2$   
 $= 34.255 \text{ kN/m run}$

Horiz.component of this force  $P_h = P * \cos(\text{RAD}(\theta))$   
 $= 34.255 * \cos(\text{RAD}(0))$   
 $= 34.255 \text{ kN/m run}$

Vertical component of this force  $P_v = P * \sin(\text{RAD}(\theta))$   
 $= 34.255 * \sin(\text{RAD}(0))$   
 $= 0 \text{ kN/m run}$

Pressure coefficient (surcharge)  $C_a = (1 - s_p) / (1 + s_p)$   
 $= (1 - 0.61566) / (1 + 0.61566)$   
 $= 0.23788$

Resultant earth force (surcharge)  $P_s = C_a * w * d_s * h = 0.23788 * 18 * 0.55556 * 4$   
 $= 9.5153 \text{ kN/m run}$

Horiz.component of this force  $P_{sh} = P_s * \cos(\text{RAD}(\theta))$   
 $= 9.5153 * \cos(\text{RAD}(0))$   
 $= 9.5153 \text{ kN/m run}$

Vertical component of this force  $P_{sv} = P_s * \sin(\text{RAD}(\theta))$   
 $= 9.5153 * \sin(\text{RAD}(0))$   
 $= 0 \text{ kN/m run}$

### Forces and moments on wall

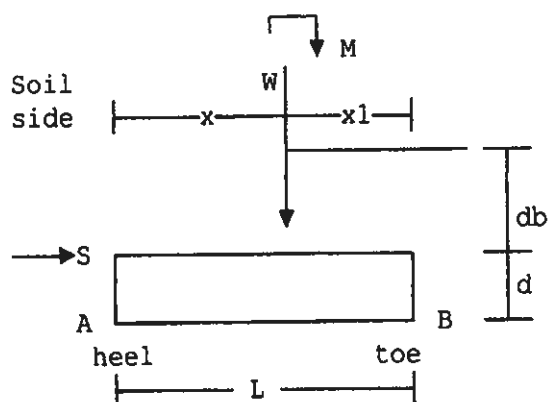
Maximum B.M. at base of stem  $M = P_h * h / 3 + P_{sh} * h / 2$   
 $= 34.255 * 4 / 3 + 9.5153 * 4 / 2$   
 $= 64.704 \text{ kNm/m}$

Maximum S.F. at base of stem  $S = P_h + P_{sh} = 34.255 + 9.5153 = 43.77 \text{ kN/m}$

Weight of wall  $w = h * t * \gamma = 4 * 0.45 * 24 = 43.2 \text{ kN/m run}$

Weight of wall plus load over  $v = w + v_o = 43.2 + 0 = 43.2 \text{ kN/m run}$

### Base

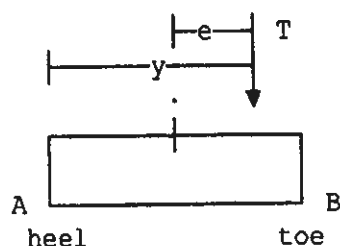


Thickness of base  $d = 0.3 \text{ m}$   
Length of base  $L = 2.4 \text{ m}$   
Distance from A to centre of stem  $x = 0.525 \text{ m}$   
Depth of soil over base at toe  $db = 0.6 \text{ m}$   
Depth of soil for passive resist.  $dp = 1.20 \text{ m}$   
For simplicity, the relatively-trivial effects of the self-weight and location of any key on the pressures, etc beneath the base are ignored.

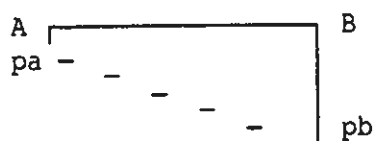
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|                                                                   |                                                                                                                                                                                                                          |
|-------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Distance from stem to front toe                                   | $x_1 = L - x = 2.4 - 0.525 = 1.875 \text{ m}$                                                                                                                                                                            |
| Allowable ground pressure                                         | $p = 75 \text{ kN/m}^2$                                                                                                                                                                                                  |
| Self-weight of foundation                                         | $Sw = L \cdot d \cdot dt = 2.4 \cdot 0.3 \cdot 24 = 17.28 \text{ kN/m run}$                                                                                                                                              |
| Wt. of soil behind wall (earth)                                   | $wbe = (h + ds) \cdot (x - t/2) \cdot w$<br>$= (4 + 0.55556) \cdot (0.525 - 0.45/2) \cdot 18$<br>$= 24.6 \text{ kN/m run}$                                                                                               |
| Wt. of soil behind wall (slope)                                   | $wbs = w \cdot (x - t/2)^2 \cdot \tan(\text{RAD}(\theta)) / 2$<br>$= 18 \cdot (0.525 - 0.45/2)^2 \cdot \tan(\text{RAD}(0)) / 2$<br>$= 0 \text{ kN/m run}$                                                                |
| Total weight of soil behind wall                                  | $wb = wbe + wbs = 24.6 + 0 = 24.6 \text{ kN/m run}$                                                                                                                                                                      |
| Weight of soil at front of wall                                   | $wf = db \cdot (x_1 - t/2) \cdot w$<br>$= 0.6 \cdot (1.875 - 0.45/2) \cdot 18$<br>$= 17.82 \text{ kN/m run}$                                                                                                             |
| Total earth pressure (active)                                     | $Pab = Ce \cdot ct \cdot w \cdot (h + d)^2 / 2$<br>$= 0.23788 \cdot 1 \cdot 18 \cdot (4 + 0.3)^2 / 2$<br>$= 39.586 \text{ kN/m run}$                                                                                     |
| Horiz.component of this force                                     | $Pabh = Pab \cdot \cos(\text{RAD}(\theta))$<br>$= 39.586 \cdot \cos(\text{RAD}(0))$<br>$= 39.586 \text{ kN/m run}$                                                                                                       |
| Vertical component of this force                                  | $Pabv = Pab \cdot \sin(\text{RAD}(\theta))$<br>$= 39.586 \cdot \sin(\text{RAD}(0))$<br>$= 0 \text{ kN/m run}$                                                                                                            |
| Total earth pressure (surcharge)                                  | $Psb = Ca \cdot w \cdot ds \cdot (h + d)$<br>$= 0.23788 \cdot 18 \cdot 0.55556 \cdot (4 + 0.3)$<br>$= 10.229 \text{ kN/m run}$                                                                                           |
| Horiz.component of this force                                     | $Psbh = Psb \cdot \cos(\text{RAD}(\theta))$<br>$= 10.229 \cdot \cos(\text{RAD}(0))$<br>$= 10.229 \text{ kN/m run}$                                                                                                       |
| Vertical component of this force                                  | $Psbv = Psb \cdot \sin(\text{RAD}(\theta))$<br>$= 10.229 \cdot \sin(\text{RAD}(0))$<br>$= 0 \text{ kN/m run}$                                                                                                            |
| Total load on soil beneath base                                   | $T = v + Sw + wb + wf + Pabv + Psbv$<br>$= 43.2 + 17.28 + 24.6 + 17.82 + 0 + 0$<br>$= 102.9 \text{ kN/m run}$                                                                                                            |
| Overturning moment due to earth pressure                          | $Mt = Pabh \cdot (h + d) / 3 + Psbh \cdot (h + d) / 2$<br>$= 39.586 \cdot (4 + 0.3) / 3 + 10.229 \cdot (4 + 0.3) / 2$<br>$= 78.732 \text{ kNm/m run}$                                                                    |
| Force u/s base (earth pressure)                                   | $St = Pabh + Psbh = 39.586 + 10.229$<br>$= 49.815 \text{ kN/m run}$                                                                                                                                                      |
| Clockwise moments about A due to weight of soil behind wall       | $Mcb = (3 \cdot wbe + 2 \cdot wbs) \cdot (x - t/2) / 6$<br>$= (3 \cdot 24.6 + 2 \cdot 0) \cdot (0.525 - 0.45/2) / 6$<br>$= 3.69 \text{ kNm/m}$                                                                           |
| Clockwise moments about A due to vert.component of earth pressure | $Mcbv = (Pabv + Psbv) \cdot (x - t/2)$<br>$= (0 + 0) \cdot (0.525 - 0.45/2)$<br>$= 0 \text{ kNm/m}$                                                                                                                      |
| Total clockwise moments about A:                                  | $Mc = v \cdot x + Mt + Sw \cdot L/2 + Mcb + Mcbv + wf \cdot (L - (x_1 - t/2) / 2)$<br>$= 43.2 \cdot 0.525 + 78.732 + 17.28 \cdot 2.4/2 + 3.69 + 0 + 17.82 \cdot (2.4 - (1.875 - 0.45/2) / 2)$<br>$= 153.9 \text{ kNm/m}$ |
| Distance to centroid of load                                      | $y = Mc / T = 153.9 / 102.9 = 1.4957 \text{ m}$                                                                                                                                                                          |

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Eccentricity  $e = y - L/2 = 1.4957 - 2.4/2 = 0.29567$  m  
Centroid of load lies within middle third. Pressure varies from  $p_a$  at A to  $p_b$  at B.



Base area modulus

$$\begin{aligned} z &= L^2/6 \\ &= 2.4^2/6 \\ &= 0.96 \text{ cu.m per metre run} \end{aligned}$$

Pressure at A

$$\begin{aligned} p_a &= T/(L \cdot 1) - T \cdot e/z \\ &= 102.9/(2.4 \cdot 1) - 102.9 \cdot 0.29567/0.96 \\ &= 11.182 \text{ kN/m}^2 \end{aligned}$$

Pressure at B

$$\begin{aligned} p_b &= T/(L \cdot 1) + T \cdot e/z \\ &= 102.9/(2.4 \cdot 1) + 102.9 \cdot 0.29567/0.96 \\ &= 74.568 \text{ kN/m}^2 \end{aligned}$$

Maximum pressure is at B

$$p_{\max} = p_b = 74.568 \text{ kN/m}^2$$

As  $p_{\max}$  does not exceed  $p$  (  $74.568 \text{ kN/m}^2 \leq 75 \text{ kN/m}^2$  ),  
pressure beneath base is within specified limit.

### Shear forces and bending moments on base

Pressure under back of wall

$$\begin{aligned} p_{wa} &= p_a + (p_b - p_a) \cdot (x - t/2)/L \\ &= 11.182 + (74.568 - 11.182) \cdot (0.525 - 0.45/2)/2.4 \\ &= 19.106 \text{ kN/m}^2 \end{aligned}$$

Pressure under front of wall

$$\begin{aligned} p_{wb} &= p_a + (p_b - p_a) \cdot (x + t/2)/L \\ &= 11.182 + (74.568 - 11.182) \cdot (0.525 + 0.45/2)/2.4 \\ &= 30.99 \text{ kN/m}^2 \end{aligned}$$

Downward S.F. on heel

$$\begin{aligned} S_{ad} &= dt \cdot d \cdot (x - t/2) + w_b \\ &= 24 \cdot 0.3 \cdot (0.525 - 0.45/2) + 24.6 \\ &= 26.76 \text{ kN/m} \end{aligned}$$

Upward S.F. on heel

$$\begin{aligned} S_{au} &= (p_a + p_{wa}) \cdot (x - t/2)/2 \\ &= (11.182 + 19.106) \cdot (0.525 - 0.45/2)/2 \\ &= 4.5432 \text{ kN/m} \end{aligned}$$

Downward B.M. on toe

$$\begin{aligned} M_{bd} &= (dt \cdot d \cdot (x_1 - t/2) + w_f) \cdot (x_1 - t/2)/2 \\ &= (24 \cdot 0.3 \cdot (1.875 - 0.45/2) + 17.82) \\ &\quad \cdot (1.875 - 0.45/2)/2 \\ &= 24.503 \text{ kNm/m} \end{aligned}$$

Downward B.M. on heel

$$\begin{aligned} M_{ad} &= (3 \cdot w_{be} + 4 \cdot w_{bs} + 3 \cdot dt \cdot d \cdot (x - t/2)) \cdot (x - t/2)/6 \\ &= (3 \cdot 24.6 + 4 \cdot 0 + 3 \cdot 24 \cdot 0.3 \cdot (0.525 - 0.45/2)) \\ &\quad \cdot (0.525 - 0.45/2)/6 \\ &= 4.014 \text{ kNm/m} \end{aligned}$$

Total S.F. on toe (plus is up)

$$\begin{aligned} S_{wb} &= ((p_{wb} + p_b)/2 - dt \cdot d) \cdot (x_1 - t/2) - w_f \\ &= ((30.99 + 74.568)/2 - 24 \cdot 0.3) \cdot (1.875 - 0.45/2) - 17.82 \end{aligned}$$

$=57.385 \text{ kN/m}$   
Total S.F. on heel (plus is up)  $Swa=Sau-Sad=4.5432-26.76$   
 $=-22.217 \text{ kN/m}$   
Total B.M. on toe (plus is up)  $Mwb=(2*pb+pwb)*(x1-t/2)^2/6-Mbd$   
 $=(2*74.568+30.99)*(1.875-0.45$   
 $/2)^2/6-24.503$   
 $=57.229 \text{ kNm/m}$   
Total B.M. on heel (plus is up)  $Mwa=(2*pa+pwa)*(x-t/2)^2/6-Mad$   
 $=(2*11.182+19.106)*(0.525-0.45$   
 $/2)^2/6-4.014$   
 $=-3.3919 \text{ kNm/m}$

### Resistance to sliding

Frictional resistance  $F=fb*T=0.6*102.9=61.74 \text{ kN/m run}$   
Rankine coeff.of passive pressure  $Kp=(\text{TAN}(\text{RAD}(45)+\text{RAD}(\text{phi}/2)))^2$   
 $=(\text{TAN}(\text{RAD}(45)+\text{RAD}(38/2)))^2$   
 $=4.2037$   
Passive resistance  $R=0.5*Kp*w*dp^2=0.5*4.2037*18*1.2^2$   
 $=54.481 \text{ kN/m}$   
FoS sliding (frict.resist.only)  $FOSF=F/St=61.74/49.815=1.2394$   
FoS sliding (friction/cohesion + passive)  $FOSF2=(F+R)/St$   
 $=(61.74+54.481)/49.815$   
 $=2.333$

### Resistance to overturning

Rotation assumed to occur about lowest forward edge of base (i.e. toe).  
Restraining moments:

Due to soil behind wall  $Mre=wbe*(L-(x-t/2)/2)+wbs*(L-(x-t/2)/3)$   
 $=24.6*(2.4-(0.525-0.45/2)/2)+0$   
 $*(2.4-(0.525-0.45/2)/3)$   
 $=55.35 \text{ kNm/m}$   
Due to base, wall and soil on toe  $Mrw=v*x1+Sw*L/2+wf*(x1-t/2)/2$   
 $=43.2*1.875+17.28*2.4/2+17.82$   
 $*(1.875-0.45/2)/2$   
 $=116.44 \text{ kNm/m}$   
Due to vert.comp.of earth pres.  $Mrv=(Pabv+Psbv)*(x1+t/2)$   
 $=(0+0)*(1.875+0.45/2)$   
 $=0 \text{ kNm/m}$

Total restraining mt.(with Mrv)  $Mr1=Mre+Mrw+Mrv=55.35+116.44+0$   
 $=171.79 \text{ kNm/m}$

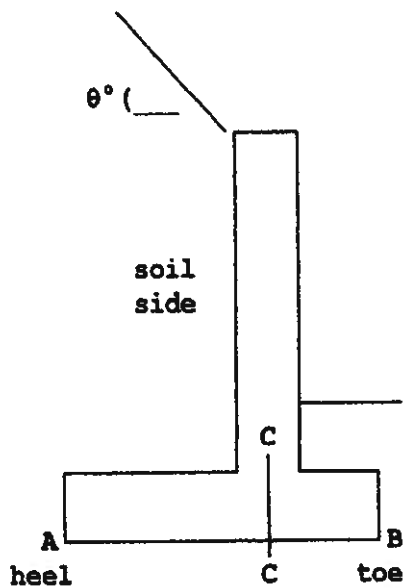
ditto (without Mrv)  $Mr2=Mre+Mrw=55.35+116.44$   
 $=171.79 \text{ kNm/m}$

Total overturning moment  $Mot=Mt=78.732 \text{ kNm/m}$

Safety factors against overturning:

Including vert.comp.of pressure  $FOSOT1=Mr1/Mot=171.79/78.732$   
 $=2.1819$

Ignoring vert.comp.of pressure  $FOSOT2=Mr2/Mot=171.79/78.732$   
 $=2.1819$



### Design Summary

|                        |             |
|------------------------|-------------|
| Moment at base of stem | 64.704 kNm  |
| Shear at base of stem  | 43.77 kN    |
| Moment at c-c (toe)    | 57.229 kNm  |
| Shear at c-c (toe)     | 57.385 kN   |
| Moment at c-c (heel)   | -3.3919 kNm |
| Shear at c-c (heel)    | -22.217 kN  |

### FoS for Overturning

|                                                          |        |
|----------------------------------------------------------|--------|
| (1) With vertical component of earth pressure considered | 2.1819 |
| (2) Ignoring vertical component of earth pressure        | 2.1819 |

### FoS for Sliding

|                      |        |
|----------------------|--------|
| (1) Friction only    | 1.2394 |
| (2) Friction+passive | 2.333  |

|               |                          |
|---------------|--------------------------|
| Pressure at A | 11.182 kN/m <sup>2</sup> |
| Pressure at B | 74.568 kN/m <sup>2</sup> |
| Allowable GBP | 75 kN/m <sup>2</sup>     |

Blockwork = 7.3 m<sup>2</sup>  
Mortar = 1:6

