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**Cwm Planning & Design Ltd.**

(Civil, Structural & Architectural)

## **STRUCTURAL CALCULATIONS**

**NEW DWELLING – REAR GARDEN RETAINING WALLs**

**at:**

**54 Lucy Road  
Skewen  
Neath**

Date: 23rd January 2024

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**BRIEF:**

- 1) The design of a Reinforced Concrete retaining wall to form a rear wall to a proposed garage and support the front wall of a proposed New residential dwelling.

**REFERENCES:**

Architectural Drawings  
SCALE structural design package (for unit loads)  
TEDDS structural design computer package.

**DESIGN LOADINGS:**

Refer to structural calculations attached.

Surcharge (Garden) = **1.5kN**

**SUMMARY**

Retained height taken as **2.7m (2.4m clear)** (300mm cover to front)  
*See Section Drawing for details*

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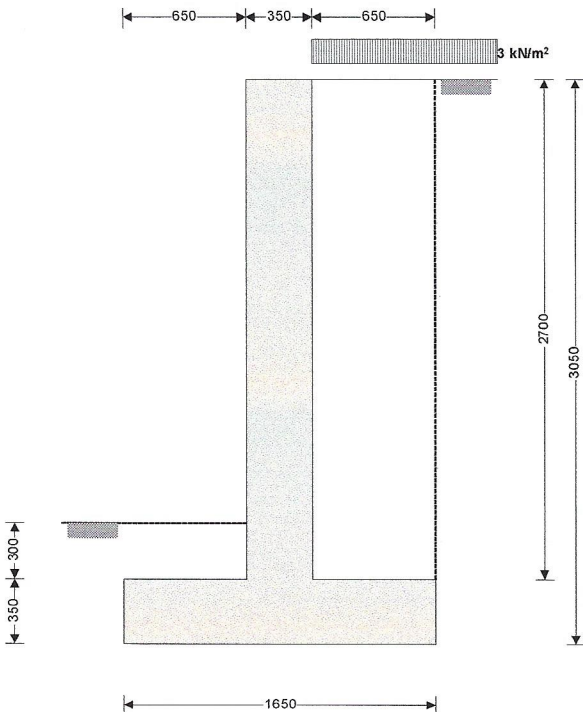
RETAINING WALL  
DESIGN CALCULATIONS

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|                                                                                                                                                                   |                                           |                          |            |                              |                              |
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|                                                                                                                                                                   | Calcs for<br>GARDEN RETAINING WALL (2.4m) |                          |            | Start page no./Revision<br>1 |                              |
|                                                                                                                                                                   | Calcs by<br>CM                            | Calcs date<br>23/01/2024 | Checked by | Checked date                 | Approved by<br>Approved date |

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.08



Wall details

- Retaining wall type
- Height of retaining wall stem
- Thickness of wall stem
- Length of toe
- Length of heel
- Overall length of base
- Thickness of base
- Depth of downstand
- Position of downstand
- Thickness of downstand
- Height of retaining wall
- Depth of cover in front of wall
- Depth of unplanned excavation
- Height of ground water behind wall
- Height of saturated fill above base
- Density of wall construction
- Density of base construction
- Angle of rear face of wall
- Angle of soil surface behind wall
- Effective height at virtual back of wall

Unpropped cantilever

- $h_{stem} = 2700 \text{ mm}$
- $t_{wall} = 350 \text{ mm}$
- $l_{toe} = 650 \text{ mm}$
- $l_{heel} = 650 \text{ mm}$
- $l_{base} = l_{toe} + l_{heel} + t_{wall} = 1650 \text{ mm}$
- $t_{base} = 350 \text{ mm}$
- $d_{ds} = 0 \text{ mm}$
- $l_{ds} = 0 \text{ mm}$
- $t_{ds} = 350 \text{ mm}$
- $h_{wall} = h_{stem} + t_{base} + d_{ds} = 3050 \text{ mm}$
- $d_{cover} = 300 \text{ mm}$
- $d_{exc} = 0 \text{ mm}$
- $h_{water} = 0 \text{ mm}$
- $h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0 \text{ mm}) = 0 \text{ mm}$
- $\gamma_{wall} = 23.6 \text{ kN/m}^3$
- $\gamma_{base} = 23.6 \text{ kN/m}^3$
- $\alpha = 90.0 \text{ deg}$
- $\beta = 0.0 \text{ deg}$
- $h_{eff} = h_{wall} + l_{heel} \times \tan(\beta) = 3050 \text{ mm}$

Retained material details

- Mobilisation factor
- M = 1.5

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Moist density of retained material  $\gamma_m = 18.0 \text{ kN/m}^3$   
Saturated density of retained material  $\gamma_s = 21.0 \text{ kN/m}^3$   
Design shear strength  $\phi' = 24.2 \text{ deg}$   
Angle of wall friction  $\delta = 18.6 \text{ deg}$

**Base material details**

Stiff or hard glacial clay  
Moist density  $\gamma_{mb} = 18.0 \text{ kN/m}^3$   
Design shear strength  $\phi'_b = 24.2 \text{ deg}$   
Design base friction  $\delta_b = 18.6 \text{ deg}$   
Allowable bearing pressure  $P_{bearing} = 150 \text{ kN/m}^2$

**Using Coulomb theory**

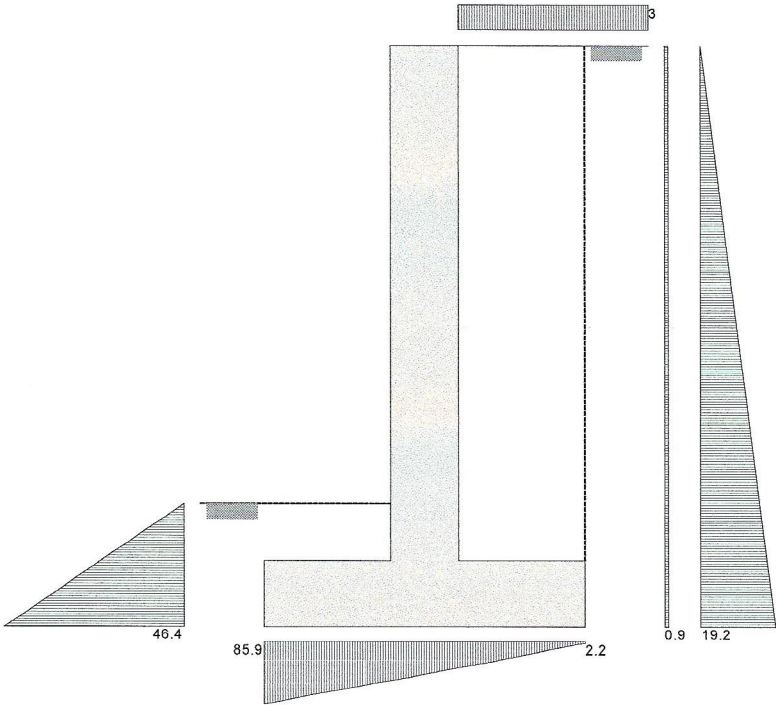
Active pressure coefficient for retained material  
 $K_a = \sin(\alpha + \phi')^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta) \times [1 + \sqrt{(\sin(\phi' + \delta) \times \sin(\phi' - \beta) / (\sin(\alpha - \delta) \times \sin(\alpha + \beta))}]^2) = 0.369$   
Passive pressure coefficient for base material  
 $K_p = \sin(90 - \phi'_b)^2 / (\sin(90 - \delta_b) \times [1 - \sqrt{(\sin(\phi'_b + \delta_b) \times \sin(\phi'_b) / (\sin(90 + \delta_b))}]^2) = 4.187$

**At-rest pressure**

At-rest pressure for retained material  $K_0 = 1 - \sin(\phi') = 0.590$

**Loading details**

Surcharge load on plan Surcharge = 2.5 kN/m<sup>2</sup>  
Applied vertical dead load on wall  $W_{dead} = 0.0 \text{ kN/m}$   
Applied vertical live load on wall  $W_{live} = 0.0 \text{ kN/m}$   
Position of applied vertical load on wall  $l_{load} = 0 \text{ mm}$   
Applied horizontal dead load on wall  $F_{dead} = 0.0 \text{ kN/m}$   
Applied horizontal live load on wall  $F_{live} = 0.0 \text{ kN/m}$   
Height of applied horizontal load on wall  $h_{load} = 0 \text{ mm}$



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|                                                                                                                                                                   |           |  |                              |            |                         | Approved date |

Loads shown in kN/m, pressures shown in kN/m<sup>2</sup>

**Vertical forces on wall**

|                               |                                                                                       |
|-------------------------------|---------------------------------------------------------------------------------------|
| Wall stem                     | $w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall} = 22.3 \text{ kN/m}$        |
| Wall base                     | $w_{base} = l_{base} \times t_{base} \times \gamma_{base} = 13.6 \text{ kN/m}$        |
| Surcharge                     | $w_{sur} = \text{Surcharge} \times l_{heel} = 1.6 \text{ kN/m}$                       |
| Moist backfill to top of wall | $w_{m\_w} = l_{heel} \times (h_{stem} - h_{sat}) \times \gamma_m = 31.6 \text{ kN/m}$ |
| Soil in front of wall         | $w_p = l_{toe} \times d_{cover} \times \gamma_{mb} = 3.5 \text{ kN/m}$                |
| Total vertical load           | $W_{total} = w_{wall} + w_{base} + w_{sur} + w_{m\_w} + w_p = 72.7 \text{ kN/m}$      |

**Horizontal forces on wall**

|                                  |                                                                                                                                  |
|----------------------------------|----------------------------------------------------------------------------------------------------------------------------------|
| Surcharge                        | $F_{sur} = K_a \times \cos(90 - \alpha + \delta) \times \text{Surcharge} \times h_{eff} = 2.7 \text{ kN/m}$                      |
| Moist backfill above water table | $F_{m\_a} = 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water})^2 = 29.3 \text{ kN/m}$ |
| Total horizontal load            | $F_{total} = F_{sur} + F_{m\_a} = 32 \text{ kN/m}$                                                                               |

**Calculate stability against sliding**

|                                                              |                                                                                                                                        |
|--------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|
| Passive resistance of soil in front of wall                  | $F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb} = 15.1 \text{ kN/m}$ |
| Resistance to sliding                                        | $F_{res} = F_p + (W_{total} - w_{sur} - w_p) \times \tan(\delta_b) = 37.8 \text{ kN/m}$                                                |
| <b>PASS - Resistance force is greater than sliding force</b> |                                                                                                                                        |

**Overturning moments**

|                                  |                                                                                                        |
|----------------------------------|--------------------------------------------------------------------------------------------------------|
| Surcharge                        | $M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2 = 4.1 \text{ kNm/m}$                         |
| Moist backfill above water table | $M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3 = 29.8 \text{ kNm/m}$ |
| Total overturning moment         | $M_{ot} = M_{sur} + M_{m\_a} = 33.8 \text{ kNm/m}$                                                     |

**Restoring moments**

|                        |                                                                                                                           |
|------------------------|---------------------------------------------------------------------------------------------------------------------------|
| Wall stem              | $M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2) = 18.4 \text{ kNm/m}$                                                |
| Wall base              | $M_{base} = w_{base} \times l_{base} / 2 = 11.2 \text{ kNm/m}$                                                            |
| Moist backfill         | $M_{m\_r} = (w_{m\_w} \times (l_{base} - l_{heel} / 2) + w_{m\_s} \times (l_{base} - l_{heel} / 3)) = 41.9 \text{ kNm/m}$ |
| Total restoring moment | $M_{rest} = M_{wall} + M_{base} + M_{m\_r} = 71.5 \text{ kNm/m}$                                                          |

**Check stability against overturning**

|                                                                   |                                 |
|-------------------------------------------------------------------|---------------------------------|
| Total overturning moment                                          | $M_{ot} = 33.8 \text{ kNm/m}$   |
| Total restoring moment                                            | $M_{rest} = 71.5 \text{ kNm/m}$ |
| <b>PASS - Restoring moment is greater than overturning moment</b> |                                 |

**Check bearing pressure**

|                                                                                |                                                                                       |
|--------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Surcharge                                                                      | $M_{sur\_r} = w_{sur} \times (l_{base} - l_{heel} / 2) = 2.2 \text{ kNm/m}$           |
| Soil in front of wall                                                          | $M_{p\_r} = w_p \times l_{toe} / 2 = 1.1 \text{ kNm/m}$                               |
| Total moment for bearing                                                       | $M_{total} = M_{rest} - M_{ot} + M_{sur\_r} + M_{p\_r} = 40.9 \text{ kNm/m}$          |
| Total vertical reaction                                                        | $R = W_{total} = 72.7 \text{ kN/m}$                                                   |
| Distance to reaction                                                           | $x_{bar} = M_{total} / R = 564 \text{ mm}$                                            |
| Eccentricity of reaction                                                       | $e = \text{abs}((l_{base} / 2) - x_{bar}) = 261 \text{ mm}$                           |
| <b>Reaction acts within middle third of base</b>                               |                                                                                       |
| Bearing pressure at toe                                                        | $p_{toe} = (R / l_{base}) + (6 \times R \times e / l_{base}^2) = 85.9 \text{ kN/m}^2$ |
| Bearing pressure at heel                                                       | $p_{heel} = (R / l_{base}) - (6 \times R \times e / l_{base}^2) = 2.2 \text{ kN/m}^2$ |
| <b>PASS - Maximum bearing pressure is less than allowable bearing pressure</b> |                                                                                       |

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**RETAINING WALL DESIGN (BS 8002:1994)**

TEDDS calculation version 1.2.01.08

**Ultimate limit state load factors**

|                                 |                       |
|---------------------------------|-----------------------|
| Dead load factor                | $\gamma_{f\_d} = 1.4$ |
| Live load factor                | $\gamma_{f\_l} = 1.6$ |
| Earth and water pressure factor | $\gamma_{f\_e} = 1.4$ |

**Factored vertical forces on wall**

|                               |                                                                                                               |
|-------------------------------|---------------------------------------------------------------------------------------------------------------|
| Wall stem                     | $W_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall} = 31.2 \text{ kN/m}$        |
| Wall base                     | $W_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base} = 19.1 \text{ kN/m}$        |
| Surcharge                     | $W_{sur\_f} = \gamma_{f\_l} \times \text{Surcharge} \times l_{heel} = 2.6 \text{ kN/m}$                       |
| Moist backfill to top of wall | $W_{m\_w\_f} = \gamma_{f\_d} \times l_{heel} \times (h_{stem} - h_{sat}) \times \gamma_m = 44.2 \text{ kN/m}$ |
| Soil in front of wall         | $W_{p\_f} = \gamma_{f\_d} \times l_{toe} \times d_{cover} \times \gamma_{mb} = 4.9 \text{ kN/m}$              |
| Total vertical load           | $W_{total\_f} = W_{wall\_f} + W_{base\_f} + W_{sur\_f} + W_{m\_w\_f} + W_{p\_f} = 102 \text{ kN/m}$           |

**Factored horizontal at-rest forces on wall**

|                                                     |                                                                                                                                                     |
|-----------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|
| Surcharge                                           | $F_{sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times h_{eff} = 7.2 \text{ kN/m}$                                                   |
| Moist backfill above water table                    | $F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2 = 69.2 \text{ kN/m}$                              |
| Total horizontal load                               | $F_{total\_f} = F_{sur\_f} + F_{m\_a\_f} = 76.4 \text{ kN/m}$                                                                                       |
| Passive resistance of soil in front of wall<br>kN/m | $F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb} = 21.1$ |

**Factored overturning moments**

|                                  |                                                                                                              |
|----------------------------------|--------------------------------------------------------------------------------------------------------------|
| Surcharge                        | $M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2 = 11 \text{ kNm/m}$                          |
| Moist backfill above water table | $M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3 = 70.3 \text{ kNm/m}$ |
| Total overturning moment         | $M_{ot\_f} = M_{sur\_f} + M_{m\_a\_f} = 81.3 \text{ kNm/m}$                                                  |

**Restoring moments**

|                        |                                                                                                                      |
|------------------------|----------------------------------------------------------------------------------------------------------------------|
| Wall stem              | $M_{wall\_f} = W_{wall\_f} \times (l_{toe} + t_{wall} / 2) = 25.8 \text{ kNm/m}$                                     |
| Wall base              | $M_{base\_f} = W_{base\_f} \times l_{base} / 2 = 15.7 \text{ kNm/m}$                                                 |
| Surcharge              | $M_{sur\_r\_f} = W_{sur\_f} \times (l_{base} - l_{heel} / 2) = 3.4 \text{ kNm/m}$                                    |
| Moist backfill         | $M_{m\_r\_f} = (W_{m\_w\_f} \times (l_{base} - l_{heel} / 2) + W_{m\_s\_f} \times (l_{base} - l_{heel} / 3)) = 58.6$ |
| kNm/m                  |                                                                                                                      |
| Soil in front of wall  | $M_{p\_r\_f} = W_{p\_f} \times l_{toe} / 2 = 1.6 \text{ kNm/m}$                                                      |
| Total restoring moment | $M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{sur\_r\_f} + M_{m\_r\_f} + M_{p\_r\_f} = 105.1 \text{ kNm/m}$          |

**Factored bearing pressure**

|                          |                                                                  |
|--------------------------|------------------------------------------------------------------|
| Total moment for bearing | $M_{total\_f} = M_{rest\_f} - M_{ot\_f} = 23.8 \text{ kNm/m}$    |
| Total vertical reaction  | $R_f = W_{total\_f} = 102.0 \text{ kN/m}$                        |
| Distance to reaction     | $x_{bar\_f} = M_{total\_f} / R_f = 234 \text{ mm}$               |
| Eccentricity of reaction | $e_f = \text{abs}((l_{base} / 2) - x_{bar\_f}) = 591 \text{ mm}$ |

**Reaction acts outside middle third of base**

|                                 |                                                                                                                                  |
|---------------------------------|----------------------------------------------------------------------------------------------------------------------------------|
| Bearing pressure at toe         | $p_{toe\_f} = R_f / (1.5 \times x_{bar\_f}) = 291.1 \text{ kN/m}^2$                                                              |
| Bearing pressure at heel        | $p_{heel\_f} = 0 \text{ kN/m}^2 = 0 \text{ kN/m}^2$                                                                              |
| Rate of change of base reaction | $\text{rate} = p_{toe\_f} / (3 \times x_{bar\_f}) = 415.22 \text{ kN/m}^2/\text{m}$                                              |
| Bearing pressure at stem / toe  | $p_{stem\_toe\_f} = \text{max}(p_{toe\_f} - (\text{rate} \times l_{toe}), 0 \text{ kN/m}^2) = 21.2 \text{ kN/m}^2$               |
| Bearing pressure at mid stem    | $p_{stem\_mid\_f} = \text{max}(p_{toe\_f} - (\text{rate} \times (l_{toe} + t_{wall} / 2)), 0 \text{ kN/m}^2) = 0 \text{ kN/m}^2$ |
| Bearing pressure at stem / heel | $p_{stem\_heel\_f} = \text{max}(p_{toe\_f} - (\text{rate} \times (l_{toe} + t_{wall})), 0 \text{ kN/m}^2) = 0 \text{ kN/m}^2$    |

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**Design of reinforced concrete retaining wall toe (BS 8002:1994)**

**Material properties**

Characteristic strength of concrete  $f_{cu} = 35 \text{ N/mm}^2$   
Characteristic strength of reinforcement  $f_y = 500 \text{ N/mm}^2$

**Base details**

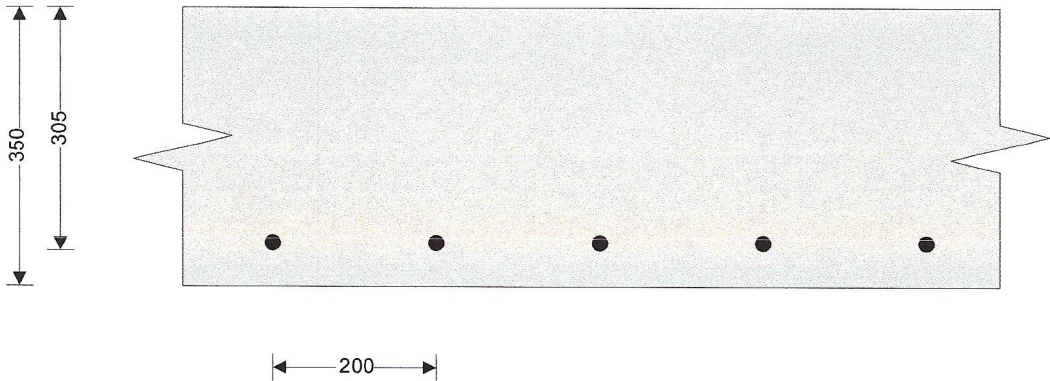
Minimum area of reinforcement  $k = 0.13 \%$   
Cover to reinforcement in toe  $c_{toe} = 35 \text{ mm}$

**Calculate shear for toe design**

Shear from bearing pressure  $V_{toe\_bear} = (p_{toe\_f} + p_{stem\_toe\_f}) \times l_{toe} / 2 = 101.5 \text{ kN/m}$   
Shear from weight of base  $V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base} = 7.5 \text{ kN/m}$   
Shear from weight of soil  $V_{toe\_wt\_soil} = w_{p\_f} - (\gamma_{f\_d} \times \gamma_m \times l_{toe} \times d_{exc}) = 4.9 \text{ kN/m}$   
Total shear for toe design  $V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base} - V_{toe\_wt\_soil} = 89.1 \text{ kN/m}$

**Calculate moment for toe design**

Moment from bearing pressure  $M_{toe\_bear} = (2 \times p_{toe\_f} + p_{stem\_mid\_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6 = 66 \text{ kNm/m}$   
Moment from weight of base  $M_{toe\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2) = 3.9 \text{ kNm/m}$   
Moment from weight of soil  $M_{toe\_wt\_soil} = (w_{p\_f} - (\gamma_{f\_d} \times \gamma_m \times l_{toe} \times d_{exc})) \times (l_{toe} + t_{wall}) / 2 = 2.5 \text{ kNm/m}$   
Total moment for toe design  $M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base} - M_{toe\_wt\_soil} = 59.7 \text{ kNm/m}$



**Check toe in bending**

Width of toe  $b = 1000 \text{ mm/m}$   
Depth of reinforcement  $d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) = 305.0 \text{ mm}$   
Constant  $K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu}) = 0.018$

*Compression reinforcement is not required*

Lever arm  $z_{toe} = \min(0.5 + \sqrt{(0.25 - (\min(K_{toe}, 0.225) / 0.9))}, 0.95) \times d_{toe}$   
 $z_{toe} = 290 \text{ mm}$

Area of tension reinforcement required  $A_{s\_toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe}) = 473 \text{ mm}^2/\text{m}$   
Minimum area of tension reinforcement  $A_{s\_toe\_min} = k \times b \times t_{base} = 455 \text{ mm}^2/\text{m}$   
Area of tension reinforcement required  $A_{s\_toe\_req} = \text{Max}(A_{s\_toe\_des}, A_{s\_toe\_min}) = 473 \text{ mm}^2/\text{m}$   
Reinforcement provided **20 mm dia.bars @ 200 mm centres**  
Area of reinforcement provided  $A_{s\_toe\_prov} = 1571 \text{ mm}^2/\text{m}$

**PASS - Reinforcement provided at the retaining wall toe is adequate**

**Check shear resistance at toe**

Design shear stress  $v_{toe} = V_{toe} / (b \times d_{toe}) = 0.292 \text{ N/mm}^2$   
Allowable shear stress  $v_{adm} = \min(0.8 \times \sqrt{f_{cu}} / 1 \text{ N/mm}^2, 5) \times 1 \text{ N/mm}^2 = 4.733 \text{ N/mm}^2$

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PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress

$V_{c\_toe} = 0.606 \text{ N/mm}^2$

$V_{toe} < V_{c\_toe}$  - No shear reinforcement required

Design of reinforced concrete retaining wall heel (BS 8002:1994)

Material properties

Characteristic strength of concrete

$f_{cu} = 35 \text{ N/mm}^2$

Characteristic strength of reinforcement

$f_y = 500 \text{ N/mm}^2$

Base details

Minimum area of reinforcement

$k = 0.13 \%$

Cover to reinforcement in heel

$C_{heel} = 35 \text{ mm}$

Calculate shear for heel design

Shear from weight of base

$V_{heel\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{heel} \times t_{base} = 7.5 \text{ kN/m}$

Shear from weight of moist backfill

$V_{heel\_wt\_m} = w_{m\_w\_f} = 44.2 \text{ kN/m}$

Shear from surcharge

$V_{heel\_sur} = w_{sur\_f} = 2.6 \text{ kN/m}$

Total shear for heel design

$V_{heel} = V_{heel\_wt\_base} + V_{heel\_wt\_m} + V_{heel\_sur} = 54.3 \text{ kN/m}$

Calculate moment for heel design

Moment from weight of base

$M_{heel\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{heel} + t_{wall} / 2)^2 / 2) = 3.9 \text{ kNm/m}$

Moment from weight of moist backfill

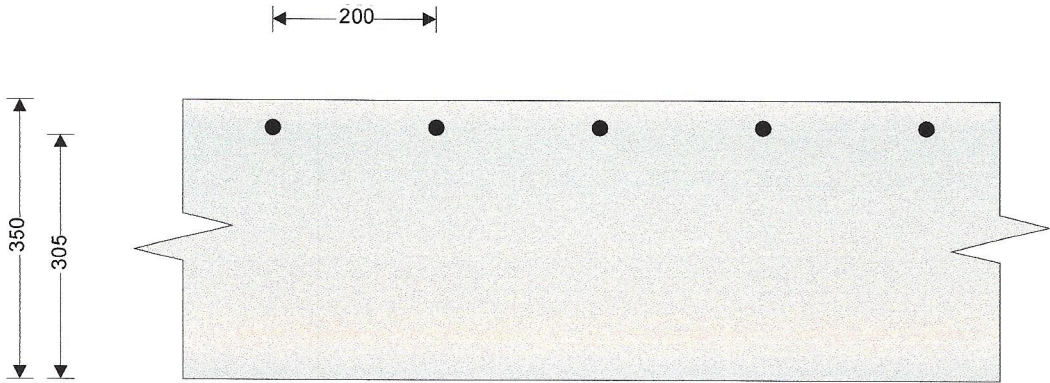
$M_{heel\_wt\_m} = w_{m\_w\_f} \times (l_{heel} + t_{wall}) / 2 = 22.1 \text{ kNm/m}$

Moment from surcharge

$M_{heel\_sur} = w_{sur\_f} \times (l_{heel} + t_{wall}) / 2 = 1.3 \text{ kNm/m}$

Total moment for heel design

$M_{heel} = M_{heel\_wt\_base} + M_{heel\_wt\_m} + M_{heel\_sur} = 27.3 \text{ kNm/m}$



Check heel in bending

Width of heel

$b = 1000 \text{ mm/m}$

Depth of reinforcement

$d_{heel} = t_{base} - C_{heel} - (\phi_{heel} / 2) = 305.0 \text{ mm}$

Constant

$K_{heel} = M_{heel} / (b \times d_{heel}^2 \times f_{cu}) = 0.008$

Compression reinforcement is not required

Lever arm

$z_{heel} = \min(0.5 + \sqrt{(0.25 - (\min(K_{heel}, 0.225) / 0.9))}, 0.95) \times d_{heel}$

$z_{heel} = 290 \text{ mm}$

Area of tension reinforcement required

$A_{s\_heel\_des} = M_{heel} / (0.87 \times f_y \times z_{heel}) = 217 \text{ mm}^2/\text{m}$

Minimum area of tension reinforcement

$A_{s\_heel\_min} = k \times b \times t_{base} = 455 \text{ mm}^2/\text{m}$

Area of tension reinforcement required

$A_{s\_heel\_req} = \text{Max}(A_{s\_heel\_des}, A_{s\_heel\_min}) = 455 \text{ mm}^2/\text{m}$

Reinforcement provided

20 mm dia.bars @ 200 mm centres

Area of reinforcement provided

$A_{s\_heel\_prov} = 1571 \text{ mm}^2/\text{m}$

# Superseded

|                                                                                                                                                                   |                                           |                          |                              |              |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------|--------------------------|------------------------------|--------------|
| <br><b>Cwm Planning &amp; Design Ltd.</b><br>(Civil, Structural & Architectural) | Project<br>54 Lucy Road, Skewen, Neath    |                          | Job no.                      |              |
|                                                                                                                                                                   | Calcs for<br>GARDEN RETAINING WALL (2.4m) |                          | Start page no./Revision<br>7 |              |
|                                                                                                                                                                   | Calcs by<br>CM                            | Calcs date<br>23/01/2024 | Checked by                   | Checked date |
|                                                                                                                                                                   |                                           | Approved by              | Approved date                |              |

**PASS - Reinforcement provided at the retaining wall heel is adequate**

**Check shear resistance at heel**

Design shear stress

$v_{heel} = V_{heel} / (b \times d_{heel}) = 0.178 \text{ N/mm}^2$

Allowable shear stress

$v_{adm} = \min(0.8 \times \sqrt{f_{cu}} / 1 \text{ N/mm}^2, 5) \times 1 \text{ N/mm}^2 = 4.733 \text{ N/mm}^2$

**PASS - Design shear stress is less than maximum shear stress**

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress

$v_{c\_heel} = 0.606 \text{ N/mm}^2$

**$v_{heel} < v_{c\_heel}$  - No shear reinforcement required**

**Design of reinforced concrete retaining wall stem (BS 8002:1994)**

**Material properties**

Characteristic strength of concrete

$f_{cu} = 35 \text{ N/mm}^2$

Characteristic strength of reinforcement

$f_y = 500 \text{ N/mm}^2$

**Wall details**

Minimum area of reinforcement

$k = 0.13 \%$

Cover to reinforcement in stem

$c_{stem} = 35 \text{ mm}$

Cover to reinforcement in wall

$c_{wall} = 35 \text{ mm}$

**Factored horizontal at-rest forces on stem**

Surcharge

$F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds}) = 6.4 \text{ kN/m}$

Moist backfill above water table

$F_{s\_m\_a\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2 = 54.2 \text{ kN/m}$

**Calculate shear for stem design**

Shear at base of stem

$V_{stem} = F_{s\_sur\_f} + F_{s\_m\_a\_f} = 60.6 \text{ kN/m}$

**Calculate moment for stem design**

Surcharge

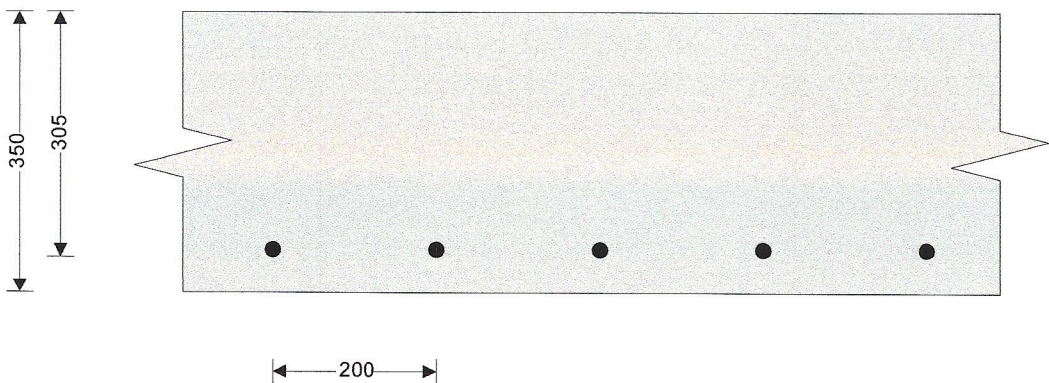
$M_{s\_sur} = F_{s\_sur\_f} \times (h_{stem} + t_{base}) / 2 = 9.7 \text{ kNm/m}$

Moist backfill above water table

$M_{s\_m\_a} = F_{s\_m\_a\_f} \times (2 \times h_{sat} + h_{eff} - d_{ds} + t_{base} / 2) / 3 = 58.3 \text{ kNm/m}$

Total moment for stem design

$M_{stem} = M_{s\_sur} + M_{s\_m\_a} = 68 \text{ kNm/m}$



**Check wall stem in bending**

Width of wall stem

$b = 1000 \text{ mm/m}$

Depth of reinforcement

$d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2) = 305.0 \text{ mm}$

Constant

$K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu}) = 0.021$

**Compression reinforcement is not required**

Lever arm

$z_{stem} = \min(0.5 + \sqrt{(0.25 - (\min(K_{stem}, 0.225) / 0.9))}, 0.95) \times d_{stem}$

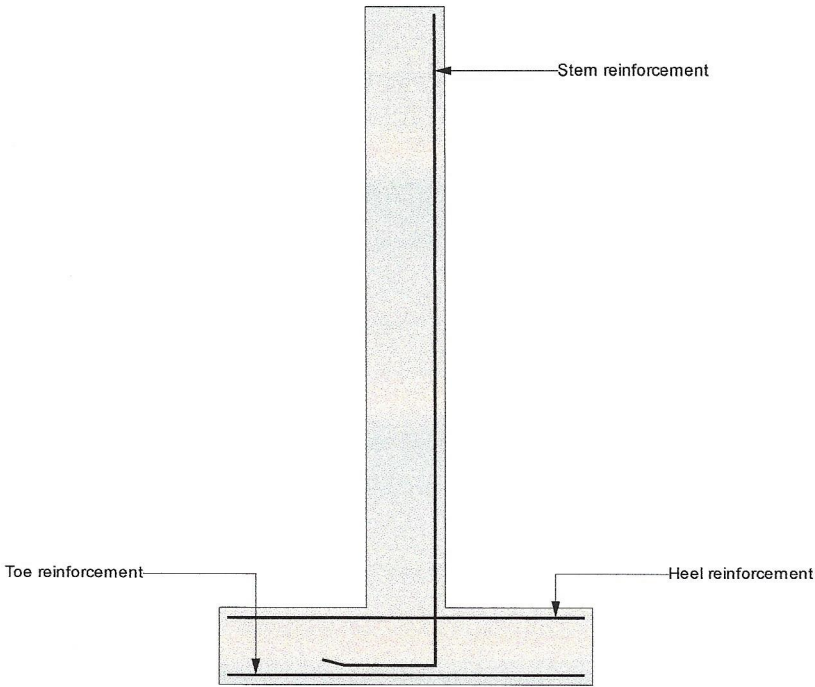
$z_{stem} = 290 \text{ mm}$



# Superseded

|                                                                                                                                                                                      |                                           |                          |            |                              |                              |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------|--------------------------|------------|------------------------------|------------------------------|
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|                                                                                                                                                                                      | Calcs for<br>GARDEN RETAINING WALL (2.4m) |                          |            | Start page no./Revision<br>9 |                              |
|                                                                                                                                                                                      | Calcs by<br>CM                            | Calcs date<br>23/01/2024 | Checked by | Checked date                 | Approved by<br>Approved date |

Indicative retaining wall reinforcement diagram



Toe bars - 20 mm dia.@ 200 mm centres - (1571 mm<sup>2</sup>/m)  
Heel bars - 20 mm dia.@ 200 mm centres - (1571 mm<sup>2</sup>/m)  
Stem bars - 20 mm dia.@ 200 mm centres - (1571 mm<sup>2</sup>/m)