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Cwm Planning & Design Ltd.

(Civil, Structural & Architectural)

STRUCTURAL CALCULATIONS

NEW DWELLING - GARAGE RETAINING WALL
(Supporting front of dwelling)

at:

**54 Lucy Road
Skewen
Neath**

Date: 11th October 2023

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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 (form dwelling) = **10kN**
Surcharge (Garden) = **1.5kN**

Vertical Dead load on stem = **39.3kN/m**
Vertical Live load = **17.25kN/m**

SUMMARY

Retained height taken as **4.6m** (300mm cover to front)
See Section Drawing for details

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RETAINING WALL
DESIGN CALCULATIONS

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LOADS (ON TOP OF WALL)

<u>ELEMENT</u>	<u>D (Kw/m²)</u>	<u>L (Kw/m²)</u>
CAVITY WALL	4.5	-
CEILING / FLOOR	2.0	1.5
ROOF STRUCTURE	1.5	0.75
FOUNDATION / SLAB	2.5	1.5

WALL - D = 2.6m x 4.5 Kw/m² = 11.7 Kw/m

BUILDING D = 4.6m x 6.0 Kw/m² = 27.6 Kw/m

(FLOOR / CEILING /
Roof etc) L = 4.6m x 3.75 Kw/m² = 17.25 Kw/m

Σ DEAD = 39.3 Kw/m

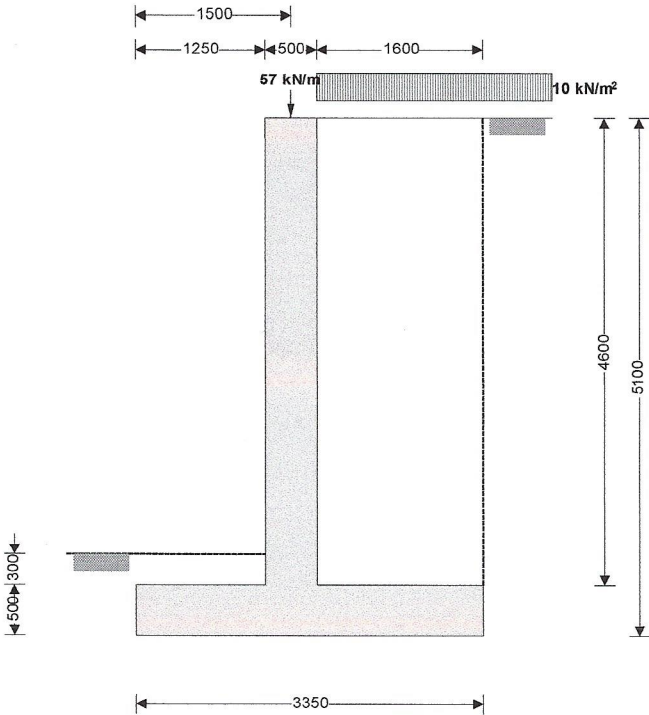
Σ LIVE = 17.25 Kw/m

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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

Retained material details

- Mobilisation factor

Unpropped cantilever

- $h_{\text{stem}} = 4600 \text{ mm}$
- $t_{\text{wall}} = 500 \text{ mm}$
- $l_{\text{toe}} = 1250 \text{ mm}$
- $l_{\text{heel}} = 1600 \text{ mm}$
- $l_{\text{base}} = l_{\text{toe}} + l_{\text{heel}} + t_{\text{wall}} = 3350 \text{ mm}$
- $t_{\text{base}} = 500 \text{ mm}$
- $d_{\text{ds}} = 0 \text{ mm}$
- $l_{\text{ds}} = 0 \text{ mm}$
- $t_{\text{ds}} = 500 \text{ mm}$
- $h_{\text{wall}} = h_{\text{stem}} + t_{\text{base}} + d_{\text{ds}} = 5100 \text{ mm}$
- $d_{\text{cover}} = 300 \text{ mm}$
- $d_{\text{exc}} = 0 \text{ mm}$
- $h_{\text{water}} = 0 \text{ mm}$
- $h_{\text{sat}} = \max(h_{\text{water}} - t_{\text{base}} - d_{\text{ds}}, 0 \text{ mm}) = 0 \text{ mm}$
- $\gamma_{\text{wall}} = 23.6 \text{ kN/m}^3$
- $\gamma_{\text{base}} = 23.6 \text{ kN/m}^3$
- $\alpha = 90.0 \text{ deg}$
- $\beta = 0.0 \text{ deg}$
- $h_{\text{eff}} = h_{\text{wall}} + l_{\text{heel}} \times \tan(\beta) = 5100 \text{ mm}$

- $M = 1.5$

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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 $P_{\text{bearing}} = 150 \text{ kN/m}^2$

Using Coulomb theory

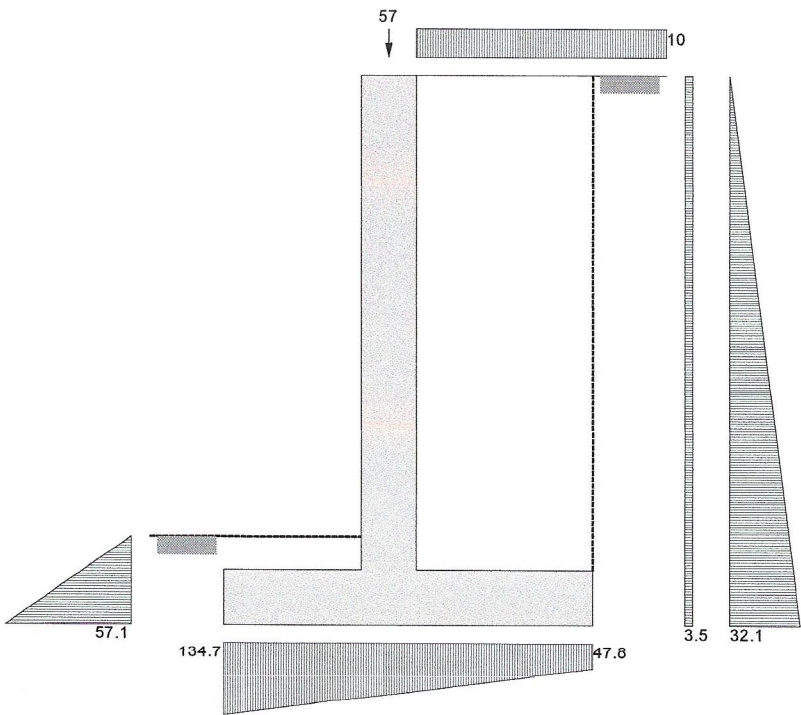
Active pressure coefficient for retained material
 $K_a = \sin(\alpha + \phi')^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta) \times [1 + \sqrt{(\sin(\phi' + \delta) \times \sin(\phi' - \beta) / (\sin(\alpha - \delta) \times \sin(\alpha + \beta))}]^2) = 0.369$
Passive pressure coefficient for base 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 = 10.0 kN/m²
Applied vertical dead load on wall $W_{\text{dead}} = 39.3 \text{ kN/m}$
Applied vertical live load on wall $W_{\text{live}} = 17.3 \text{ kN/m}$
Position of applied vertical load on wall $l_{\text{load}} = 1500 \text{ mm}$
Applied horizontal dead load on wall $F_{\text{dead}} = 0.0 \text{ kN/m}$
Applied horizontal live load on wall $F_{\text{live}} = 0.0 \text{ kN/m}$
Height of applied horizontal load on wall $h_{\text{load}} = 0 \text{ mm}$



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Loads shown in kN/m, pressures shown in kN/m²

Vertical forces on wall

Wall stem	$W_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall} = 54.3 \text{ kN/m}$
Wall base	$W_{base} = l_{base} \times t_{base} \times \gamma_{base} = 39.5 \text{ kN/m}$
Surcharge	$W_{sur} = \text{Surcharge} \times l_{heel} = 16 \text{ kN/m}$
Moist backfill to top of wall	$W_{m_w} = l_{heel} \times (h_{stem} - h_{sat}) \times \gamma_m = 132.5 \text{ kN/m}$
Soil in front of wall	$W_p = l_{toe} \times d_{cover} \times \gamma_{mb} = 6.8 \text{ kN/m}$
Applied vertical load	$W_v = W_{dead} + W_{live} = 56.6 \text{ kN/m}$
Total vertical load	$W_{total} = W_{wall} + W_{base} + W_{sur} + W_{m_w} + W_p + W_v = 305.6 \text{ kN/m}$

Horizontal forces on wall

Surcharge	$F_{sur} = K_a \times \cos(90 - \alpha + \delta) \times \text{Surcharge} \times h_{eff} = 17.8 \text{ kN/m}$
Moist backfill above water table	$F_{m_a} = 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water})^2 = 81.9 \text{ kN/m}$
Total horizontal load	$F_{total} = F_{sur} + F_{m_a} = 99.7 \text{ kN/m}$

Calculate stability against sliding

Passive resistance of soil in front of wall	$F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb} = 22.9 \text{ kN/m}$
Resistance to sliding	$F_{res} = F_p + (W_{total} - W_{sur} - W_p - W_{live}) \times \tan(\delta_b) = 112.2 \text{ kN/m}$
PASS - Resistance force is greater than sliding force	

Overturning moments

Surcharge	$M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2 = 45.5 \text{ kNm/m}$
Moist backfill above water table	$M_{m_a} = F_{m_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3 = 139.2 \text{ kNm/m}$
Total overturning moment	$M_{ot} = M_{sur} + M_{m_a} = 184.7 \text{ kNm/m}$

Restoring moments

Wall stem	$M_{wall} = W_{wall} \times (l_{toe} + t_{wall} / 2) = 81.4 \text{ kNm/m}$
Wall base	$M_{base} = W_{base} \times l_{base} / 2 = 66.2 \text{ kNm/m}$
Moist backfill	$M_{m_r} = (W_{m_w} \times (l_{base} - l_{heel} / 2) + W_{m_s} \times (l_{base} - l_{heel} / 3)) = 337.8 \text{ kNm/m}$
Design vertical dead load	$M_{dead} = W_{dead} \times l_{load} = 59 \text{ kNm/m}$
Total restoring moment	$M_{rest} = M_{wall} + M_{base} + M_{m_r} + M_{dead} = 544.4 \text{ kNm/m}$

Check stability against overturning

Total overturning moment	$M_{ot} = 184.7 \text{ kNm/m}$
Total restoring moment	$M_{rest} = 544.4 \text{ kNm/m}$
PASS - Restoring moment is greater than overturning moment	

Check bearing pressure

Surcharge	$M_{sur_r} = W_{sur} \times (l_{base} - l_{heel} / 2) = 40.8 \text{ kNm/m}$
Soil in front of wall	$M_{p_r} = W_p \times l_{toe} / 2 = 4.2 \text{ kNm/m}$
Design vertical live load	$M_{live} = W_{live} \times l_{load} = 25.9 \text{ kNm/m}$
Total moment for bearing	$M_{total} = M_{rest} - M_{ot} + M_{sur_r} + M_{p_r} + M_{live} = 430.6 \text{ kNm/m}$
Total vertical reaction	$R = W_{total} = 305.6 \text{ kN/m}$
Distance to reaction	$x_{bar} = M_{total} / R = 1409 \text{ mm}$
Eccentricity of reaction	$e = \text{abs}((l_{base} / 2) - x_{bar}) = 266 \text{ mm}$

Reaction acts within middle third of base

Bearing pressure at toe	$p_{toe} = (R / l_{base}) + (6 \times R \times e / l_{base}^2) = 134.7 \text{ kN/m}^2$
Bearing pressure at heel	$p_{heel} = (R / l_{base}) - (6 \times R \times e / l_{base}^2) = 47.8 \text{ kN/m}^2$

PASS - Maximum bearing pressure is less than allowable bearing pressure

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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	$W_{wall_f} = \gamma_{f_d} \times h_{stem} \times t_{wall} \times \gamma_{wall} = 76 \text{ kN/m}$
Wall base	$W_{base_f} = \gamma_{f_d} \times l_{base} \times t_{base} \times \gamma_{base} = 55.3 \text{ kN/m}$
Surcharge	$W_{sur_f} = \gamma_{f_l} \times \text{Surcharge} \times l_{heel} = 25.6 \text{ kN/m}$
Moist backfill to top of wall	$W_{m_w_f} = \gamma_{f_d} \times l_{heel} \times (h_{stem} - h_{sat}) \times \gamma_m = 185.5 \text{ kN/m}$
Soil in front of wall	$W_{p_f} = \gamma_{f_d} \times l_{toe} \times d_{cover} \times \gamma_{mb} = 9.5 \text{ kN/m}$
Applied vertical load	$W_{v_f} = \gamma_{f_d} \times W_{dead} + \gamma_{f_l} \times W_{live} = 82.6 \text{ kN/m}$
Total vertical load	$W_{total_f} = W_{wall_f} + W_{base_f} + W_{sur_f} + W_{m_w_f} + W_{p_f} + W_{v_f} = 434.5 \text{ kN/m}$

Factored horizontal at-rest forces on wall

Surcharge	$F_{sur_f} = \gamma_{f_l} \times K_0 \times \text{Surcharge} \times h_{eff} = 48.2 \text{ kN/m}$
Moist backfill above water table	$F_{m_a_f} = \gamma_{f_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2 = 193.4 \text{ kN/m}$
Total horizontal load	$F_{total_f} = F_{sur_f} + F_{m_a_f} = 241.5 \text{ kN/m}$
Passive resistance of soil in front of wall	$F_{p_f} = \gamma_{f_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb} = 32 \text{ kN/m}$

Factored overturning moments

Surcharge	$M_{sur_f} = F_{sur_f} \times (h_{eff} - 2 \times d_{ds}) / 2 = 122.8 \text{ kNm/m}$
Moist backfill above water table	$M_{m_a_f} = F_{m_a_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3 = 328.8 \text{ kNm/m}$
Total overturning moment	$M_{ot_f} = M_{sur_f} + M_{m_a_f} = 451.5 \text{ kNm/m}$

Restoring moments

Wall stem	$M_{wall_f} = W_{wall_f} \times (l_{toe} + t_{wall} / 2) = 114 \text{ kNm/m}$
Wall base	$M_{base_f} = W_{base_f} \times l_{base} / 2 = 92.7 \text{ kNm/m}$
Surcharge	$M_{sur_r_f} = W_{sur_f} \times (l_{base} - l_{heel} / 2) = 65.3 \text{ kNm/m}$
Moist backfill	$M_{m_r_f} = (W_{m_w_f} \times (l_{base} - l_{heel} / 2) + W_{m_s_f} \times (l_{base} - l_{heel} / 3)) = 473 \text{ kNm/m}$
Soil in front of wall	$M_{p_r_f} = W_{p_f} \times l_{toe} / 2 = 5.9 \text{ kNm/m}$
Design vertical load	$M_{v_f} = W_{v_f} \times l_{load} = 123.9 \text{ kNm/m}$
Total restoring moment	$M_{rest_f} = M_{wall_f} + M_{base_f} + M_{sur_r_f} + M_{m_r_f} + M_{p_r_f} + M_{v_f} = 874.8 \text{ kNm/m}$

Factored bearing pressure

Total moment for bearing	$M_{total_f} = M_{rest_f} - M_{ot_f} = 423.2 \text{ kNm/m}$
Total vertical reaction	$R_f = W_{total_f} = 434.5 \text{ kN/m}$
Distance to reaction	$x_{bar_f} = M_{total_f} / R_f = 974 \text{ mm}$
Eccentricity of reaction	$e_f = \text{abs}((l_{base} / 2) - x_{bar_f}) = 701 \text{ mm}$

Reaction acts outside middle third of base

Bearing pressure at toe	$p_{toe_f} = R_f / (1.5 \times x_{bar_f}) = 297.4 \text{ kN/m}^2$
Bearing pressure at heel	$p_{heel_f} = 0 \text{ kN/m}^2 = 0 \text{ kN/m}^2$
Rate of change of base reaction	$\text{rate} = p_{toe_f} / (3 \times x_{bar_f}) = 101.75 \text{ kN/m}^2/\text{m}$
Bearing pressure at stem / toe	$p_{stem_toe_f} = \text{max}(p_{toe_f} - (\text{rate} \times l_{toe}), 0 \text{ kN/m}^2) = 170.2 \text{ kN/m}^2$

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Bearing pressure at mid stem

$p_{stem_mid_f} = \max(p_{toe_f} - (rate \times (l_{toe} + t_{wall} / 2)), 0 \text{ kN/m}^2) = 144.7 \text{ kN/m}^2$

Bearing pressure at stem / heel

$p_{stem_heel_f} = \max(p_{toe_f} - (rate \times (l_{toe} + t_{wall})), 0 \text{ kN/m}^2) = 119.3 \text{ kN/m}^2$

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

Material properties

Characteristic strength of concrete

$f_{cu} = 40 \text{ N/mm}^2$

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

$V_{toe_bear} = (p_{toe_f} + p_{stem_toe_f}) \times l_{toe} / 2 = 292.2 \text{ kN/m}$

Shear from weight of base

$V_{toe_wt_base} = \gamma_{f_d} \times \gamma_{base} \times l_{toe} \times t_{base} = 20.7 \text{ kN/m}$

Shear from weight of soil

$V_{toe_wt_soil} = w_{p_f} - (\gamma_{f_d} \times \gamma_m \times l_{toe} \times d_{exc}) = 9.5 \text{ kN/m}$

Total shear for toe design

$V_{toe} = V_{toe_bear} - V_{toe_wt_base} - V_{toe_wt_soil} = 262.1 \text{ kN/m}$

Calculate moment for toe design

Moment from bearing pressure

$M_{toe_bear} = (2 \times p_{toe_f} + p_{stem_mid_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6 = 277.3 \text{ kNm/m}$

Moment from weight of base

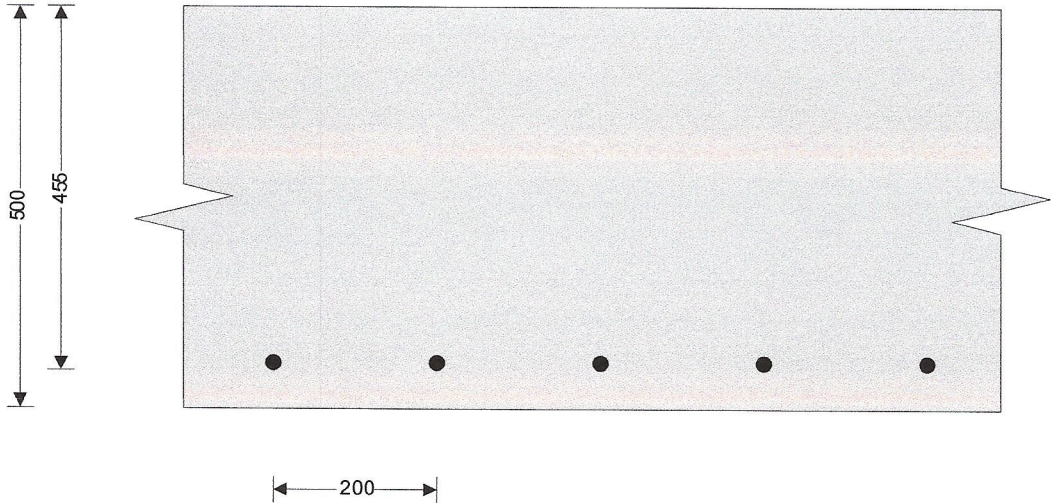
$M_{toe_wt_base} = (\gamma_{f_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2) = 18.6 \text{ kNm/m}$

Moment from weight of soil

$M_{toe_wt_soil} = (w_{p_f} - (\gamma_{f_d} \times \gamma_m \times l_{toe} \times d_{exc})) \times (l_{toe} + t_{wall}) / 2 = 8.3 \text{ kNm/m}$

Total moment for toe design

$M_{toe} = M_{toe_bear} - M_{toe_wt_base} - M_{toe_wt_soil} = 250.4 \text{ kNm/m}$



Check toe in bending

Width of toe

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

Depth of reinforcement

$d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) = 455.0 \text{ mm}$

Constant

$K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu}) = 0.030$

Compression reinforcement is not required

Lever arm

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

Area of tension reinforcement required

$A_{s_toe_des} = M_{toe} / (0.87 \times f_y \times z_{toe}) = 1332 \text{ mm}^2/\text{m}$

Minimum area of tension reinforcement

$A_{s_toe_min} = k \times b \times t_{base} = 650 \text{ mm}^2/\text{m}$

Area of tension reinforcement required

$A_{s_toe_req} = \text{Max}(A_{s_toe_des}, A_{s_toe_min}) = 1332 \text{ mm}^2/\text{m}$

Reinforcement provided

20 mm dia.bars @ 200 mm centres

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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

$v_{toe} = V_{toe} / (b \times d_{toe}) = 0.576 \text{ N/mm}^2$

Allowable shear stress

$v_{adm} = \min(0.8 \times \sqrt{f_{cu}} / 1 \text{ N/mm}^2, 5) \times 1 \text{ N/mm}^2 = 5.000 \text{ N/mm}^2$

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress

$v_{c_toe} = 0.519 \text{ N/mm}^2$

WARNING - Shear reinforcement required

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

Material properties

Characteristic strength of concrete

$f_{cu} = 40 \text{ N/mm}^2$

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 bearing pressure

$V_{heel_bear} = p_{stem_heel_f} \times ((3 \times x_{bar_f}) - l_{toe} - t_{wall}) / 2 = 69.9 \text{ kN/m}$

Shear from weight of base

$V_{heel_wt_base} = \gamma_{f_d} \times \gamma_{base} \times l_{heel} \times t_{base} = 26.4 \text{ kN/m}$

Shear from weight of moist backfill

$V_{heel_wt_m} = w_{m_w_f} = 185.5 \text{ kN/m}$

Shear from surcharge

$V_{heel_sur} = w_{sur_f} = 25.6 \text{ kN/m}$

Total shear for heel design

$V_{heel} = - V_{heel_bear} + V_{heel_wt_base} + V_{heel_wt_m} + V_{heel_sur} = 167.6 \text{ kN/m}$

Calculate moment for heel design

Moment from bearing pressure

$M_{heel_bear} = p_{stem_mid_f} \times ((3 \times x_{bar_f}) - l_{toe} - t_{wall} / 2)^2 / 6 = 48.8 \text{ kNm/m}$

Moment from weight of base

$M_{heel_wt_base} = (\gamma_{f_d} \times \gamma_{base} \times t_{base} \times (l_{heel} + t_{wall} / 2)^2 / 2) = 28.3 \text{ kNm/m}$

Moment from weight of moist backfill

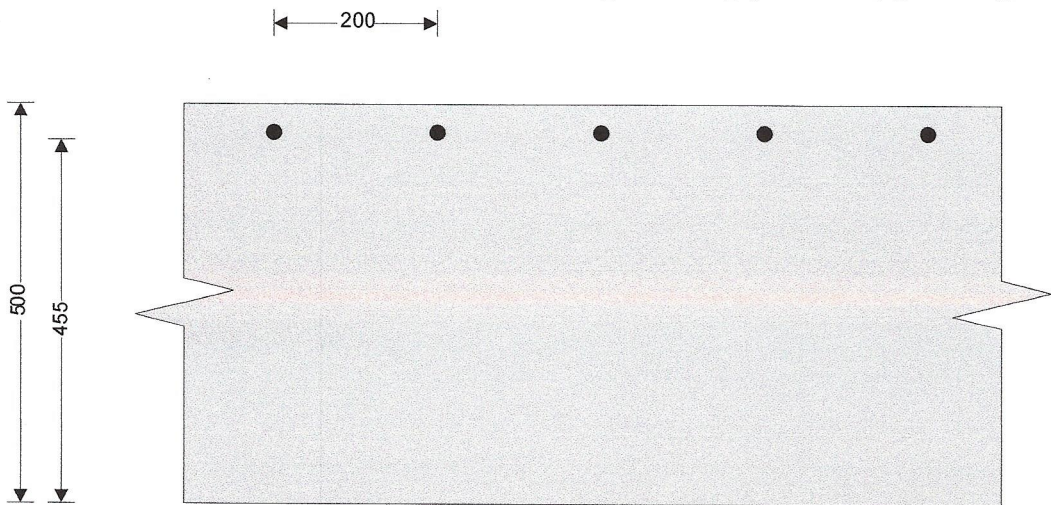
$M_{heel_wt_m} = w_{m_w_f} \times (l_{heel} + t_{wall}) / 2 = 194.7 \text{ kNm/m}$

Moment from surcharge

$M_{heel_sur} = w_{sur_f} \times (l_{heel} + t_{wall}) / 2 = 26.9 \text{ kNm/m}$

Total moment for heel design

$M_{heel} = - M_{heel_bear} + M_{heel_wt_base} + M_{heel_wt_m} + M_{heel_sur} = 201.1 \text{ kNm/m}$



Check heel in bending

Width of heel

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

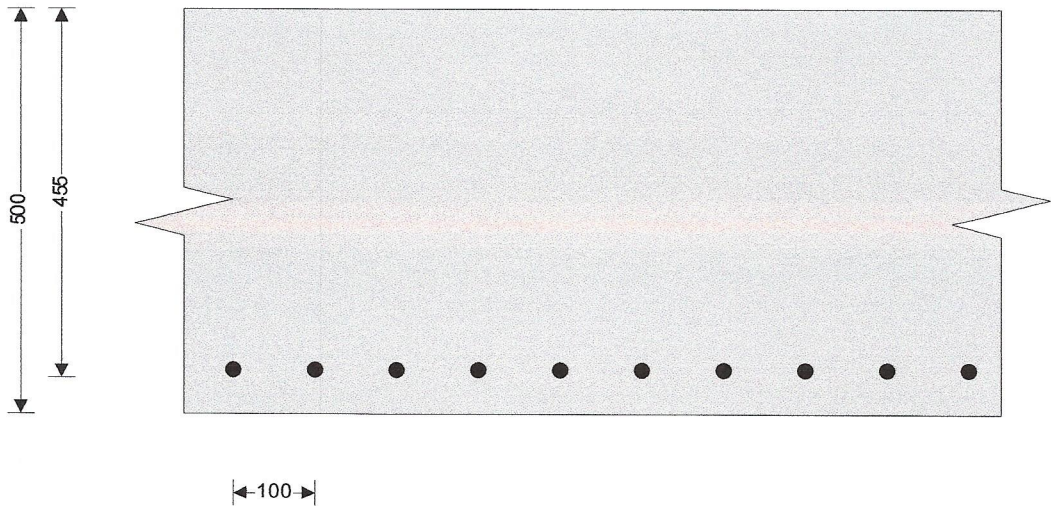
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Depth of reinforcement	$d_{heel} = t_{base} - c_{heel} - (\phi_{heel} / 2) = 455.0 \text{ mm}$
Constant	$K_{heel} = M_{heel} / (b \times d_{heel}^2 \times f_{cu}) = 0.024$ Compression reinforcement is not required
Lever arm	$z_{heel} = \min(0.5 + \sqrt{(0.25 - (\min(K_{heel}, 0.225) / 0.9))}, 0.95) \times d_{heel}$
$z_{heel} = 432 \text{ mm}$	
Area of tension reinforcement required	$A_{s_heel_des} = M_{heel} / (0.87 \times f_y \times z_{heel}) = 1070 \text{ mm}^2/\text{m}$
Minimum area of tension reinforcement	$A_{s_heel_min} = k \times b \times t_{base} = 650 \text{ mm}^2/\text{m}$
Area of tension reinforcement required	$A_{s_heel_req} = \text{Max}(A_{s_heel_des}, A_{s_heel_min}) = 1070 \text{ mm}^2/\text{m}$
Reinforcement provided	20 mm dia.bars @ 200 mm centres
Area of reinforcement provided	$A_{s_heel_prov} = 1571 \text{ mm}^2/\text{m}$ PASS - Reinforcement provided at the retaining wall heel is adequate
Check shear resistance at heel	
Design shear stress	$v_{heel} = V_{heel} / (b \times d_{heel}) = 0.368 \text{ N/mm}^2$
Allowable shear stress	$v_{adm} = \min(0.8 \times \sqrt{f_{cu} / 1 \text{ N/mm}^2}, 5) \times 1 \text{ N/mm}^2 = 5.000 \text{ N/mm}^2$ PASS - Design shear stress is less than maximum shear stress
From BS8110:Part 1:1997 – Table 3.8	
Design concrete shear stress	$v_{c_heel} = 0.519 \text{ N/mm}^2$ $v_{heel} < v_{c_heel}$ - No shear reinforcement required
Design of reinforced concrete retaining wall stem (BS 8002:1994)	
Material properties	
Characteristic strength of concrete	$f_{cu} = 40 \text{ N/mm}^2$
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	$F_{s_sur_f} = \gamma_{f_l} \times K_0 \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds}) = 43.4 \text{ kN/m}$
Moist backfill above water table	$F_{s_m_a_f} = 0.5 \times \gamma_{f_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2 = 157.3 \text{ kN/m}$
Calculate shear for stem design	
Shear at base of stem	$V_{stem} = F_{s_sur_f} + F_{s_m_a_f} = 200.8 \text{ kN/m}$
Calculate moment for stem design	
Surcharge	$M_{s_sur} = F_{s_sur_f} \times (h_{stem} + t_{base}) / 2 = 110.7 \text{ kNm/m}$
Moist backfill above water table	$M_{s_m_a} = F_{s_m_a_f} \times (2 \times h_{sat} + h_{eff} - d_{ds} + t_{base} / 2) / 3 = 280.6 \text{ kNm/m}$
Total moment for stem design	$M_{stem} = M_{s_sur} + M_{s_m_a} = 391.3 \text{ kNm/m}$

Superseded

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Check wall stem in bending

Width of wall stem
Depth of reinforcement
Constant

Lever arm
Z_{stem} = 430 mm

Area of tension reinforcement required
Minimum area of tension reinforcement
Area of tension reinforcement required
Reinforcement provided
Area of reinforcement provided

Check shear resistance at wall stem

Design shear stress
Allowable shear stress

From BS8110:Part 1:1997 – Table 3.8
Design concrete shear stress

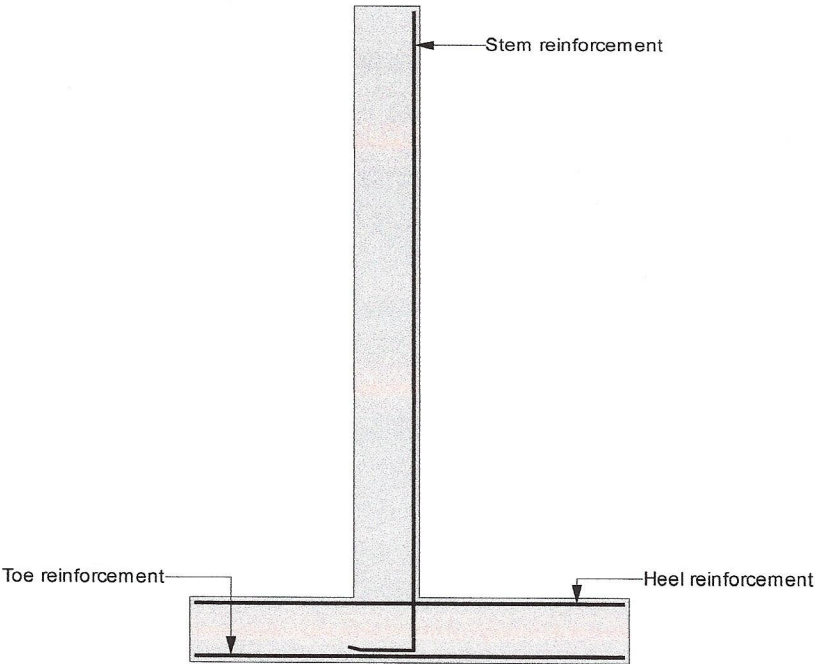
b = 1000 mm/m
d_{stem} = t_{wall} – c_{stem} – (φ_{stem} / 2) = 455.0 mm
K_{stem} = M_{stem} / (b × d_{stem}² × f_{cu}) = 0.047
Compression reinforcement is not required
z_{stem} = min(0.5 + √(0.25 – (min(K_{stem}, 0.225) / 0.9)), 0.95) × d_{stem}
A_{s_stem_des} = M_{stem} / (0.87 × f_y × z_{stem}) = 2093 mm²/m
A_{s_stem_min} = k × b × t_{wall} = 650 mm²/m
A_{s_stem_req} = Max(A_{s_stem_des}, A_{s_stem_min}) = 2093 mm²/m
20 mm dia.bars @ 100 mm centres
A_{s_stem_prov} = 3142 mm²/m
PASS - Reinforcement provided at the retaining wall stem is adequate

v_{stem} = V_{stem} / (b × d_{stem}) = 0.441 N/mm²
v_{adm} = min(0.8 × √(f_{cu} / 1 N/mm²), 5) × 1 N/mm² = 5.000 N/mm²
PASS - Design shear stress is less than maximum shear stress
V_{c_stem} = 0.653 N/mm²
V_{stem} < V_{c_stem} - No shear reinforcement required

Superseded

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Indicative retaining wall reinforcement diagram



Toe bars - 20 mm dia.@ 200 mm centres - (1571 mm²/m)
Heel bars - 20 mm dia.@ 200 mm centres - (1571 mm²/m)
Stem bars - 20 mm dia.@ 100 mm centres - (3142 mm²/m)