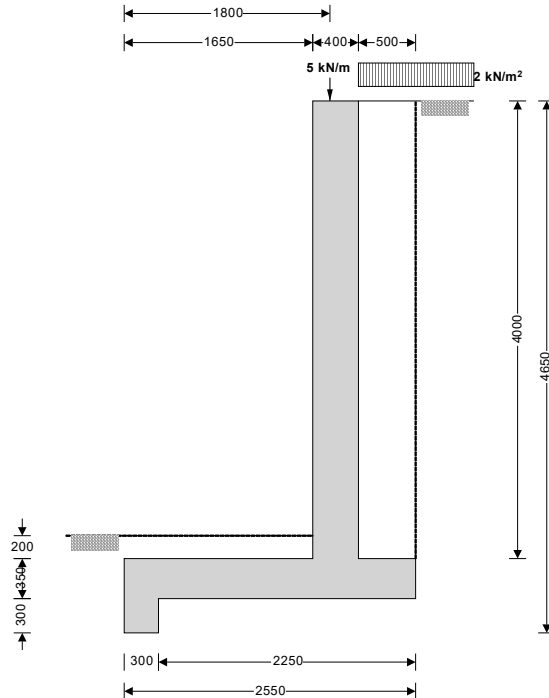


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RETAINING WALL ANALYSIS (BS 8002:1994)

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

Unpropped cantilever

$h_{\text{stem}} = 4000$ mm
 $t_{\text{wall}} = 400$ mm
 $l_{\text{toe}} = 1650$ mm
 $l_{\text{heel}} = 500$ mm
 $l_{\text{base}} = l_{\text{toe}} + l_{\text{heel}} + t_{\text{wall}} = 2550$ mm
 $t_{\text{base}} = 350$ mm
 $d_{\text{ds}} = 300$ mm
 $l_{\text{ds}} = 0$ mm
 $t_{\text{ds}} = 300$ mm
 $h_{\text{wall}} = h_{\text{stem}} + t_{\text{base}} + d_{\text{ds}} = 4650$ mm
 $d_{\text{cover}} = 200$ mm
 $d_{\text{exc}} = 0$ mm
 $h_{\text{water}} = 0$ mm
 $h_{\text{sat}} = \max(h_{\text{water}} - t_{\text{base}} - d_{\text{ds}}, 0 \text{ mm}) = 0$ mm
 $\gamma_{\text{wall}} = 23.6$ kN/m³
 $\gamma_{\text{base}} = 23.6$ kN/m³
 $\alpha = 90.0$ deg
 $\beta = 0.0$ deg
 $h_{\text{eff}} = h_{\text{wall}} + l_{\text{heel}} \times \tan(\beta) = 4650$ mm

Retained material details

Mobilisation factor
Moist density of retained material

$M = 1.5$
 $\gamma_m = 18.0$ kN/m³

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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 $\delta = 0.0 \text{ deg}$

Base material details

Moist density $\gamma_{mb} = 20.0 \text{ kN/m}^3$

Design shear strength $\phi'_b = 27.0 \text{ deg}$

Design base friction $\delta_b = 25.0 \text{ deg}$

Allowable bearing pressure $P_{\text{bearing}} = 100 \text{ kN/m}^2$

Using Coulomb theory

Active pressure coefficient for retained material

$$K_a = \sin(\alpha + \phi')^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta) \times [1 + \sqrt{(\sin(\phi' + \delta) \times \sin(\phi' - \beta) / (\sin(\alpha - \delta) \times \sin(\alpha + \beta)))})^2] = 0.419$$

Passive pressure coefficient for base material

$$K_p = \sin(90 - \phi'_b)^2 / (\sin(90 - \delta_b) \times [1 - \sqrt{(\sin(\phi'_b + \delta_b) \times \sin(\phi'_b) / (\sin(90 + \delta_b)))})^2] = 6.339$$

At-rest pressure

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

Loading details

Surcharge load on plan Surcharge = **1.5 kN/m²**

Applied vertical dead load on wall $W_{\text{dead}} = 5.0 \text{ kN/m}$

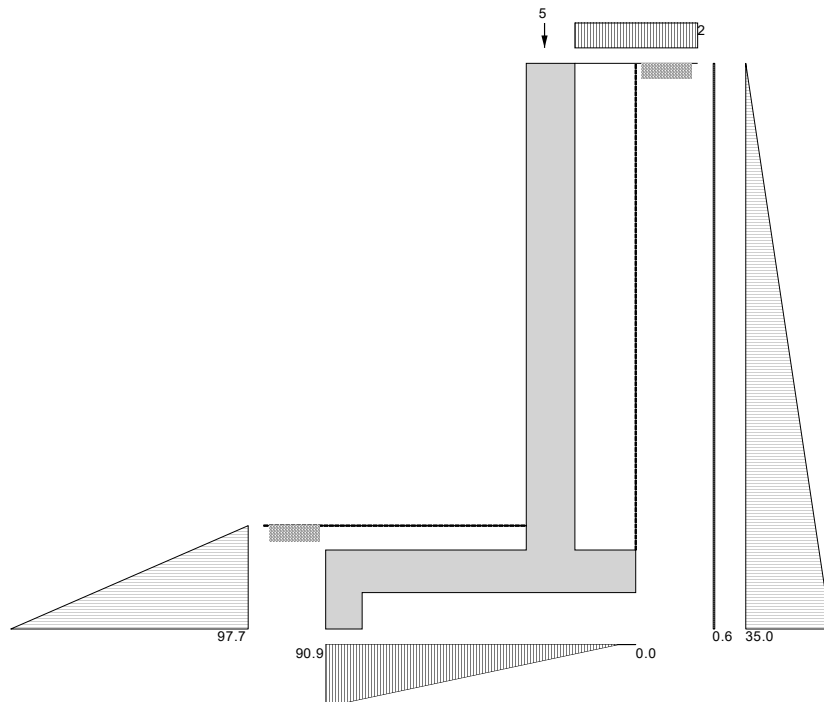
Applied vertical live load on wall $W_{\text{live}} = 0.0 \text{ kN/m}$

Position of applied vertical load on wall $l_{\text{load}} = 1800 \text{ mm}$

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 $h_{\text{load}} = 0 \text{ mm}$



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

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Vertical forces on wall

Wall stem	$W_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall} = 37.8 \text{ kN/m}$
Wall base	$W_{base} = l_{base} \times t_{base} \times \gamma_{base} = 21.1 \text{ kN/m}$
Wall downstand	$W_{ds} = d_{ds} \times t_{ds} \times \gamma_{base} = 2.1 \text{ kN/m}$
Surcharge	$W_{sur} = \text{Surcharge} \times l_{heel} = 0.8 \text{ kN/m}$
Moist backfill to top of wall	$W_{m_w} = l_{heel} \times (h_{stem} - h_{sat}) \times \gamma_m = 36 \text{ kN/m}$
Soil in front of wall	$W_p = l_{toe} \times d_{cover} \times \gamma_{mb} = 6.6 \text{ kN/m}$
Applied vertical load	$W_v = W_{dead} + W_{live} = 5 \text{ kN/m}$
Total vertical load	$W_{total} = W_{wall} + W_{base} + W_{ds} + W_{sur} + W_{m_w} + W_p + W_v = 109.3 \text{ kN/m}$

Horizontal forces on wall

Surcharge	$F_{sur} = K_a \times \text{Surcharge} \times h_{eff} = 2.9 \text{ kN/m}$
Moist backfill above water table	$F_{m_a} = 0.5 \times K_a \times \gamma_m \times (h_{eff} - h_{water})^2 = 81.4 \text{ kN/m}$
Total horizontal load	$F_{total} = F_{sur} + F_{m_a} = 84.4 \text{ kN/m}$

Calculate stability against sliding

Passive resistance of soil in front of wall	$F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb} = 41.5 \text{ kN/m}$
Resistance to sliding	$F_{res} = F_p + (W_{total} - W_{sur} - W_p) \times \tan(\delta_b) = 89.0 \text{ kN/m}$
PASS - Resistance force is greater than sliding force	

Overturning moments

Surcharge	$M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2 = 5.9 \text{ kNm/m}$
Moist backfill above water table	$M_{m_a} = F_{m_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3 = 101.8 \text{ kNm/m}$
Soil in front of wall	$M_{p_o} = F_p \times [2 \times d_{ds} - t_{base} - d_{cover} + d_{exc}] / 3 = 0.7 \text{ kNm/m}$
Total overturning moment	$M_{ot} = M_{sur} + M_{m_a} + M_{p_o} = 108.4 \text{ kNm/m}$

Restoring moments

Wall stem	$M_{wall} = W_{wall} \times (l_{toe} + t_{wall} / 2) = 69.9 \text{ kNm/m}$
Wall base	$M_{base} = W_{base} \times l_{base} / 2 = 26.9 \text{ kNm/m}$
Wall downstand	$M_{ds} = W_{ds} \times (l_{ds} + t_{ds} / 2) = 0.3 \text{ kNm/m}$
Moist backfill	$M_{m_r} = (W_{m_w} \times (l_{base} - l_{heel} / 2) + W_{m_s} \times (l_{base} - l_{heel} / 3)) = 82.8 \text{ kNm/m}$
Design vertical dead load	$M_{dead} = W_{dead} \times l_{load} = 9 \text{ kNm/m}$
Total restoring moment	$M_{rest} = M_{wall} + M_{base} + M_{ds} + M_{m_r} + M_{dead} = 188.8 \text{ kNm/m}$

Check stability against overturning

Total overturning moment	$M_{ot} = 108.4 \text{ kNm/m}$
Total restoring moment	$M_{rest} = 188.8 \text{ kNm/m}$
PASS - Restoring moment is greater than overturning moment	

Check bearing pressure

Surcharge	$M_{sur_r} = W_{sur} \times (l_{base} - l_{heel} / 2) = 1.7 \text{ kNm/m}$
Soil in front of wall	$M_{p_r} = W_p \times l_{toe} / 2 = 5.4 \text{ kNm/m}$
Total moment for bearing	$M_{total} = M_{rest} - M_{ot} + M_{sur_r} + M_{p_r} = 87.6 \text{ kNm/m}$
Total vertical reaction	$R = W_{total} = 109.3 \text{ kN/m}$
Distance to reaction	$x_{bar} = M_{total} / R = 801 \text{ mm}$
Eccentricity of reaction	$e = \text{abs}((l_{base} / 2) - x_{bar}) = 474 \text{ mm}$
Reaction acts outside middle third of base	
Bearing pressure at toe	$p_{toe} = R / (1.5 \times x_{bar}) = 90.9 \text{ kN/m}^2$
Bearing pressure at heel	$p_{heel} = 0 \text{ kN/m}^2 = 0 \text{ kN/m}^2$

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	$W_{wall_f} = \gamma_{f_d} \times h_{stem} \times t_{wall} \times \gamma_{wall} = 52.9 \text{ kN/m}$
Wall base	$W_{base_f} = \gamma_{f_d} \times l_{base} \times t_{base} \times \gamma_{base} = 29.5 \text{ kN/m}$
Wall downstand	$W_{ds_f} = \gamma_{f_d} \times d_{ds} \times t_{ds} \times \gamma_{base} = 3 \text{ kN/m}$
Surcharge	$W_{sur_f} = \gamma_{f_l} \times \text{Surcharge} \times l_{heel} = 1.2 \text{ kN/m}$
Moist backfill to top of wall	$W_{m_w_f} = \gamma_{f_d} \times l_{heel} \times (h_{stem} - h_{sat}) \times \gamma_m = 50.4 \text{ kN/m}$
Soil in front of wall	$W_{p_f} = \gamma_{f_d} \times l_{toe} \times d_{cover} \times \gamma_{mb} = 9.2 \text{ kN/m}$
Applied vertical load	$W_{v_f} = \gamma_{f_d} \times W_{dead} + \gamma_{f_l} \times W_{live} = 7 \text{ kN/m}$
Total vertical load kN/m	$W_{total_f} = W_{wall_f} + W_{base_f} + W_{ds_f} + W_{sur_f} + W_{m_w_f} + W_{p_f} + W_{v_f} = 153.2$

Factored horizontal at-rest forces on wall

Surcharge	$F_{sur_f} = \gamma_{f_l} \times K_0 \times \text{Surcharge} \times h_{eff} = 6.6 \text{ kN/m}$
Moist backfill above water table	$F_{m_a_f} = \gamma_{f_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2 = 160.8 \text{ kN/m}$
Total horizontal load	$F_{total_f} = F_{sur_f} + F_{m_a_f} = 167.3 \text{ kN/m}$
Passive resistance of soil in front of wall kN/m	$F_{p_f} = \gamma_{f_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb} = 58.1$

Factored overturning moments

Surcharge	$M_{sur_f} = F_{sur_f} \times (h_{eff} - 2 \times d_{ds}) / 2 = 13.3 \text{ kNm/m}$
Moist backfill above water table	$M_{m_a_f} = F_{m_a_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3 = 201 \text{ kNm/m}$
Soil in front of wall	$M_{p_o_f} = F_{p_f} \times [2 \times d_{ds} - t_{base} - d_{cover} + d_{exc}] / 3 = 1 \text{ kNm/m}$
Total overturning moment	$M_{ot_f} = M_{sur_f} + M_{m_a_f} + M_{p_o_f} = 215.3 \text{ kNm/m}$

Restoring moments

Wall stem	$M_{wall_f} = W_{wall_f} \times (l_{toe} + t_{wall} / 2) = 97.8 \text{ kNm/m}$
Wall base	$M_{base_f} = W_{base_f} \times l_{base} / 2 = 37.6 \text{ kNm/m}$
Wall downstand	$M_{ds_f} = W_{ds_f} \times (l_{ds} + t_{ds} / 2) = 0.4 \text{ kNm/m}$
Surcharge	$M_{sur_r_f} = W_{sur_f} \times (l_{base} - l_{heel} / 2) = 2.8 \text{ kNm/m}$
Moist backfill	$M_{m_r_f} = (W_{m_w_f} \times (l_{base} - l_{heel} / 2) + W_{m_s_f} \times (l_{base} - l_{heel} / 3)) = 115.9$
kNm/m	
Soil in front of wall	$M_{p_r_f} = W_{p_f} \times l_{toe} / 2 = 7.6 \text{ kNm/m}$
Design vertical load	$M_{v_f} = W_{v_f} \times l_{load} = 12.6 \text{ kNm/m}$
Total restoring moment kNm/m	$M_{rest_f} = M_{wall_f} + M_{base_f} + M_{ds_f} + M_{sur_r_f} + M_{m_r_f} + M_{p_r_f} + M_{v_f} = 274.7$

Factored bearing pressure

Total moment for bearing	$M_{total_f} = M_{rest_f} - M_{ot_f} = 59.5 \text{ kNm/m}$
Total vertical reaction	$R_f = W_{total_f} = 153.2 \text{ kN/m}$
Distance to reaction	$x_{bar_f} = M_{total_f} / R_f = 388 \text{ mm}$
Eccentricity of reaction	$e_f = \text{abs}((l_{base} / 2) - x_{bar_f}) = 887 \text{ mm}$

Reaction acts outside middle third of base

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Bearing pressure at toe	$p_{toe_f} = R_f / (1.5 \times x_{bar_f}) = \mathbf{262.9 \text{ kN/m}^2}$
Bearing pressure at heel	$p_{heel_f} = 0 \text{ kN/m}^2 = \mathbf{0 \text{ kN/m}^2}$
Rate of change of base reaction	$rate = p_{toe_f} / (3 \times x_{bar_f}) = \mathbf{225.64 \text{ kN/m}^2/\text{m}}$
Bearing pressure at stem / toe	$p_{stem_toe_f} = \max(p_{toe_f} - (rate \times l_{toe}), 0 \text{ kN/m}^2) = \mathbf{0 \text{ kN/m}^2}$
Bearing pressure at mid stem	$p_{stem_mid_f} = \max(p_{toe_f} - (rate \times (l_{toe} + t_{wall} / 2)), 0 \text{ kN/m}^2) = \mathbf{0 \text{ kN/m}^2}$
Bearing pressure at stem / heel	$p_{stem_heel_f} = \max(p_{toe_f} - (rate \times (l_{toe} + t_{wall})), 0 \text{ kN/m}^2) = \mathbf{0 \text{ kN/m}^2}$

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

Material properties

Characteristic strength of concrete	$f_{cu} = \mathbf{40 \text{ N/mm}^2}$
Characteristic strength of reinforcement	$f_y = \mathbf{500 \text{ N/mm}^2}$

Base details

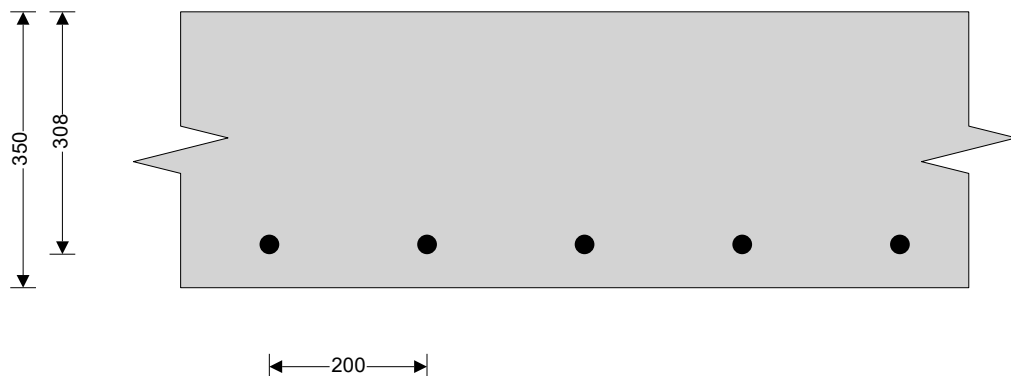
Minimum area of reinforcement	$k = \mathbf{0.13 \%}$
Cover to reinforcement in toe	$c_{toe} = \mathbf{30 \text{ mm}}$

Calculate shear for toe design

Shear from bearing pressure	$V_{toe_bear} = 3 \times p_{toe_f} \times x_{bar_f} / 2 = \mathbf{153.2 \text{ kN/m}}$
Shear from weight of base	$V_{toe_wt_base} = \gamma_{f_d} \times \gamma_{base} \times l_{toe} \times t_{base} = \mathbf{19.1 \text{ kN/m}}$
Shear from weight of downstand	$V_{toe_wt_ds} = \gamma_{f_d} \times \gamma_{base} \times d_{ds} \times t_{ds} = \mathbf{3 \text{ kN/m}}$
Shear from weight of soil	$V_{toe_wt_soil} = w_{p_f} - (\gamma_{f_d} \times \gamma_m \times l_{toe} \times d_{exc}) = \mathbf{9.2 \text{ kN/m}}$
Total shear for toe design	$V_{toe} = V_{toe_bear} - V_{toe_wt_base} - V_{toe_wt_ds} - V_{toe_wt_soil} = \mathbf{121.9 \text{ kN/m}}$

Calculate moment for toe design

Moment from bearing pressure	$M_{toe_bear} = 3 \times p_{toe_f} \times x_{bar_f} \times (l_{toe} - x_{bar_f} + t_{wall} / 2) / 2 = \mathbf{223.9 \text{ kNm/m}}$
Moment from weight of base	$M_{toe_wt_base} = (\gamma_{f_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2) = \mathbf{19.8 \text{ kNm/m}}$
Moment from weight of downstand	$M_{toe_wt_ds} = \gamma_{f_d} \times \gamma_{base} \times d_{ds} \times t_{ds} \times (l_{toe} - l_{ds} + (t_{wall} - t_{ds}) / 2) = \mathbf{5.1 \text{ kNm/m}}$
Moment from weight of soil	$M_{toe_wt_soil} = (w_{p_f} - (\gamma_{f_d} \times \gamma_m \times l_{toe} \times d_{exc})) \times (l_{toe} + t_{wall}) / 2 = \mathbf{9.5 \text{ kNm/m}}$
Total moment for toe design	$M_{toe} = M_{toe_bear} - M_{toe_wt_base} - M_{toe_wt_ds} - M_{toe_wt_soil} = \mathbf{189.6 \text{ kNm/m}}$



Check toe in bending

Width of toe	$b = \mathbf{1000 \text{ mm/m}}$
Depth of reinforcement	$d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) = \mathbf{307.5 \text{ mm}}$
Constant	$K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu}) = \mathbf{0.050}$
Compression reinforcement is not required	
Lever arm	$z_{toe} = \min(0.5 + \sqrt{(0.25 - (\min(K_{toe}, 0.225) / 0.9))}, 0.95) \times d_{toe}$
	$z_{toe} = \mathbf{289 \text{ mm}}$
Area of tension reinforcement required	$A_{s_toe_des} = M_{toe} / (0.87 \times f_y \times z_{toe}) = \mathbf{1506 \text{ mm}^2/\text{m}}$

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Minimum area of tension reinforcement

$$A_{s_toe_min} = k \times b \times t_{base} = \mathbf{455 \text{ mm}^2/m}$$

Area of tension reinforcement required

$$A_{s_toe_req} = \text{Max}(A_{s_toe_des}, A_{s_toe_min}) = \mathbf{1506 \text{ mm}^2/m}$$

Reinforcement provided

25 mm dia.bars @ 200 mm centres

Area of reinforcement provided

$$A_{s_toe_prov} = \mathbf{2454 \text{ mm}^2/m}$$

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress

$$v_{toe} = V_{toe} / (b \times d_{toe}) = \mathbf{0.396 \text{ N/mm}^2}$$

Allowable shear stress

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

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress

$$v_{c_toe} = \mathbf{0.732 \text{ N/mm}^2}$$

$v_{toe} < v_{c_toe}$ - No shear reinforcement required

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

Material properties

Characteristic strength of concrete

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

Characteristic strength of reinforcement

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

Base details

Minimum area of reinforcement

$$k = \mathbf{0.13 \%}$$

Cover to reinforcement in heel

$$c_{heel} = \mathbf{30 \text{ mm}}$$

Calculate shear for heel design

Shear from weight of base

$$V_{heel_wt_base} = \gamma_{f_d} \times \gamma_{base} \times l_{heel} \times t_{base} = \mathbf{5.8 \text{ kN/m}}$$

Shear from weight of moist backfill

$$V_{heel_wt_m} = w_{m_w_f} = \mathbf{50.4 \text{ kN/m}}$$

Shear from surcharge

$$V_{heel_sur} = w_{sur_f} = \mathbf{1.2 \text{ kN/m}}$$

Total shear for heel design

$$V_{heel} = V_{heel_wt_base} + V_{heel_wt_m} + V_{heel_sur} = \mathbf{57.4 \text{ kN/m}}$$

Calculate moment for heel design

Moment from weight of base

$$M_{heel_wt_base} = (\gamma_{f_d} \times \gamma_{base} \times t_{base} \times (l_{heel} + t_{wall} / 2)^2 / 2) = \mathbf{2.8 \text{ kNm/m}}$$

Moment from weight of moist backfill

$$M_{heel_wt_m} = w_{m_w_f} \times (l_{heel} + t_{wall}) / 2 = \mathbf{22.7 \text{ kNm/m}}$$

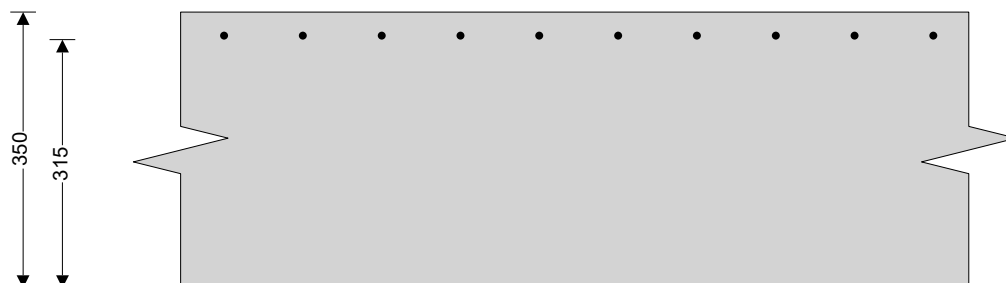
Moment from surcharge

$$M_{heel_sur} = w_{sur_f} \times (l_{heel} + t_{wall}) / 2 = \mathbf{0.5 \text{ kNm/m}}$$

Total moment for heel design

$$M_{heel} = M_{heel_wt_base} + M_{heel_wt_m} + M_{heel_sur} = \mathbf{26.1 \text{ kNm/m}}$$

←100→



Check heel in bending

Width of heel

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

Depth of reinforcement

$$d_{heel} = t_{base} - c_{heel} - (\phi_{heel} / 2) = \mathbf{315.0 \text{ mm}}$$

Constant

$$K_{heel} = M_{heel} / (b \times d_{heel}^2 \times f_{cu}) = \mathbf{0.007}$$

Compression reinforcement is not required

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Lever arm

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

$$Z_{heel} = \mathbf{299 \text{ mm}}$$

Area of tension reinforcement required

$$A_{s_heel_des} = M_{heel} / (0.87 \times f_y \times Z_{heel}) = \mathbf{200 \text{ mm}^2/\text{m}}$$

Minimum area of tension reinforcement

$$A_{s_heel_min} = k \times b \times t_{base} = \mathbf{455 \text{ mm}^2/\text{m}}$$

Area of tension reinforcement required

$$A_{s_heel_req} = \text{Max}(A_{s_heel_des}, A_{s_heel_min}) = \mathbf{455 \text{ mm}^2/\text{m}}$$

Reinforcement provided

$$\mathbf{10 \text{ mm dia. bars @ } 100 \text{ mm centres}}$$

Area of reinforcement provided

$$A_{s_heel_prov} = \mathbf{785 \text{ mm}^2/\text{m}}$$

PASS - Reinforcement provided at the retaining wall heel is adequate

Check shear resistance at heel

Design shear stress

$$V_{heel} = V_{heel} / (b \times d_{heel}) = \mathbf{0.182 \text{ N/mm}^2}$$

Allowable shear stress

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

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress

$$V_{c_heel} = \mathbf{0.494 \text{ N/mm}^2}$$

$V_{heel} < V_{c_heel}$ - No shear reinforcement required

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

Material properties

Characteristic strength of concrete

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

Characteristic strength of reinforcement

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

Base details

Minimum area of reinforcement

$$k = \mathbf{0.13 \%}$$

Cover to reinforcement in downstand

$$C_{ds} = \mathbf{30 \text{ mm}}$$

Calculate shear for downstand design

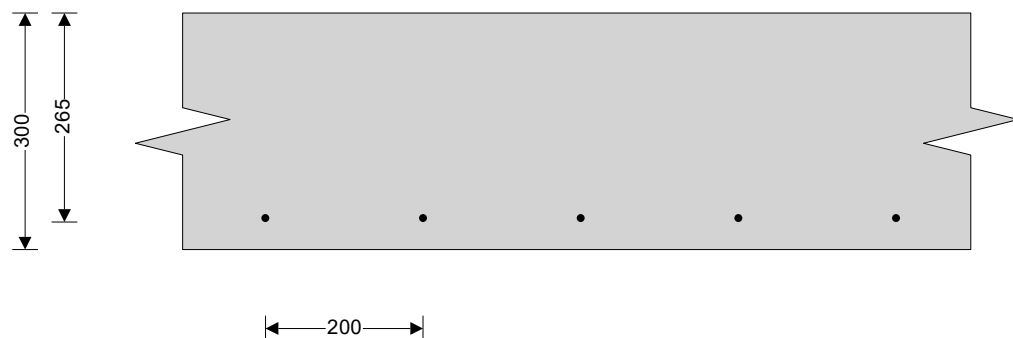
Total shear for downstand design

$$V_{down} = \gamma_{f_e} \times K_p \times \cos(\delta_b) \times \gamma_m \times d_{ds} \times (d_{cover} + t_{base} + d_{ds} / 2) = \mathbf{30.4 \text{ kN/m}}$$

Calculate moment for downstand design

Total moment for downstand design

$$M_{down} = \gamma_{f_e} \times K_p \times \cos(\delta_b) \times \gamma_m \times d_{ds} \times [(d_{cover} + t_{base}) \times (t_{base} + d_{ds}) + d_{ds} \times (t_{base} / 2 + 2 \times d_{ds} / 3)] / 2 = \mathbf{10.2 \text{ kNm/m}}$$



Check downstand in bending

Width of downstand

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

Depth of reinforcement

$$d_{down} = t_{ds} - C_{ds} - (\phi_{down} / 2) = \mathbf{265.0 \text{ mm}}$$

Constant

$$K_{down} = M_{down} / (b \times d_{down}^2 \times f_{cu}) = \mathbf{0.004}$$

Compression reinforcement is not required

Lever arm

$$Z_{down} = \text{Min}(0.5 + \sqrt{(0.25 - (\min(K_{down}, 0.225) / 0.9)), 0.95}) \times d_{down}$$

$$Z_{down} = \mathbf{252 \text{ mm}}$$

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Area of tension reinforcement required

$$A_{s_down_des} = M_{down} / (0.87 \times f_y \times z_{down}) = \mathbf{93 \text{ mm}^2/m}$$

Minimum area of tension reinforcement

$$A_{s_down_min} = k \times b \times t_{ds} = \mathbf{390 \text{ mm}^2/m}$$

Area of tension reinforcement required

$$A_{s_down_req} = \text{Max}(A_{s_down_des}, A_{s_down_min}) = \mathbf{390 \text{ mm}^2/m}$$

Reinforcement provided

A393 mesh

Area of reinforcement provided

$$A_{s_down_prov} = \mathbf{393 \text{ mm}^2/m}$$

PASS - Reinforcement provided at the retaining wall downstand is adequate

Check shear resistance at downstand

Design shear stress

$$V_{down} = V_{down} / (b \times d_{down}) = \mathbf{0.115 \text{ N/mm}^2}$$

Allowable shear stress

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

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress

$$V_{c_down} = \mathbf{0.434 \text{ N/mm}^2}$$

$V_{down} < V_{c_down}$ - No shear reinforcement required

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

Material properties

Characteristic strength of concrete

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

Characteristic strength of reinforcement

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

Wall details

Minimum area of reinforcement

$$k = \mathbf{0.13 \%}$$

Cover to reinforcement in stem

$$C_{stem} = \mathbf{30 \text{ mm}}$$

Cover to reinforcement in wall

$$C_{wall} = \mathbf{30 \text{ mm}}$$

Factored horizontal at-rest forces on stem

Surcharge

$$F_{s_sur_f} = \gamma_{f_l} \times K_0 \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds}) = \mathbf{5.7 \text{ kN/m}}$$

Moist backfill above water table

$$F_{s_m_a_f} = 0.5 \times \gamma_{f_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2 = \mathbf{119 \text{ kN/m}}$$

Calculate shear for stem design

Shear at base of stem

$$V_{stem} = F_{s_sur_f} + F_{s_m_a_f} = \mathbf{124.6 \text{ kN/m}}$$

Calculate moment for stem design

Surcharge

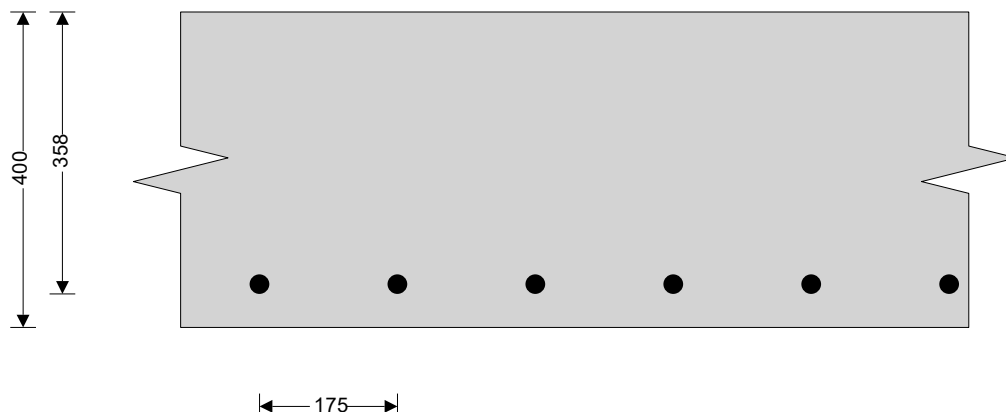
$$M_{s_sur} = F_{s_sur_f} \times (h_{stem} + t_{base}) / 2 = \mathbf{12.3 \text{ kNm/m}}$$

Moist backfill above water table

$$M_{s_m_a} = F_{s_m_a_f} \times (2 \times h_{sat} + h_{eff} - d_{ds} + t_{base} / 2) / 3 = \mathbf{179.4 \text{ kNm/m}}$$

Total moment for stem design

$$M_{stem} = M_{s_sur} + M_{s_m_a} = \mathbf{191.8 \text{ kNm/m}}$$



Check wall stem in bending

Width of wall stem

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

Depth of reinforcement

$$d_{stem} = t_{wall} - C_{stem} - (\phi_{stem} / 2) = \mathbf{357.5 \text{ mm}}$$

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Constant

$$K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu}) = \mathbf{0.038}$$

Compression reinforcement is not required

Lever arm

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

$$Z_{stem} = \mathbf{340 \text{ mm}}$$

Area of tension reinforcement required

$$A_{s_stem_des} = M_{stem} / (0.87 \times f_y \times Z_{stem}) = \mathbf{1298 \text{ mm}^2/\text{m}}$$

Minimum area of tension reinforcement

$$A_{s_stem_min} = k \times b \times t_{wall} = \mathbf{520 \text{ mm}^2/\text{m}}$$

Area of tension reinforcement required

$$A_{s_stem_req} = \text{Max}(A_{s_stem_des}, A_{s_stem_min}) = \mathbf{1298 \text{ mm}^2/\text{m}}$$

Reinforcement provided

$$\mathbf{25 \text{ mm dia. bars @ 175 mm centres}}$$

Area of reinforcement provided

$$A_{s_stem_prov} = \mathbf{2805 \text{ mm}^2/\text{m}}$$

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress

$$V_{stem} = V_{stem} / (b \times d_{stem}) = \mathbf{0.349 \text{ N/mm}^2}$$

Allowable shear stress

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

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress

$$V_{c_stem} = \mathbf{0.701 \text{ N/mm}^2}$$

$V_{stem} < V_{c_stem}$ - No shear reinforcement required

Check retaining wall deflection

Basic span/effective depth ratio

$$\text{ratio}_{bas} = \mathbf{7}$$

Design service stress

$$f_s = 2 \times f_y \times A_{s_stem_req} / (3 \times A_{s_stem_prov}) = \mathbf{154.2 \text{ N/mm}^2}$$

Modification factor

$$\text{factor}_{tens} = \min(0.55 + (477 \text{ N/mm}^2 - f_s) / (120 \times (0.9 \text{ N/mm}^2 + (M_{stem} / (b \times d_{stem}^2)))), 2) = \mathbf{1.67}$$

Maximum span/effective depth ratio

$$\text{ratio}_{max} = \text{ratio}_{bas} \times \text{factor}_{tens} = \mathbf{11.69}$$

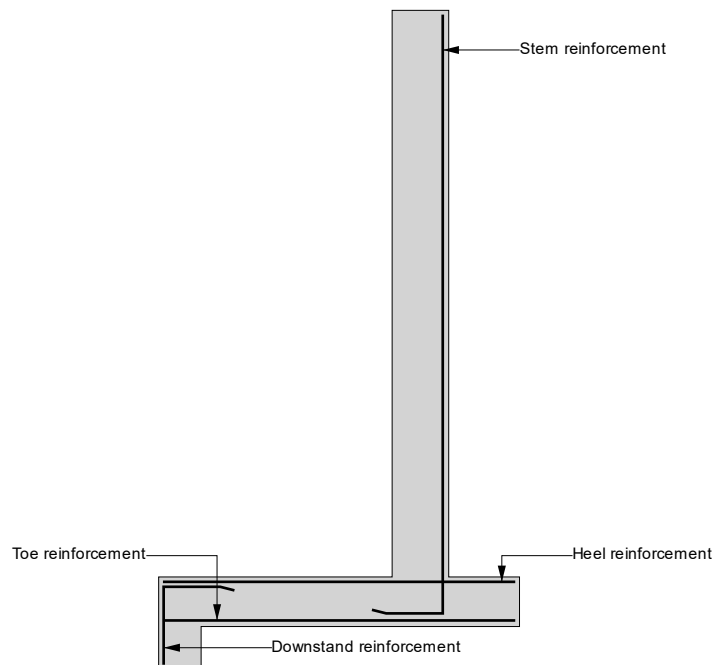
Actual span/effective depth ratio

$$\text{ratio}_{act} = h_{stem} / d_{stem} = \mathbf{11.19}$$

PASS - Span to depth ratio is acceptable

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Indicative retaining wall reinforcement diagram



Toe bars - 25 mm dia.@ 200 mm centres - (2454 mm²/m)
 Heel bars - 10 mm dia.@ 100 mm centres - (785 mm²/m)
 Downstand mesh - A393 - (393 mm²/m)
 Stem bars - 25 mm dia.@ 175 mm centres - (2805 mm²/m)