



Vale Consultancy
CONSULTING CIVIL & STRUCTURAL ENGINEERS

Title: Structural Calculations for retaining wall
and pillar

Project: The Gables, School Road, Swansea. SA10
6JE

Client: Darkin Architects

Document No: 001
Project No: N2747
Prepared By: NL
Checked By: MJ

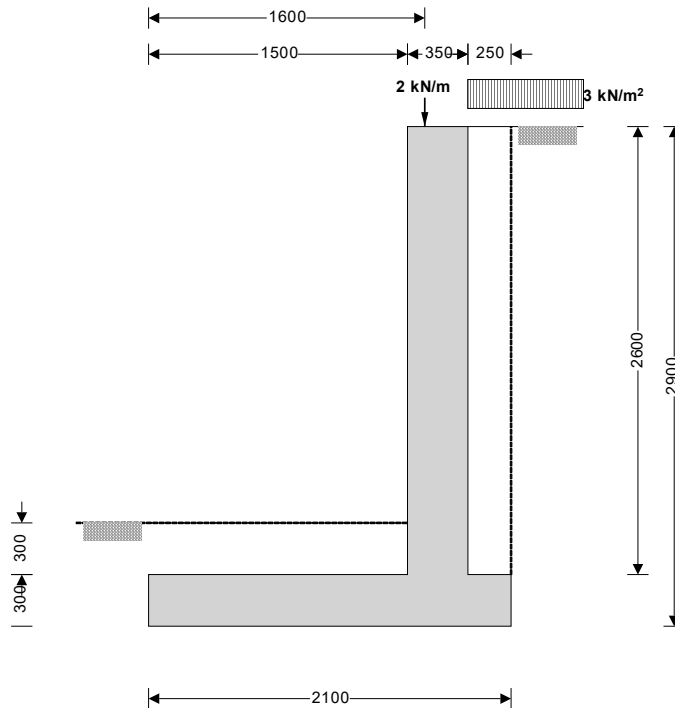
Revision: -

Date: 12.07.23



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

 $h_{\text{stem}} = 2600 \text{ mm}$
 $t_{\text{wall}} = 350 \text{ mm}$
 $l_{\text{toe}} = 1500 \text{ mm}$
 $l_{\text{heel}} = 250 \text{ mm}$
 $l_{\text{base}} = l_{\text{toe}} + l_{\text{heel}} + t_{\text{wall}} = 2100 \text{ mm}$
 $t_{\text{base}} = 300 \text{ mm}$
 $d_{\text{ds}} = 0 \text{ mm}$
 $l_{\text{ds}} = 1650 \text{ mm}$
 $t_{\text{ds}} = 300 \text{ mm}$
 $h_{\text{wall}} = h_{\text{stem}} + t_{\text{base}} + d_{\text{ds}} = 2900 \text{ mm}$
 $d_{\text{cover}} = 300 \text{ mm}$
 $d_{\text{exc}} = 0 \text{ mm}$
 $h_{\text{water}} = 0 \text{ mm}$
 $h_{\text{sat}} = \max(h_{\text{water}} - t_{\text{base}} - d_{\text{ds}}, 0 \text{ mm}) = 0 \text{ mm}$
 $\gamma_{\text{wall}} = 23.6 \text{ kN/m}^3$
 $\gamma_{\text{base}} = 23.6 \text{ kN/m}^3$
 $\alpha = 90.0 \text{ deg}$
 $\beta = 0.0 \text{ deg}$
 $h_{\text{eff}} = h_{\text{wall}} + l_{\text{heel}} \times \tan(\beta) = 2900 \text{ mm}$

Retained material details

Mobilisation factor

 $M = 1.5$

Moist density of retained material

 $\gamma_{\text{m}} = 18.0 \text{ kN/m}^3$

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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 $\gamma_{mb} = 18.0 \text{ kN/m}^3$

Design shear strength $\phi'_b = 27.5 \text{ deg}$

Design base friction $\delta_b = 21.3 \text{ deg}$

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

$$K_p = \sin(90 - \phi'_b)^2 / (\sin(90 - \delta_b) \times [1 - \sqrt{(\sin(\phi'_b + \delta_b) \times \sin(\phi'_b) / (\sin(90 + \delta_b)))^2}] = 5.571$$

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/m²**

Applied vertical dead load on wall $W_{\text{dead}} = 2.0 \text{ kN/m}$

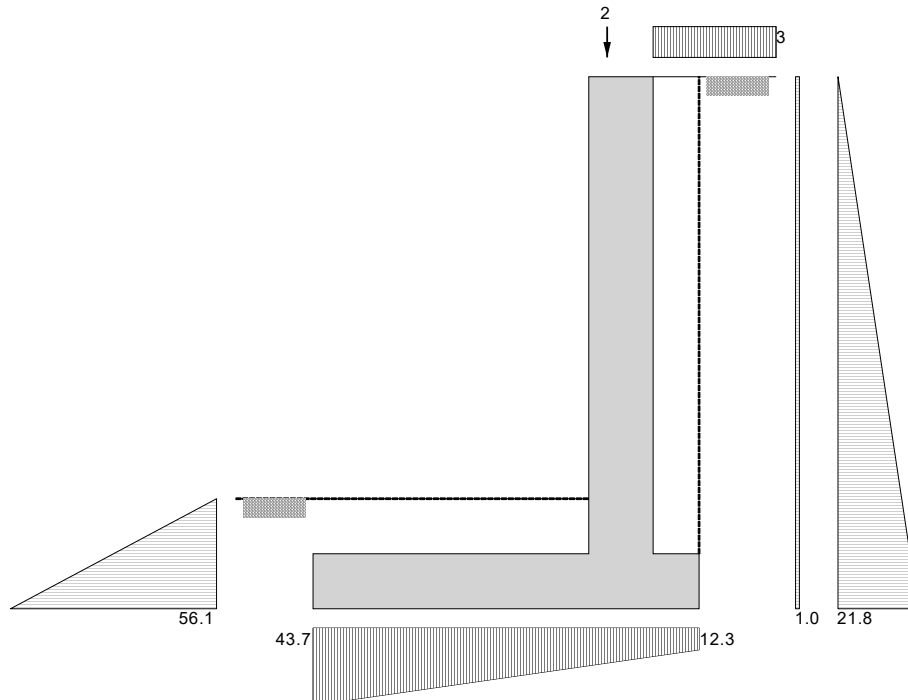
Applied vertical live load on wall $W_{\text{live}} = 0.0 \text{ kN/m}$

Position of applied vertical load on wall $l_{\text{load}} = 1600 \text{ mm}$

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	$W_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall} = 21.5 \text{ kN/m}$
Wall base	$W_{base} = l_{base} \times t_{base} \times \gamma_{base} = 14.9 \text{ kN/m}$
Surcharge	$W_{sur} = \text{Surcharge} \times l_{heel} = 0.6 \text{ kN/m}$
Moist backfill to top of wall	$W_{m_w} = l_{heel} \times (h_{stem} - h_{sat}) \times \gamma_m = 11.7 \text{ kN/m}$
Soil in front of wall	$W_p = l_{toe} \times d_{cover} \times \gamma_{mb} = 8.1 \text{ kN/m}$
Applied vertical load	$W_v = W_{dead} + W_{live} = 2 \text{ kN/m}$
Total vertical load	$W_{total} = W_{wall} + W_{base} + W_{sur} + W_{m_w} + W_p + W_v = 58.8 \text{ kN/m}$

Horizontal forces on wall

Surcharge	$F_{sur} = K_a \times \text{Surcharge} \times h_{eff} = 3 \text{ kN/m}$
Moist backfill above water table	$F_{m_a} = 0.5 \times K_a \times \gamma_m \times (h_{eff} - h_{water})^2 = 31.7 \text{ kN/m}$
Total horizontal load	$F_{total} = F_{sur} + F_{m_a} = 34.7 \text{ kN/m}$

Calculate stability against sliding

Passive resistance of soil in front of wall	$F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb} = 16.8 \text{ kN/m}$
Resistance to sliding	$F_{res} = F_p + (W_{total} - W_{sur} - W_p) \times \tan(\delta_b) = 36.3 \text{ kN/m}$

PASS - Resistance force is greater than sliding force

Overturning moments

Surcharge	$M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2 = 4.4 \text{ kNm/m}$
Moist backfill above water table	$M_{m_a} = F_{m_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3 = 30.6 \text{ kNm/m}$
Total overturning moment	$M_{ot} = M_{sur} + M_{m_a} = 35 \text{ kNm/m}$

Restoring moments

Wall stem	$M_{wall} = W_{wall} \times (l_{toe} + t_{wall} / 2) = 36 \text{ kNm/m}$
Wall base	$M_{base} = W_{base} \times l_{base} / 2 = 15.6 \text{ kNm/m}$
Moist backfill	$M_{m_r} = (W_{m_w} \times (l_{base} - l_{heel} / 2) + W_{m_s} \times (l_{base} - l_{heel} / 3)) = 23.1 \text{ kNm/m}$
Design vertical dead load	$M_{dead} = W_{dead} \times l_{load} = 3.2 \text{ kNm/m}$
Total restoring moment	$M_{rest} = M_{wall} + M_{base} + M_{m_r} + M_{dead} = 77.9 \text{ kNm/m}$

Check stability against overturning

Total overturning moment	$M_{ot} = 35.0 \text{ kNm/m}$
Total restoring moment	$M_{rest} = 77.9 \text{ kNm/m}$

PASS - Restoring moment is greater than overturning moment

Check bearing pressure

Surcharge	$M_{sur_r} = W_{sur} \times (l_{base} - l_{heel} / 2) = 1.2 \text{ kNm/m}$
Soil in front of wall	$M_{p_r} = W_p \times l_{toe} / 2 = 6.1 \text{ kNm/m}$
Total moment for bearing	$M_{total} = M_{rest} - M_{ot} + M_{sur_r} + M_{p_r} = 50.2 \text{ kNm/m}$
Total vertical reaction	$R = W_{total} = 58.8 \text{ kN/m}$
Distance to reaction	$x_{bar} = M_{total} / R = 854 \text{ mm}$
Eccentricity of reaction	$e = \text{abs}((l_{base} / 2) - x_{bar}) = 196 \text{ mm}$

Reaction acts within middle third of base

Bearing pressure at toe	$p_{toe} = (R / l_{base}) + (6 \times R \times e / l_{base}^2) = 43.7 \text{ kN/m}^2$
Bearing pressure at heel	$p_{heel} = (R / l_{base}) - (6 \times R \times e / l_{base}^2) = 12.3 \text{ kN/m}^2$

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	$W_{wall_f} = \gamma_{f_d} \times h_{stem} \times t_{wall} \times \gamma_{wall} = 30.1 \text{ kN/m}$
Wall base	$W_{base_f} = \gamma_{f_d} \times l_{base} \times t_{base} \times \gamma_{base} = 20.8 \text{ kN/m}$
Surcharge	$W_{sur_f} = \gamma_{f_l} \times \text{Surcharge} \times l_{heel} = 1 \text{ kN/m}$
Moist backfill to top of wall	$W_{m_w_f} = \gamma_{f_d} \times l_{heel} \times (h_{stem} - h_{sat}) \times \gamma_m = 16.4 \text{ kN/m}$
Soil in front of wall	$W_{p_f} = \gamma_{f_d} \times l_{toe} \times d_{cover} \times \gamma_{mb} = 11.3 \text{ kN/m}$
Applied vertical load	$W_{v_f} = \gamma_{f_d} \times W_{dead} + \gamma_{f_l} \times W_{live} = 2.8 \text{ kN/m}$
Total vertical load	$W_{total_f} = W_{wall_f} + W_{base_f} + W_{sur_f} + W_{m_w_f} + W_{p_f} + W_{v_f} = 82.4 \text{ kN/m}$

Factored horizontal at-rest forces on wall

Surcharge	$F_{sur_f} = \gamma_{f_l} \times K_0 \times \text{Surcharge} \times h_{eff} = 6.8 \text{ kN/m}$
Moist backfill above water table	$F_{m_a_f} = \gamma_{f_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2 = 62.5 \text{ kN/m}$
Total horizontal load	$F_{total_f} = F_{sur_f} + F_{m_a_f} = 69.4 \text{ kN/m}$
Passive resistance of soil in front of wall kN/m	$F_{p_f} = \gamma_{f_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb} = 23.5$

Factored overturning moments

Surcharge	$M_{sur_f} = F_{sur_f} \times (h_{eff} - 2 \times d_{ds}) / 2 = 9.9 \text{ kNm/m}$
Moist backfill above water table	$M_{m_a_f} = F_{m_a_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3 = 60.4 \text{ kNm/m}$
Total overturning moment	$M_{ot_f} = M_{sur_f} + M_{m_a_f} = 70.4 \text{ kNm/m}$

Restoring moments

Wall stem	$M_{wall_f} = W_{wall_f} \times (l_{toe} + t_{wall} / 2) = 50.4 \text{ kNm/m}$
Wall base	$M_{base_f} = W_{base_f} \times l_{base} / 2 = 21.9 \text{ kNm/m}$
Surcharge	$M_{sur_r_f} = W_{sur_f} \times (l_{base} - l_{heel} / 2) = 2 \text{ kNm/m}$
Moist backfill	$M_{m_r_f} = (W_{m_w_f} \times (l_{base} - l_{heel} / 2) + W_{m_s_f} \times (l_{base} - l_{heel} / 3)) = 32.4 \text{ kNm/m}$
Soil in front of wall	$M_{p_r_f} = W_{p_f} \times l_{toe} / 2 = 8.5 \text{ kNm/m}$
Design vertical load	$M_{v_f} = W_{v_f} \times l_{load} = 4.5 \text{ kNm/m}$
Total restoring moment	$M_{rest_f} = M_{wall_f} + M_{base_f} + M_{sur_r_f} + M_{m_r_f} + M_{p_r_f} + M_{v_f} = 119.5 \text{ kNm/m}$

Factored bearing pressure

Total moment for bearing	$M_{total_f} = M_{rest_f} - M_{ot_f} = 49.2 \text{ kNm/m}$
Total vertical reaction	$R_f = W_{total_f} = 82.4 \text{ kN/m}$
Distance to reaction	$x_{bar_f} = M_{total_f} / R_f = 597 \text{ mm}$
Eccentricity of reaction	$e_f = \text{abs}((l_{base} / 2) - x_{bar_f}) = 453 \text{ mm}$

Reaction acts outside middle third of base

Bearing pressure at toe	$p_{toe_f} = R_f / (1.5 \times x_{bar_f}) = 92.1 \text{ kN/m}^2$
Bearing pressure at heel	$p_{heel_f} = 0 \text{ kN/m}^2 = 0 \text{ kN/m}^2$
Rate of change of base reaction	$\text{rate} = p_{toe_f} / (3 \times x_{bar_f}) = 51.45 \text{ kN/m}^2/\text{m}$
Bearing pressure at stem / toe	$p_{stem_toe_f} = \text{max}(p_{toe_f} - (\text{rate} \times l_{toe}), 0 \text{ kN/m}^2) = 14.9 \text{ kN/m}^2$
Bearing pressure at mid stem	$p_{stem_mid_f} = \text{max}(p_{toe_f} - (\text{rate} \times (l_{toe} + t_{wall} / 2)), 0 \text{ kN/m}^2) = 5.9 \text{ kN/m}^2$
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 $f_{cu} = 40 \text{ N/mm}^2$
Characteristic strength of reinforcement $f_y = 500 \text{ N/mm}^2$

Base details

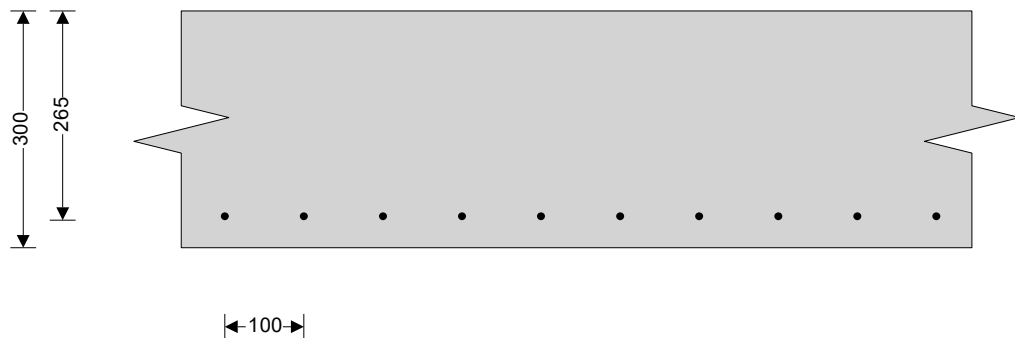
Minimum area of reinforcement $k = 0.13 \%$
Cover to reinforcement in toe $c_{toe} = 30 \text{ mm}$

Calculate shear for toe design

Shear from bearing pressure $V_{toe_bear} = (p_{toe_f} + p_{stem_toe_f}) \times l_{toe} / 2 = 80.2 \text{ kN/m}$
Shear from weight of base $V_{toe_wt_base} = \gamma_{f_d} \times \gamma_{base} \times l_{toe} \times t_{base} = 14.9 \text{ kN/m}$
Shear from weight of soil $V_{toe_wt_soil} = w_{p_f} - (\gamma_{f_d} \times \gamma_m \times l_{toe} \times d_{exc}) = 11.3 \text{ kN/m}$
Total shear for toe design $V_{toe} = V_{toe_bear} - V_{toe_wt_base} - V_{toe_wt_soil} = 54 \text{ kN/m}$

Calculate moment for toe design

Moment from bearing pressure $M_{toe_bear} = (2 \times p_{toe_f} + p_{stem_mid_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6 = 88.9 \text{ kNm/m}$
Moment from weight of base $M_{toe_wt_base} = (\gamma_{f_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2) = 13.9 \text{ kNm/m}$
Moment from weight of soil $M_{toe_wt_soil} = (w_{p_f} - (\gamma_{f_d} \times \gamma_m \times l_{toe} \times d_{exc})) \times (l_{toe} + t_{wall} / 2) = 10.5 \text{ kNm/m}$
Total moment for toe design $M_{toe} = M_{toe_bear} - M_{toe_wt_base} - M_{toe_wt_soil} = 64.5 \text{ kNm/m}$



Check toe in bending

Width of toe $b = 1000 \text{ mm/m}$
Depth of reinforcement $d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) = 265.0 \text{ mm}$
Constant $K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu}) = 0.023$

Compression reinforcement is not required

Lever arm $z_{toe} = \min(0.5 + \sqrt{(0.25 - (\min(K_{toe}, 0.225) / 0.9))}, 0.95) \times d_{toe}$
 $z_{toe} = 252 \text{ mm}$

Area of tension reinforcement required $A_{s_toe_des} = M_{toe} / (0.87 \times f_y \times z_{toe}) = 589 \text{ mm}^2/\text{m}$

Minimum area of tension reinforcement $A_{s_toe_min} = k \times b \times t_{base} = 390 \text{ mm}^2/\text{m}$

Area of tension reinforcement required $A_{s_toe_req} = \text{Max}(A_{s_toe_des}, A_{s_toe_min}) = 589 \text{ mm}^2/\text{m}$

Reinforcement provided

B785 mesh

Area of reinforcement provided

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

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress $v_{toe} = V_{toe} / (b \times d_{toe}) = 0.204 \text{ N/mm}^2$

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

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Design concrete shear stress

$$V_{c_toe} = 0.546 \text{ N/mm}^2$$

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

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

Material properties

Characteristic strength of concrete

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

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

$$C_{heel} = 30 \text{ mm}$$

Calculate shear for heel design

Shear from weight of base

$$V_{heel_wt_base} = \gamma_{f_d} \times \gamma_{base} \times l_{heel} \times t_{base} = 2.5 \text{ kN/m}$$

Shear from weight of moist backfill

$$V_{heel_wt_m} = w_{m_w_f} = 16.4 \text{ kN/m}$$

Shear from surcharge

$$V_{heel_sur} = w_{sur_f} = 1 \text{ kN/m}$$

Total shear for heel design

$$V_{heel} = V_{heel_wt_base} + V_{heel_wt_m} + V_{heel_sur} = 19.9 \text{ kN/m}$$

Calculate moment for heel design

Moment from weight of base

$$M_{heel_wt_base} = (\gamma_{f_d} \times \gamma_{base} \times t_{base} \times (l_{heel} + t_{wall} / 2)^2 / 2) = 0.9 \text{ kNm/m}$$

Moment from weight of moist backfill

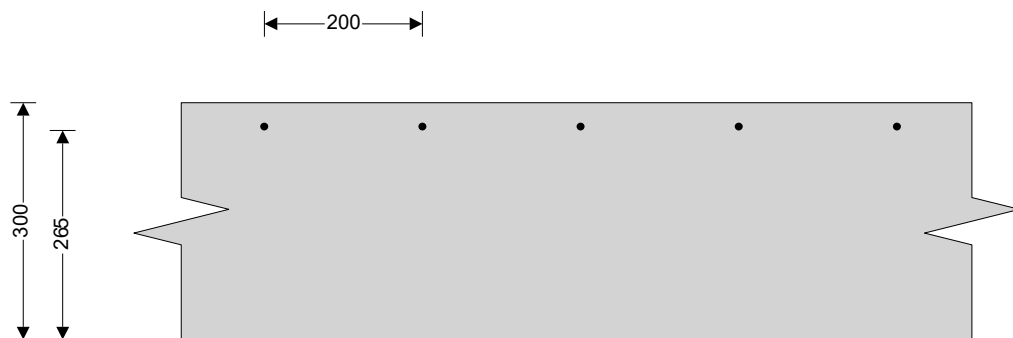
$$M_{heel_wt_m} = w_{m_w_f} \times (l_{heel} + t_{wall}) / 2 = 4.9 \text{ kNm/m}$$

Moment from surcharge

$$M_{heel_sur} = w_{sur_f} \times (l_{heel} + t_{wall}) / 2 = 0.3 \text{ kNm/m}$$

Total moment for heel design

$$M_{heel} = M_{heel_wt_base} + M_{heel_wt_m} + M_{heel_sur} = 6.1 \text{ kNm/m}$$



Check heel in bending

Width of heel

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

Depth of reinforcement

$$d_{heel} = t_{base} - C_{heel} - (\phi_{heel} / 2) = 265.0 \text{ mm}$$

Constant

$$K_{heel} = M_{heel} / (b \times d_{heel}^2 \times f_{cu}) = 0.002$$

Compression reinforcement is not required

Lever arm

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

$$Z_{heel} = 252 \text{ mm}$$

Area of tension reinforcement required

$$A_{s_heel_des} = M_{heel} / (0.87 \times f_y \times Z_{heel}) = 56 \text{ mm}^2/\text{m}$$

Minimum area of tension reinforcement

$$A_{s_heel_min} = k \times b \times t_{base} = 390 \text{ mm}^2/\text{m}$$

Area of tension reinforcement required

$$A_{s_heel_req} = \text{Max}(A_{s_heel_des}, A_{s_heel_min}) = 390 \text{ mm}^2/\text{m}$$

Reinforcement provided

A393 mesh

Area of reinforcement provided

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

PASS - Reinforcement provided at the retaining wall heel is adequate

Check shear resistance at heel

Design shear stress

$$V_{heel} = V_{heel} / (b \times d_{heel}) = 0.075 \text{ N/mm}^2$$

Allowable shear stress

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

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PASS - Design shear stress is less than maximum shear stress

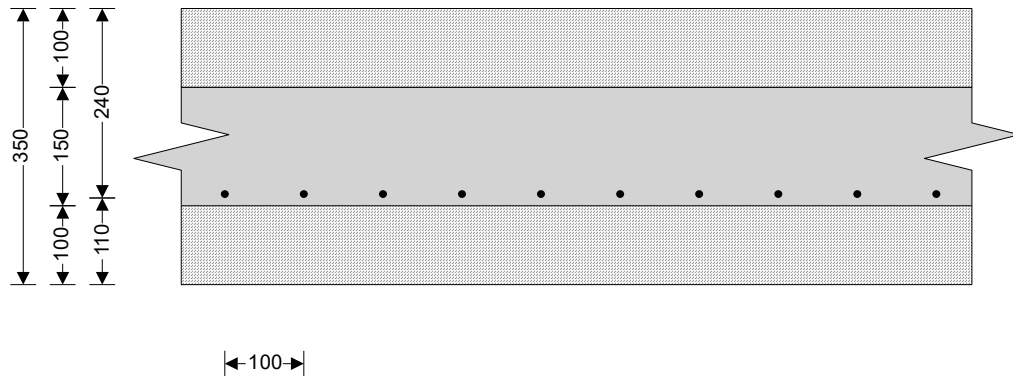
From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress

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

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

Design of cavity reinforced masonry retaining wall stem - BS5628-2:2000



Wall details

Thickness of outer leaf of wall

$$t_{outer} = 100 \text{ mm}$$

Thickness of inner leaf of wall

$$t_{inner} = 100 \text{ mm}$$

Thickness of reinforced cavity

$$t_{cavity} = t_{wall} - t_{outer} - t_{inner} = 150 \text{ mm}$$

Depth of stem reinforcement

$$d_{stem} = 240 \text{ mm}$$

Masonry details

Masonry type

Aggregate concrete blocks no voids

Compressive strength of units

$$p_{unit} = 10.0 \text{ N/mm}^2$$

Mortar designation

(ii)

Category of manufacturing control of units

Normal

Partial safety factor for material strength

$$\gamma_{mm} = 2.3$$

Characteristic compressive strength of masonry

Least horizontal dimension of masonry units

$$b_{unit} = 100.0 \text{ mm}$$

Height of masonry units

$$h_{unit} = 215.0 \text{ mm}$$

Ratio of height to least horizontal dimension

$$\text{ratio} = h_{unit} / b_{unit} = 2.2$$

From BS5628:2 Table 3d, mortar ii

Characteristic compressive strength

$$f_k = 8.1 \text{ N/mm}^2$$

Factored horizontal at-rest forces on stem

Surcharge

$$F_{s_sur_f} = \gamma_{f_l} \times K_0 \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds}) = 6.1 \text{ kN/m}$$

Moist backfill above water table

$$F_{s_m_a_f} = 0.5 \times \gamma_{f_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2 = 50.3 \text{ kN/m}$$

Calculate shear for stem design

Shear at base of stem

$$V_{stem} = F_{s_sur_f} + F_{s_m_a_f} = 56.4 \text{ kN/m}$$

Calculate moment for stem design

Surcharge

$$M_{s_sur} = F_{s_sur_f} \times (h_{stem} + t_{base}) / 2 = 8.9 \text{ kNm/m}$$

Moist backfill above water table

$$M_{s_m_a} = F_{s_m_a_f} \times (2 \times h_{sat} + h_{eff} - d_{ds} + t_{base} / 2) / 3 = 51.1 \text{ kNm/m}$$

Total moment for stem design

$$M_{stem} = M_{s_sur} + M_{s_m_a} = 60 \text{ kNm/m}$$

Check maximum design moment for wall stem

Width of wall

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

Maximum design moment

$$M_{d_stem} = 0.4 \times f_k \times b \times d_{stem}^2 / \gamma_{mm} = 81.6 \text{ kNm/m}$$

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PASS - Applied moment is less than maximum design moment

Check wall stem in bending

Moment of resistance factor

$$Q = M_{stem} / d_{stem}^2 = 1.042 \text{ N/mm}^2$$

$$Q = 2 \times c \times (1 - c) \times f_k / \gamma_{mm}$$

$$c = 0.821$$

Lever arm factor

$$Z_{stem} = \min(0.95, c) \times d_{stem} = 197.0 \text{ mm}$$

Lever arm

$$A_{s_stem_des} = M_{stem} \times \gamma_{ms} / (f_y \times Z_{stem}) = 701 \text{ mm}^2/\text{m}$$

Area of tension reinforcement required

$$A_{s_stem_min} = k \times b \times t_{wall} = 455 \text{ mm}^2/\text{m}$$

Minimum area of tension reinforcement

$$A_{s_stem_req} = \text{Max}(A_{s_stem_des}, A_{s_stem_min}) = 701 \text{ mm}^2/\text{m}$$

Area of tension reinforcement required

Reinforcement provided

B785 mesh

Area of reinforcement provided

$$A_{s_stem_prov} = \pi \times \phi_{stem}^2 / (4 \times s_{stem}) = 785 \text{ mm}^2/\text{m}$$

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress

$$V_{stem} = V_{stem} / (b \times d_{stem}) = 0.235 \text{ N/mm}^2$$

Basic characteristic shear strength of masonry

$$f_{vbas} = \min[0.35 + (17.5 \times A_{s_stem_prov} / (b \times d_{stem})), 0.7] \times 1 \text{ N/mm}^2$$

$$f_{vbas} = 0.407 \text{ N/mm}^2$$

Shear span

$$a = M_{stem} / V_{stem} = 1063.8 \text{ mm}$$

Characteristic shear strength of masonry

$$f_v = \text{Min}(f_{vbas} \times \max(2.5 - 0.25 \times (a / d_{stem}), 1), 1.75 \text{ N/mm}^2)$$

$$f_v = 0.567 \text{ N/mm}^2$$

Allowable shear stress

$$V_{adm} = f_v / \gamma_{mv} = 0.283 \text{ N/mm}^2$$

PASS - Design shear stress is less than maximum shear stress

Check limiting dimensions

Limiting span/effective depth ratio

$$\text{ratio}_{max} = 18.00$$

Actual span/effective depth ratio

$$\text{ratio}_{act} = (h_{stem} + d_{stem} / 2) / d_{stem} = 11.33$$

PASS - Span to depth ratio is acceptable

Axial load check

Factored axial load on wall

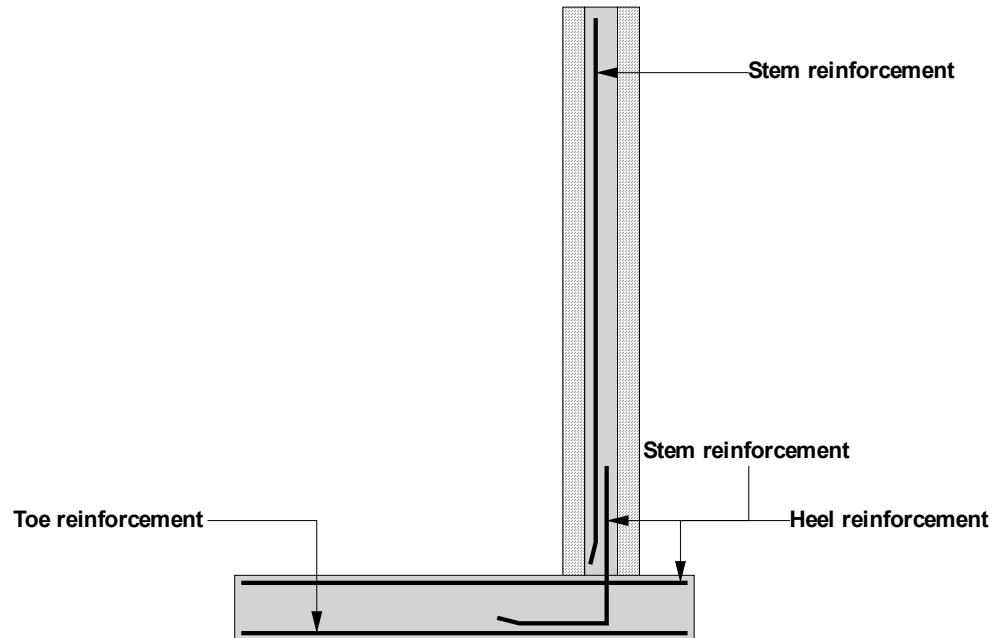
$$N_{wall} = ([t_{wall} \times h_{stem} \times \gamma_{wall} + W_{dead}] \times \gamma_{f_d}) + (W_{live} \times \gamma_{f_l}) = 32.9 \text{ kN/m}$$

Limiting axial load

$$N_{limit} = 0.1 \times f_k \times t_{wall} = 285.0 \text{ kN/m}$$

Applied axial load may be ignored - calculations valid

Indicative retaining wall reinforcement diagram

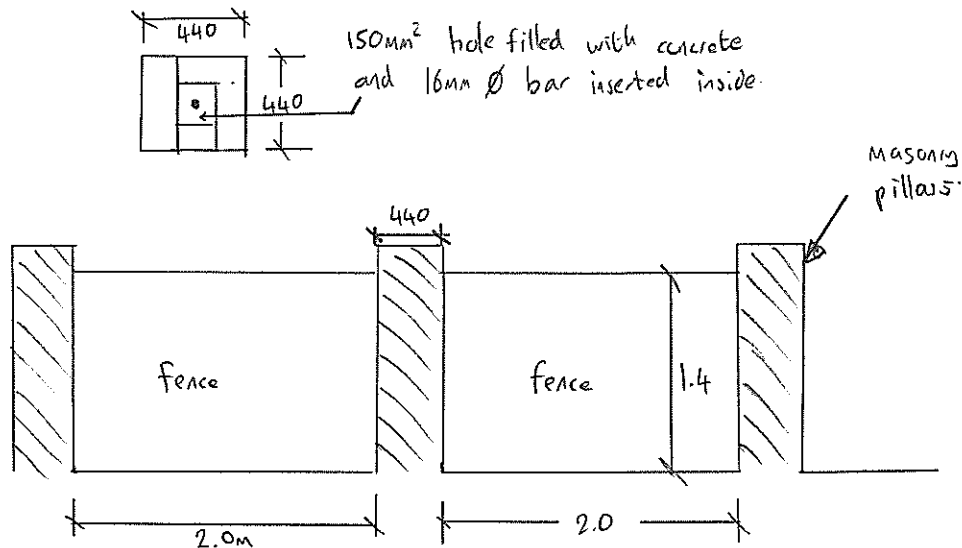


Toe mesh - B785 - (785 mm²/m)

Heel mesh - A393 - (393 mm²/m)

Stem mesh - B785 - (785 mm²/m)

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Overturning Weight

$$\text{Wind Loading on panel} = 2.0 \times 2.0 = \frac{4.0\text{m}}{2} = 2.0\text{m} \times 0.7\text{kN/m}^2$$

$$= 1.4\text{kN/m} \times 1.4\text{m} = 1.96\text{kN} \times 1.6 = 3.14\text{kN}$$

Restoring Weight.

$$\text{Self Weight of pillar} = 0.44 \times 0.44 \times 1.4\text{m} \times 24\text{kN/m}^3 = 6.5\text{kN}$$

$\therefore$ Pillars adequate to provide resistance to wind; without taking into account the H16 bar & concrete infill.

TIMBER JOIST DESIGN (BS5268-2:2002)

Tedds calculation version 1.1.04

Joist details

Joist breadth

b = 50 mm

Joist depth

h = 225 mm

Joist spacing

s = 400 mm

Timber strength class

C24

Service class of timber

1



Span details

Number of spans

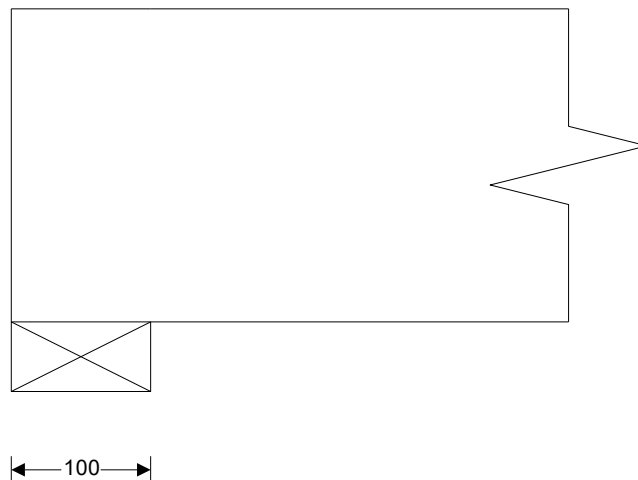
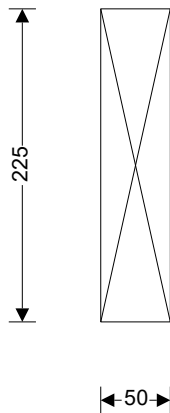
N_{span} = 1

Length of bearing

L_b = 100 mm

Effective length of span

L_{s1} = 4500 mm



Section properties

Second moment of area

I = b × h³ / 12 = 47460937 mm⁴

Section modulus

Z = b × h² / 6 = 421875 mm³

Loading details

Joist self weight

F_{swt} = b × h × ρ_{char} × g_{acc} = 0.04 kN/m

Dead load

F_{d_udi} = 1.50 kN/m²

Imposed UDL(Long term)

F_{i_udi} = 1.50 kN/m²

Imposed point load (Medium term)

F_{i_pt} = 1.40 kN

Modification factors

Service class for bending parallel to grain

K_{2m} = 1.00

Service class for compression

K_{2c} = 1.00

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Service class for shear parallel to grain

$$K_{2s} = 1.00$$

Service class for modulus of elasticity

$$K_{2e} = 1.00$$

Section depth factor

$$K_7 = 1.03$$

Load sharing factor

$$K_8 = 1.10$$

Consider long term loads

Load duration factor

$$K_3 = 1.00$$

Maximum bending moment

$$M = 3.135 \text{ kNm}$$

Maximum shear force

$$V = 2.787 \text{ kN}$$

Maximum support reaction

$$R = 2.787 \text{ kN}$$

Maximum deflection

$$\delta = 13.398 \text{ mm}$$

Check bending stress

Bending stress

$$\sigma_m = 7.500 \text{ N/mm}^2$$

Permissible bending stress

$$\sigma_{m_adm} = \sigma_m \times K_{2m} \times K_3 \times K_7 \times K_8 = 8.515 \text{ N/mm}^2$$

Applied bending stress

$$\sigma_{m_max} = M / Z = 7.432 \text{ N/mm}^2$$

PASS - Applied bending stress within permissible limits

Check shear stress

Shear stress

$$\tau = 0.710 \text{ N/mm}^2$$

Permissible shear stress

$$\tau_{adm} = \tau \times K_{2s} \times K_3 \times K_8 = 0.781 \text{ N/mm}^2$$

Applied shear stress

$$\tau_{max} = 3 \times V / (2 \times b \times h) = 0.372 \text{ N/mm}^2$$

PASS - Applied shear stress within permissible limits

Check bearing stress

Compression perpendicular to grain (no wane)

$$\sigma_{cp1} = 2.400 \text{ N/mm}^2$$

Permissible bearing stress

$$\sigma_{c_adm} = \sigma_{cp1} \times K_{2c} \times K_3 \times K_8 = 2.640 \text{ N/mm}^2$$

Applied bearing stress

$$\sigma_{c_max} = R / (b \times L_b) = 0.557 \text{ N/mm}^2$$

PASS - Applied bearing stress within permissible limits

Check deflection

Permissible deflection

$$\delta_{adm} = \min(L_{s1} \times 0.003, 14 \text{ mm}) = 13.500 \text{ mm}$$

Bending deflection (based on E_{mean})

$$\delta_{bending} = 12.902 \text{ mm}$$

Shear deflection

$$\delta_{shear} = 0.495 \text{ mm}$$

Total deflection

$$\delta = \delta_{bending} + \delta_{shear} = 13.398 \text{ mm}$$

PASS - Actual deflection within permissible limits

Consider medium term loads

Load duration factor

$$K_3 = 1.25$$

Maximum bending moment

$$M = 3.191 \text{ kNm}$$

Maximum shear force

$$V = 2.837 \text{ kN}$$

Maximum support reaction

$$R = 2.837 \text{ kN}$$

Maximum deflection

$$\delta = 12.342 \text{ mm}$$

Check bending stress

Bending stress

$$\sigma_m = 7.500 \text{ N/mm}^2$$

Permissible bending stress

$$\sigma_{m_adm} = \sigma_m \times K_{2m} \times K_3 \times K_7 \times K_8 = 10.644 \text{ N/mm}^2$$

Applied bending stress

$$\sigma_{m_max} = M / Z = 7.565 \text{ N/mm}^2$$

PASS - Applied bending stress within permissible limits

Check shear stress

Shear stress

$$\tau = 0.710 \text{ N/mm}^2$$

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Permissible shear stress

$$\tau_{adm} = \tau \times K_{2s} \times K_3 \times K_8 = \mathbf{0.976 \text{ N/mm}^2}$$

Applied shear stress

$$\tau_{max} = 3 \times V / (2 \times b \times h) = \mathbf{0.378 \text{ N/mm}^2}$$

PASS - Applied shear stress within permissible limits

Check bearing stress

Compression perpendicular to grain (no wane)

$$\sigma_{cp1} = \mathbf{2.400 \text{ N/mm}^2}$$

Permissible bearing stress

$$\sigma_{c_adm} = \sigma_{cp1} \times K_{2c} \times K_3 \times K_8 = \mathbf{3.300 \text{ N/mm}^2}$$

Applied bearing stress

$$\sigma_{c_max} = R / (b \times L_b) = \mathbf{0.567 \text{ N/mm}^2}$$

PASS - Applied bearing stress within permissible limits

Check deflection

Permissible deflection

$$\delta_{adm} = \min(L_{s1} \times 0.003, 14 \text{ mm}) = \mathbf{13.500 \text{ mm}}$$

Bending deflection (based on E_{mean})

$$\delta_{bending} = \mathbf{11.837 \text{ mm}}$$

Shear deflection

$$\delta_{shear} = \mathbf{0.504 \text{ mm}}$$

Total deflection

$$\delta = \delta_{bending} + \delta_{shear} = \mathbf{12.342 \text{ mm}}$$

PASS - Actual deflection within permissible limits