

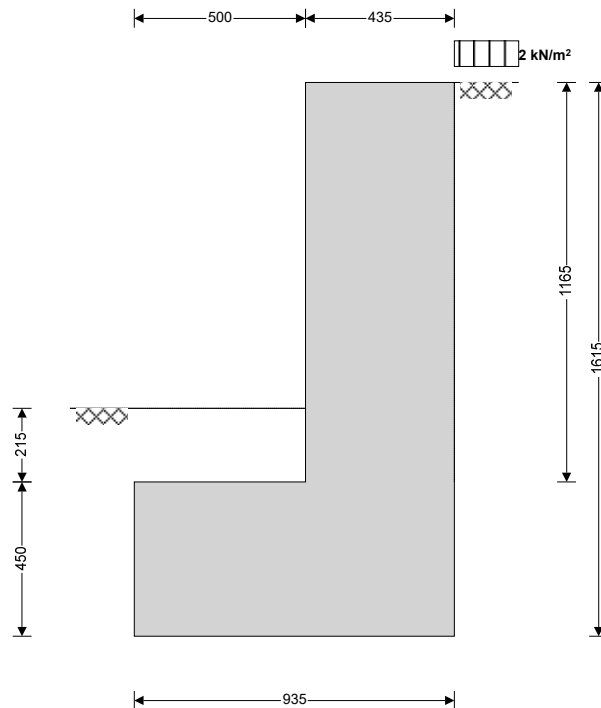
Project 42 HILLSTONE AVE. SHAWCLOUGH				Job Ref. 24326	
Section GARDEN RETAINING WALL				Sheet no./rev. 1	
Calc. by M.B.	Date 27/06/2024	Chk'd by	Date	App'd by	Date

DESIGN CHECK CALCULATIONS FOR A PARTIALLY AS-BUILT RETAINING WALL

THE RETAINING WALL WILL BE RETAINING A GRASSED LAWN AREA ONLY, INFREQUENT ACCESS MAINLY FOR LAWNMOWERING TO MAINTAIN THE AREA

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06



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

$h_{\text{stem}} = 1165 \text{ mm}$
 $t_{\text{wall}} = 435 \text{ mm}$
 $l_{\text{toe}} = 500 \text{ mm}$
 $l_{\text{heel}} = 0 \text{ mm}$
 $l_{\text{base}} = l_{\text{toe}} + l_{\text{heel}} + t_{\text{wall}} = 935 \text{ mm}$
 $t_{\text{base}} = 450 \text{ mm}$
 $d_{\text{ds}} = 0 \text{ mm}$
 $l_{\text{ds}} = 150 \text{ mm}$
 $t_{\text{ds}} = 450 \text{ mm}$
 $h_{\text{wall}} = h_{\text{stem}} + t_{\text{base}} + d_{\text{ds}} = 1615 \text{ mm}$
 $d_{\text{cover}} = 215 \text{ mm}$
 $d_{\text{exc}} = 0 \text{ mm}$
 $h_{\text{water}} = 0 \text{ mm}$
 $h_{\text{sat}} = \max(h_{\text{water}} - t_{\text{base}} - d_{\text{ds}}, 0 \text{ mm}) = 0 \text{ mm}$
 $\gamma_{\text{wall}} = 23.6 \text{ kN/m}^3$
 $\gamma_{\text{base}} = 23.6 \text{ kN/m}^3$
 $\alpha = 90.0 \text{ deg}$
 $\beta = 0.0 \text{ deg}$
 $h_{\text{eff}} = h_{\text{wall}} + l_{\text{heel}} \times \tan(\beta) = 1615 \text{ mm}$

Project		42 HILLSTONE AVE. SHAWCLOUGH		Job Ref.		24326
Section		GARDEN RETAINING WALL		Sheet no./rev.		2
Calc. by	Date	Chk'd by	Date	App'd by	Date	
M.B.	27/06/2024					

Retained material details

Mobilisation factor	$M = 1.5$
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	$\delta = 0.0 \text{ deg}$

Base material details

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

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

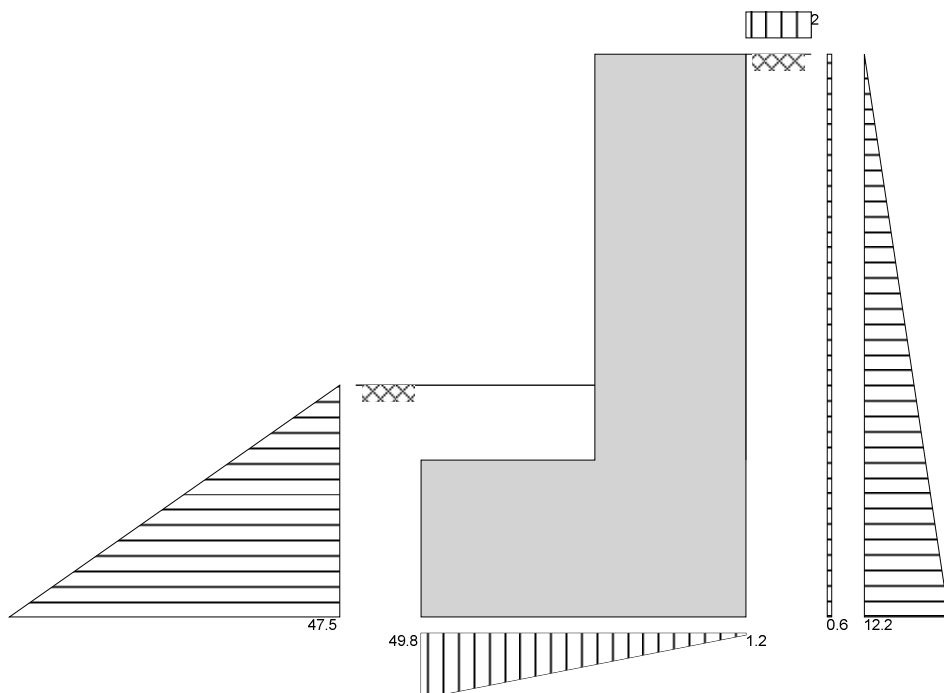
$$K_p = \sin(90 - \phi'_b)^2 / (\sin(90 - \delta_b) \times [1 - \sqrt{(\sin(\phi'_b + \delta_b) \times \sin(\phi'_b) / (\sin(90 + \delta_b)))^2})] = 4.187$$

At-rest pressure

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

Surcharge load on plan	Surcharge = 1.5 kN/m^2
Applied vertical dead load on wall	$W_{\text{dead}} = 0.0 \text{ kN/m}$
Applied vertical live load on wall	$W_{\text{live}} = 0.0 \text{ kN/m}$
Position of applied vertical load on wall	$l_{\text{load}} = 0 \text{ mm}$
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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63 Dale Street
Milnrow
OL16 3NJ

Project		42 HILLSTONE AVE. SHAWCLOUGH		Job Ref.		24326
Section		GARDEN RETAINING WALL		Sheet no./rev.		3
Calc. by	Date	Chk'd by	Date	App'd by	Date	
M.B.	27/06/2024					

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

Vertical forces on wall

Wall stem	$W_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall} = 12 \text{ kN/m}$
Wall base	$W_{base} = l_{base} \times t_{base} \times \gamma_{base} = 9.9 \text{ kN/m}$
Soil in front of wall	$W_p = l_{toe} \times d_{cover} \times \gamma_{mb} = 1.9 \text{ kN/m}$
Total vertical load	$W_{total} = W_{wall} + W_{base} + W_p = 23.8 \text{ kN/m}$

Horizontal forces on wall

Surcharge	$F_{sur} = K_a \times \text{Surcharge} \times h_{eff} = 1 \text{ kN/m}$
Moist backfill above water table	$F_{m_a} = 0.5 \times K_a \times \gamma_m \times (h_{eff} - h_{water})^2 = 9.8 \text{ kN/m}$
Total horizontal load	$F_{total} = F_{sur} + F_{m_a} = 10.8 \text{ kN/m}$

Calculate stability against sliding

Passive resistance of soil in front of wall	$F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb} = 15.8 \text{ kN/m}$
Resistance to sliding	$F_{res} = F_p + (W_{total} - w_p) \times \tan(\delta_b) = 23.2 \text{ kN/m}$
PASS - Resistance force is greater than sliding force	

Overturning moments

Surcharge	$M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2 = 0.8 \text{ kNm/m}$
Moist backfill above water table	$M_{m_a} = F_{m_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3 = 5.3 \text{ kNm/m}$
Total overturning moment	$M_{ot} = M_{sur} + M_{m_a} = 6.1 \text{ kNm/m}$

Restoring moments

Wall stem	$M_{wall} = W_{wall} \times (l_{toe} + t_{wall} / 2) = 8.6 \text{ kNm/m}$
Wall base	$M_{base} = W_{base} \times l_{base} / 2 = 4.6 \text{ kNm/m}$
Total restoring moment	$M_{rest} = M_{wall} + M_{base} = 13.2 \text{ kNm/m}$

Check stability against overturning

Total overturning moment	$M_{ot} = 6.1 \text{ kNm/m}$
Total restoring moment	$M_{rest} = 13.2 \text{ kNm/m}$
PASS - Restoring moment is greater than overturning moment	

Check bearing pressure

Soil in front of wall	$M_{p_r} = w_p \times l_{toe} / 2 = 0.5 \text{ kNm/m}$
Total moment for bearing	$M_{total} = M_{rest} - M_{ot} + M_{p_r} = 7.6 \text{ kNm/m}$
Total vertical reaction	$R = W_{total} = 23.8 \text{ kN/m}$
Distance to reaction	$x_{bar} = M_{total} / R = 319 \text{ mm}$
Eccentricity of reaction	$e = \text{abs}((l_{base} / 2) - x_{bar}) = 149 \text{ mm}$
Reaction acts within middle third of base	
Bearing pressure at toe	$p_{toe} = (R / l_{base}) + (6 \times R \times e / l_{base}^2) = 49.8 \text{ kN/m}^2$
Bearing pressure at heel	$p_{heel} = (R / l_{base}) - (6 \times R \times e / l_{base}^2) = 1.2 \text{ kN/m}^2$

PASS - Maximum bearing pressure is less than allowable bearing pressure

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	Section GARDEN RETAINING WALL				Sheet no./rev. 4	
	Calc. by M.B.	Date 27/06/2024	Chk'd by	Date	App'd by	Date

RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.06

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	$W_{wall_f} = \gamma_{f_d} \times h_{stem} \times t_{wall} \times \gamma_{wall} = 16.7 \text{ kN/m}$
Wall base	$W_{base_f} = \gamma_{f_d} \times l_{base} \times t_{base} \times \gamma_{base} = 13.9 \text{ kN/m}$
Soil in front of wall	$W_{p_f} = \gamma_{f_d} \times l_{toe} \times d_{cover} \times \gamma_{mb} = 2.7 \text{ kN/m}$
Total vertical load	$W_{total_f} = W_{wall_f} + W_{base_f} + W_{p_f} = 33.4 \text{ kN/m}$

Factored horizontal at-rest forces on wall

Surcharge	$F_{sur_f} = \gamma_{f_l} \times K_0 \times \text{Surcharge} \times h_{eff} = 2.3 \text{ kN/m}$
Moist backfill above water table	$F_{m_{a_f}} = \gamma_{f_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2 = 19.4 \text{ kN/m}$
Total horizontal load	$F_{total_f} = F_{sur_f} + F_{m_{a_f}} = 21.7 \text{ kN/m}$
Passive resistance of soil in front of wall kN/m	$F_{p_f} = \gamma_{f_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb} = 22.1 \text{ kN/m}$

Factored overturning moments

Surcharge	$M_{sur_f} = F_{sur_f} \times (h_{eff} - 2 \times d_{ds}) / 2 = 1.8 \text{ kNm/m}$
Moist backfill above water table	$M_{m_{a_f}} = F_{m_{a_f}} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3 = 10.4 \text{ kNm/m}$
Total overturning moment	$M_{ot_f} = M_{sur_f} + M_{m_{a_f}} = 12.3 \text{ kNm/m}$

Restoring moments

Wall stem	$M_{wall_f} = W_{wall_f} \times (l_{toe} + t_{wall} / 2) = 12 \text{ kNm/m}$
Wall base	$M_{base_f} = W_{base_f} \times l_{base} / 2 = 6.5 \text{ kNm/m}$
Soil in front of wall	$M_{p_{r_f}} = W_{p_f} \times l_{toe} / 2 = 0.7 \text{ kNm/m}$
Total restoring moment	$M_{rest_f} = M_{wall_f} + M_{base_f} + M_{p_{r_f}} = 19.2 \text{ kNm/m}$

Factored bearing pressure

Total moment for bearing	$M_{total_f} = M_{rest_f} - M_{ot_f} = 6.9 \text{ kNm/m}$
Total vertical reaction	$R_f = W_{total_f} = 33.4 \text{ kN/m}$
Distance to reaction	$\bar{x}_{bar_f} = M_{total_f} / R_f = 207 \text{ mm}$
Eccentricity of reaction	$e_f = \text{abs}((l_{base} / 2) - \bar{x}_{bar_f}) = 261 \text{ mm}$

Reaction acts outside middle third of base

Bearing pressure at toe	$p_{toe_f} = R_f / (1.5 \times \bar{x}_{bar_f}) = 107.4 \text{ kN/m}^2$
Bearing pressure at heel	$p_{heel_f} = 0 \text{ kN/m}^2 = 0 \text{ kN/m}^2$
Rate of change of base reaction	$\text{rate} = p_{toe_f} / (3 \times \bar{x}_{bar_f}) = 173.02 \text{ kN/m}^2/\text{m}$
Bearing pressure at stem / toe	$p_{stem_toe_f} = \max(p_{toe_f} - (\text{rate} \times l_{toe}), 0 \text{ kN/m}^2) = 20.9 \text{ kN/m}^2$
Bearing pressure at mid stem	$p_{stem_mid_f} = \max(p_{toe_f} - (\text{rate} \times (l_{toe} + t_{wall} / 2)), 0 \text{ kN/m}^2) = 0 \text{ kN/m}^2$
Bearing pressure at stem / heel	$p_{stem_heel_f} = \max(p_{toe_f} - (\text{rate} \times (l_{toe} + t_{wall})), 0 \text{ kN/m}^2) = 0 \text{ kN/m}^2$

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	$c_{toe} = 30 \text{ mm}$

Project		42 HILLSTONE AVE. SHAWCLOUGH		Job Ref.		24326
Section		GARDEN RETAINING WALL		Sheet no./rev.		5
Calc. by	Date	Chk'd by	Date	App'd by	Date	
M.B.	27/06/2024					

Calculate shear for toe design

Shear from bearing pressure

$$V_{toe_bear} = (p_{toe_f} + p_{stem_toe_f}) \times l_{toe} / 2 = \mathbf{32.1 \text{ kN/m}}$$

Shear from weight of base

$$V_{toe_wt_base} = \gamma_{t_d} \times \gamma_{base} \times l_{toe} \times t_{base} = \mathbf{7.4 \text{ kN/m}}$$

Shear from weight of soil

$$V_{toe_wt_soil} = w_{p_f} - (\gamma_{t_d} \times \gamma_m \times l_{toe} \times d_{exc}) = \mathbf{2.7 \text{ kN/m}}$$

Total shear for toe design

$$V_{toe} = V_{toe_bear} - V_{toe_wt_base} - V_{toe_wt_soil} = \mathbf{21.9 \text{ kN/m}}$$

Calculate moment for toe design

Moment from bearing pressure

$$M_{toe_bear} = (2 \times p_{toe_f} + p_{stem_mid_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6 = \mathbf{18.4 \text{ kNm/m}}$$

Moment from weight of base

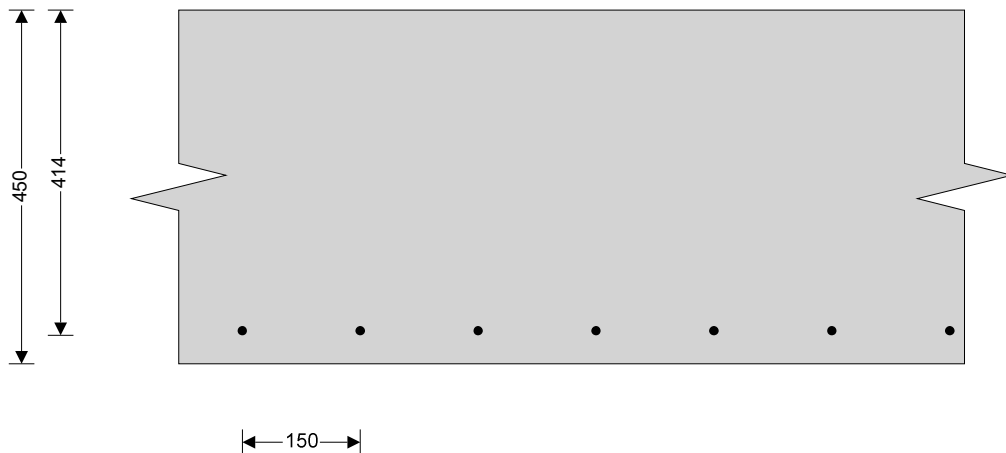
$$M_{toe_wt_base} = (\gamma_{t_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2) = \mathbf{3.8 \text{ kNm/m}}$$

Moment from weight of soil

$$M_{toe_wt_soil} = (w_{p_f} - (\gamma_{t_d} \times \gamma_m \times l_{toe} \times d_{exc})) \times (l_{toe} + t_{wall}) / 2 = \mathbf{1.3 \text{ kNm/m}}$$

Total moment for toe design

$$M_{toe} = M_{toe_bear} - M_{toe_wt_base} - M_{toe_wt_soil} = \mathbf{13.3 \text{ kNm/m}}$$



Check toe in bending

Width of toe

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

Depth of reinforcement

$$d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) = \mathbf{414.0 \text{ mm}}$$

Constant

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

Compression reinforcement is not required

Lever arm

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

$$Z_{toe} = \mathbf{393 \text{ mm}}$$

Area of tension reinforcement required

$$A_{s_toe_des} = M_{toe} / (0.87 \times f_y \times Z_{toe}) = \mathbf{78 \text{ mm}^2/\text{m}}$$

Minimum area of tension reinforcement

$$A_{s_toe_min} = k \times b \times t_{base} = \mathbf{585 \text{ mm}^2/\text{m}}$$

Area of tension reinforcement required

$$A_{s_toe_req} = \text{Max}(A_{s_toe_des}, A_{s_toe_min}) = \mathbf{585 \text{ mm}^2/\text{m}}$$

Reinforcement provided

$$\mathbf{12 \text{ mm dia. bars @ 150 mm centres}}$$

Area of reinforcement provided

$$A_{s_toe_prov} = \mathbf{754 \text{ mm}^2/\text{m}}$$

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress

$$v_{toe} = V_{toe} / (b \times d_{toe}) = \mathbf{0.053 \text{ N/mm}^2}$$

Allowable shear stress

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

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

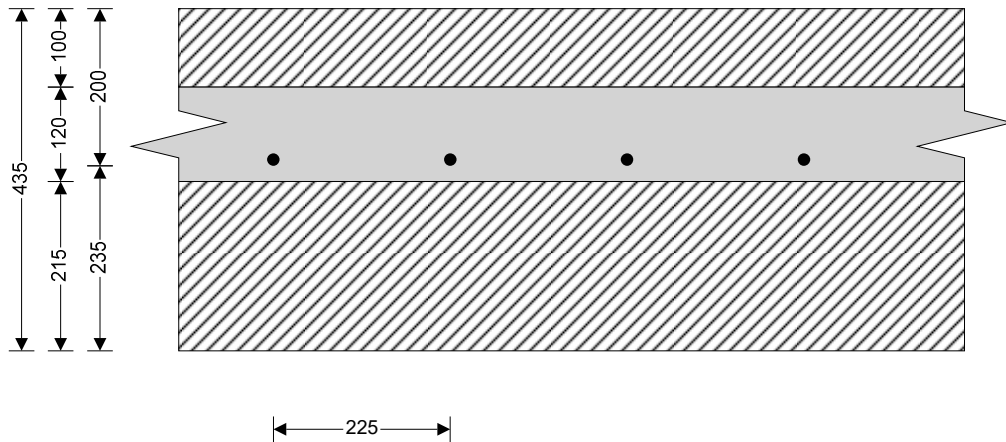
Design concrete shear stress

$$v_{c_toe} = \mathbf{0.401 \text{ N/mm}^2}$$

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

Project		42 HILLSTONE AVE. SHAWCLOUGH		Job Ref.		24326
Section		GARDEN RETAINING WALL		Sheet no./rev.		6
Calc. by	Date	Chk'd by	Date	App'd by	Date	
M.B.	27/06/2024					

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



Wall details

Thickness of outer leaf of wall
Thickness of inner leaf of wall
Thickness of reinforced cavity
Depth of stem reinforcement

$t_{\text{outer}} = 100 \text{ mm}$
 $t_{\text{inner}} = 215 \text{ mm}$
 $t_{\text{cavity}} = t_{\text{wall}} - t_{\text{outer}} - t_{\text{inner}} = 120 \text{ mm}$
 $d_{\text{stem}} = 200 \text{ mm}$

Masonry details

Masonry type
Compressive strength of units
Mortar designation
Category of manufacturing control of units
Partial safety factor for material strength

Aggregate concrete blocks no voids
 $p_{\text{unit}} = 7.3 \text{ N/mm}^2$
(ii)
Category I
 $\gamma_{\text{mm}} = 2.0$

Characteristic compressive strength of masonry

Least horizontal dimension of masonry units
Height of masonry units
Ratio of height to least horizontal dimension

$b_{\text{unit}} = 100.0 \text{ mm}$
 $h_{\text{unit}} = 215.0 \text{ mm}$
 $\text{ratio} = h_{\text{unit}} / b_{\text{unit}} = 2.2$

From BS5628:2 Table 3d, mortar ii

Characteristic compressive strength

$f_k = 6.4 \text{ N/mm}^2$

Factored horizontal at-rest forces on stem

Surcharge
Moist backfill above water table

$F_{s_sur_f} = \gamma_{t_l} \times K_0 \times \text{Surcharge} \times (h_{\text{eff}} - t_{\text{base}} - d_{\text{ds}}) = 1.6 \text{ kN/m}$
 $F_{s_m_a_f} = 0.5 \times \gamma_{t_e} \times K_0 \times \gamma_m \times (h_{\text{eff}} - t_{\text{base}} - d_{\text{ds}} - h_{\text{sat}})^2 = 10.1 \text{ kN/m}$

Calculate shear for stem design

Shear at base of stem

$V_{\text{stem}} = F_{s_sur_f} + F_{s_m_a_f} = 11.7 \text{ kN/m}$

Calculate moment for stem design

Surcharge
Moist backfill above water table
Total moment for stem design

$M_{s_sur} = F_{s_sur_f} \times (h_{\text{stem}} + t_{\text{base}}) / 2 = 1.3 \text{ kNm/m}$
 $M_{s_m_a} = F_{s_m_a_f} \times (2 \times h_{\text{sat}} + h_{\text{eff}} - d_{\text{ds}} + t_{\text{base}} / 2) / 3 = 6.2 \text{ kNm/m}$
 $M_{\text{stem}} = M_{s_sur} + M_{s_m_a} = 7.5 \text{ kNm/m}$

Check maximum design moment for wall stem

Width of wall
Maximum design moment

$b = 1000 \text{ mm/m}$
 $M_{d_stem} = 0.4 \times f_k \times b \times d_{\text{stem}}^2 / \gamma_{\text{mm}} = 51.2 \text{ kNm/m}$

PASS - Applied moment is less than maximum design moment



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Healey Consulting LTD

63 Dale Street

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Job Ref.

24326

Section

GARDEN RETAINING WALL

Sheet no./rev.

7

Calc. by

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Date

27/06/2024

Chk'd by

Date

App'd by

Date

Check wall stem in bending

Moment of resistance factor

$$Q = M_{\text{stem}} / d_{\text{stem}}^2 = \mathbf{0.188 \text{ N/mm}^2}$$

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

Lever arm factor

$$c = \mathbf{0.970}$$

Lever arm

$$Z_{\text{stem}} = \min(0.95, c) \times d_{\text{stem}} = \mathbf{190.0 \text{ mm}}$$

Area of tension reinforcement required

$$A_{s_stem_des} = M_{\text{stem}} \times \gamma_{\text{ms}} / (f_y \times Z_{\text{stem}}) = \mathbf{91 \text{ mm}^2/\text{m}}$$

Minimum area of tension reinforcement

$$A_{s_stem_min} = k \times b \times t_{\text{wall}} = \mathbf{566 \text{ mm}^2/\text{m}}$$

Area of tension reinforcement required

$$A_{s_stem_req} = \text{Max}(A_{s_stem_des}, A_{s_stem_min}) = \mathbf{566 \text{ mm}^2/\text{m}}$$

Reinforcement provided

16 mm dia.bars @ 225 mm centres

Area of reinforcement provided

$$A_{s_stem_prov} = \pi \times \phi_{\text{stem}}^2 / (4 \times s_{\text{stem}}) = \mathbf{894 \text{ mm}^2/\text{m}}$$

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress

$$V_{\text{stem}} = V_{\text{stem}} / (b \times d_{\text{stem}}) = \mathbf{0.059 \text{ N/mm}^2}$$

Basic characteristic shear strength of masonry

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

$$f_{v\text{bas}} = \mathbf{0.428 \text{ N/mm}^2}$$

Shear span

$$a = M_{\text{stem}} / V_{\text{stem}} = \mathbf{640.6 \text{ mm}}$$

Characteristic shear strength of masonry

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

$$f_v = \mathbf{0.728 \text{ N/mm}^2}$$

Allowable shear stress

$$V_{\text{adm}} = f_v / \gamma_{\text{mv}} = \mathbf{0.364 \text{ N/mm}^2}$$

PASS - Design shear stress is less than maximum shear stress

Check limiting dimensions

Limiting span/effective depth ratio

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

Actual span/effective depth ratio

$$\text{ratio}_{\text{act}} = (h_{\text{stem}} + d_{\text{stem}} / 2) / d_{\text{stem}} = \mathbf{6.33}$$

PASS - Span to depth ratio is acceptable

Axial load check

Factored axial load on wall

$$N_{\text{wall}} = ([t_{\text{wall}} \times h_{\text{stem}} \times \gamma_{\text{wall}} + W_{\text{dead}}] \times \gamma_{\text{f_d}}) + (W_{\text{live}} \times \gamma_{\text{f_l}}) = \mathbf{16.7 \text{ kN/m}}$$

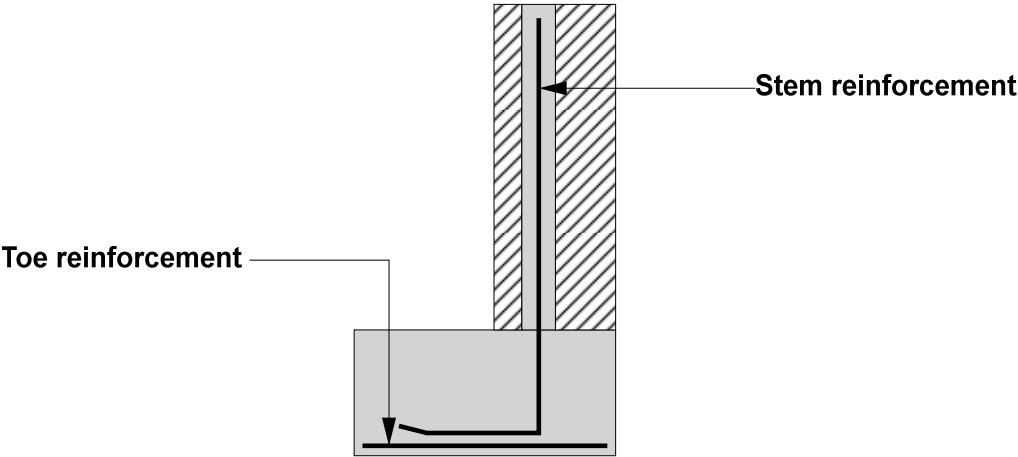
Limiting axial load

$$N_{\text{limit}} = 0.1 \times f_k \times t_{\text{wall}} = \mathbf{278.4 \text{ kN/m}}$$

Applied axial load may be ignored - calculations valid

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	42 HILLSTONE AVE. SHAWCLOUGH				24326	
	Section				Sheet no./rev.	
	GARDEN RETAINING WALL				8	
	Calc. by	Date	Chk'd by	Date	App'd by	Date
	M.B.	27/06/2024				

Indicative retaining wall reinforcement diagram



Toe bars - 12 mm dia.@ 150 mm centres - (754 mm²/m)
Stem bars - 16 mm dia.@ 225 mm centres - (894 mm²/m)