Tekla Tedds AJS Structural Design Ltd 62 Carter Street Uttoxeter Staffordshire ST14 8EU	Project				Job Ref.	
	Section				Sheet no./rev. 1	
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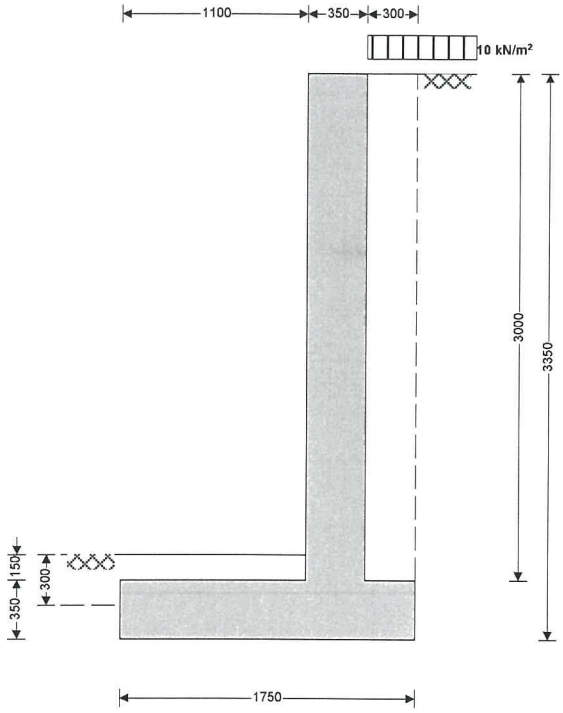
RETAINING WALL ANALYSIS & DESIGN (BS8002)

RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06



Wall details

Retaining wall type	**Unpropped cantilever**
Height of retaining wall stem	h_{stem} = **3000** mm
Thickness of wall stem	t_{wall} = **350** mm
Length of toe	l_{toe} = **1100** mm
Length of heel	l_{heel} = **300** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **1750** mm
Thickness of base	t_{base} = **350** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **750** mm
Thickness of downstand	t_{ds} = **350** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **3350** mm
Depth of cover in front of wall	d_{cover} = **150** mm
Depth of unplanned excavation	d_{exc} = **300** mm
Height of ground water behind wall	h_{water} = **0** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0\ mm)$ = **0** mm
Density of wall construction	γ_{wall} = **23.6** kN/m^3
Density of base construction	γ_{base} = **23.6** kN/m^3
Angle of rear face of wall	α = **90.0** deg
Angle of soil surface behind wall	β = **0.0** deg
Effective height at virtual back of wall	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **3350** mm

Retained material details

Mobilisation factor	M = **1.2**

Moist density of retained material	γ_m = **17.5** kN/m^3
Saturated density of retained material	γ_s = **21.0** kN/m^3
Design shear strength	ϕ' = **33.1** deg
Angle of wall friction	δ = **26.1** deg

Base material details

Moist density	γ_{mb} = **17.5** kN/m^3
Design shear strength	ϕ'_b = **35.9** deg
Design base friction	δ_b = **28.5** deg
Allowable bearing pressure	$P_{bearing}$ = **250** kN/m^2

Using Coulomb theory

Active pressure coefficient for retained material

$$K_a = \sin(\alpha + \phi')^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta) \times [1 + \sqrt{(\sin(\phi' + \delta) \times \sin(\phi' - \beta) / (\sin(\alpha - \delta) \times \sin(\alpha + \beta)))}]^2) = \mathbf{0.263}$$

Passive pressure coefficient for base material

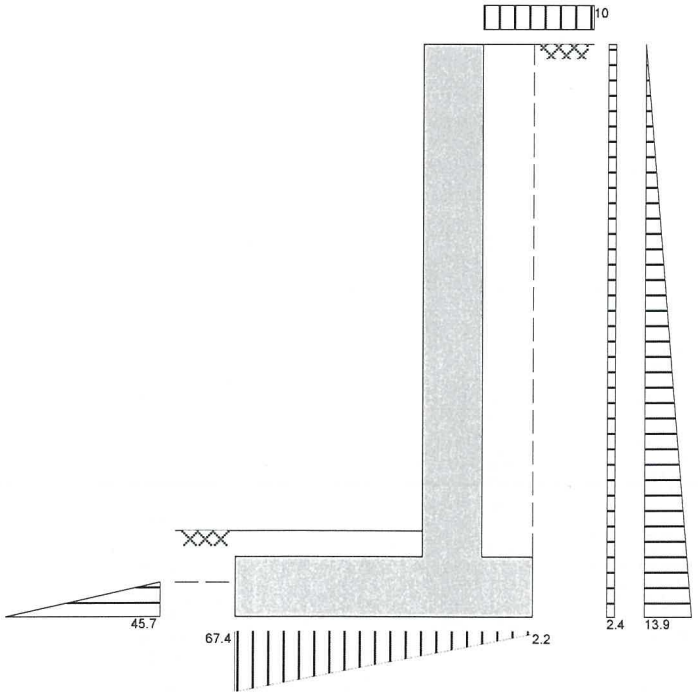
$$K_p = \sin(90 - \phi'_b)^2 / (\sin(90 - \delta_b) \times [1 - \sqrt{(\sin(\phi'_b + \delta_b) \times \sin(\phi'_b) / (\sin(90 + \delta_b)))}]^2) = \mathbf{14.842}$$

At-rest pressure

At-rest pressure for retained material	$K_0 = 1 - \sin(\phi')$ = **0.454**

Loading details

Surcharge load on plan	Surcharge = **10.0** kN/m^2
Applied vertical dead load on wall	W_{dead} = **0.0** kN/m
Applied vertical live load on wall	W_{live} = **0.0** kN/m
Position of applied vertical load on wall	l_{load} = **0** mm
Applied horizontal dead load on wall	F_{dead} = **0.0** kN/m
Applied horizontal live load on wall	F_{live} = **0.0** kN/m
Height of applied horizontal load on wall	h_{load} = **0** mm



Loads shown in kN/m, pressures shown in kN/m^2

Vertical forces on wall

Wall stem	$w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **24.8** kN/m
Wall base	$w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **14.5** kN/m
Surcharge	$w_{sur} = Surcharge \times l_{heel}$ = **3** kN/m
Moist backfill to top of wall	$w_{m_w} = l_{heel} \times (h_{stem} - h_{sat}) \times \gamma_m$ = **15.7** kN/m
Soil in front of wall	$w_p = l_{toe} \times d_{cover} \times \gamma_{mb}$ = **2.9** kN/m
Total vertical load	$W_{total} = w_{wall} + w_{base} + w_{sur} + w_{m_w} + w_p$ = **60.9** kN/m

Horizontal forces on wall

Surcharge	$F_{sur} = K_a \times \cos(90 - \alpha + \delta) \times Surcharge \times h_{eff}$ = **7.9** kN/m
Moist backfill above water table	$F_{m_a} = 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water})^2$ = **23.2** kN/m
Total horizontal load	$F_{total} = F_{sur} + F_{m_a}$ = **31.1** kN/m

Calculate stability against sliding

Passive resistance of soil in front of wall	$F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **4.6** kN/m
Resistance to sliding	$F_{res} = F_p + (W_{total} - w_{sur} - w_p) \times \tan(\delta_b)$ = **34.4** kN/m

PASS - Resistance force is greater than sliding force

Overturning moments

Surcharge	$M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **13.3** kNm/m
Moist backfill above water table	$M_{m_a} = F_{m_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **25.9** kNm/m
Total overturning moment	$M_{ot} = M_{sur} + M_{m_a}$ = **39.2** kNm/m

Restoring moments

Wall stem	$M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2)$ = **31.6** kNm/m
Wall base	$M_{base} = w_{base} \times l_{base} / 2$ = **12.6** kNm/m
Moist backfill	$M_{m_r} = (w_{m_w} \times (l_{base} - l_{heel} / 2) + w_{m_s} \times (l_{base} - l_{heel} / 3))$ = **25.2** kNm/m
Total restoring moment	$M_{rest} = M_{wall} + M_{base} + M_{m_r}$ = **69.4** kNm/m

Check stability against overturning

Total overturning moment	M_{ot} = **39.2** kNm/m
Total restoring moment	M_{rest} = **69.4** kNm/m

PASS - Restoring moment is greater than overturning moment

Check bearing pressure

Surcharge	$M_{sur_r} = w_{sur} \times (l_{base} - l_{heel} / 2)$ = **4.8** kNm/m
Soil in front of wall	$M_{p_r} = w_p \times l_{toe} / 2$ = **1.6** kNm/m
Total moment for bearing	$M_{total} = M_{rest} - M_{ot} + M_{sur_r} + M_{p_r}$ = **36.6** kNm/m
Total vertical reaction	$R = W_{total}$ = **60.9** kN/m
Distance to reaction	$x_{bar} = M_{total} / R$ = **602** mm
Eccentricity of reaction	$e = abs((l_{base} / 2) - x_{bar})$ = **273** mm

Reaction acts within middle third of base

Bearing pressure at toe	$p_{toe} = (R / l_{base}) + (6 \times R \times e / l_{base}^2)$ = **67.4** kN/m^2
Bearing pressure at heel	$p_{heel} = (R / l_{base}) - (6 \times R \times e / l_{base}^2)$ = **2.2** kN/m^2

PASS - Maximum bearing pressure is less than allowable bearing pressure

RETAINING WALL DESIGN (BS 8002:1994)

TEDDS calculation version 1.2.01.06

Ultimate limit state load factors

Dead load factor	γ_{f_d} = **1.4**
Live load factor	γ_{f_l} = **1.6**
Earth and water pressure factor	γ_{f_e} = **1.4**

Factored vertical forces on wall

Wall stem	$w_{wall_f} = \gamma_{f_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **34.7** kN/m
Wall base	$w_{base_f} = \gamma_{f_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **20.2** kN/m
Surcharge	$w_{sur_f} = \gamma_{f_l} \times$ Surcharge $\times l_{heel}$ = **4.8** kN/m
Moist backfill to top of wall	$w_{m_w_f} = \gamma_{f_d} \times l_{heel} \times (h_{stem} - h_{sat}) \times \gamma_m$ = **22.1** kN/m
Soil in front of wall	$w_{p_f} = \gamma_{f_d} \times l_{toe} \times d_{cover} \times \gamma_{mb}$ = **4** kN/m
Total vertical load	$W_{total_f} = w_{wall_f} + w_{base_f} + w_{sur_f} + w_{m_w_f} + w_{p_f}$ = **85.8** kN/m

Factored horizontal at-rest forces on wall

Surcharge	$F_{sur_f} = \gamma_{f_l} \times K_0 \times$ Surcharge $\times h_{eff}$ = **24.3** kN/m
Moist backfill above water table	$F_{m_a_f} = \gamma_{f_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2$ = **62.4** kN/m
Total horizontal load	$F_{total_f} = F_{sur_f} + F_{m_a_f}$ = **86.7** kN/m
Passive resistance of soil in front of wall	$F_{p_f} = \gamma_{f_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **6.4** kN/m

Factored overturning moments

Surcharge	$M_{sur_f} = F_{sur_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **40.8** kNm/m
Moist backfill above water table	$M_{m_a_f} = F_{m_a_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **69.7** kNm/m
Total overturning moment	$M_{ot_f} = M_{sur_f} + M_{m_a_f}$ = **110.4** kNm/m

Restoring moments

Wall stem	$M_{wall_f} = w_{wall_f} \times (l_{toe} + t_{wall} / 2)$ = **44.2** kNm/m
Wall base	$M_{base_f} = w_{base_f} \times l_{base} / 2$ = **17.7** kNm/m
Surcharge	$M_{sur_r_f} = w_{sur_f} \times (l_{base} - l_{heel} / 2)$ = **7.7** kNm/m
Moist backfill	$M_{m_r_f} = (w_{m_w_f} \times (l_{base} - l_{heel} / 2) + w_{m_s_f} \times (l_{base} - l_{heel} / 3))$ = **35.3** kNm/m
Soil in front of wall	$M_{p_r_f} = w_{p_f} \times l_{toe} / 2$ = **2.2** kNm/m
Total restoring moment	$M_{rest_f} = M_{wall_f} + M_{base_f} + M_{sur_r_f} + M_{m_r_f} + M_{p_r_f}$ = **107.1** kNm/m

Factored bearing pressure

Total moment for bearing	$M_{total_f} = M_{rest_f} - M_{ot_f}$ = **-3.3** kNm/m
Total vertical reaction	$R_f = W_{total_f}$ = **85.8** kN/m
Distance to reaction	$x_{bar_f} = M_{total_f} / R_f$ = **-39** mm
Eccentricity of reaction	$e_f = \text{abs}((l_{base} / 2) - x_{bar_f})$ = **914** mm
	WARNING - Beyond scope of calculation
Bearing pressure at toe	$p_{toe_f} = R_f / (1.5 \times x_{bar_f})$ = **-1484.4** kN/m^2
Bearing pressure at heel	p_{heel_f} = 0 kN/m^2 = **0** kN/m^2
Rate of change of base reaction	rate = $p_{toe_f} / (3 \times x_{bar_f})$ = **12837.82** kN/m^2/m
Bearing pressure at stem / toe	$p_{stem_toe_f} = \max(p_{toe_f} - (\text{rate} \times l_{toe}), 0\ \text{kN/m}^2)$ = **0** 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** 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** kN/m^2

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

Material properties

Characteristic strength of concrete — f_{cu} = **35** N/mm²

Characteristic strength of reinforcement — f_y = **500** N/mm²

Base details

Minimum area of reinforcement — k = **0.13** %

Cover to reinforcement in toe — c_{toe} = **40** mm

Calculate shear for toe design

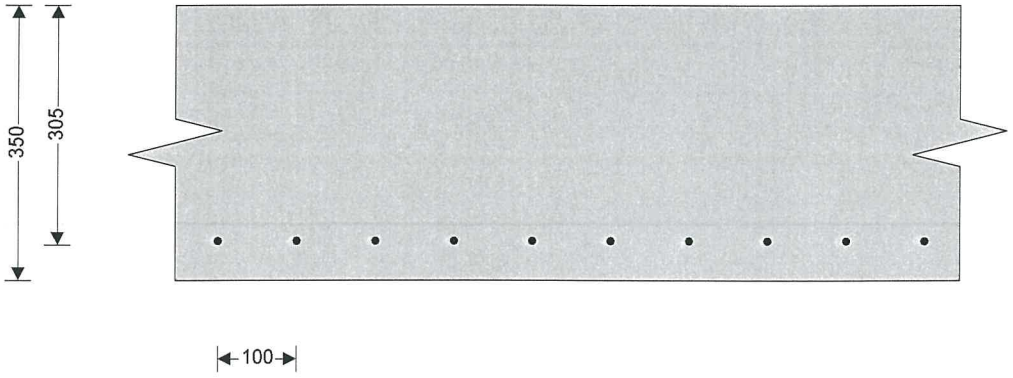
Shear from weight of base — $V_{toe_wt_base} = \gamma_{f_d} \times \gamma_{base} \times l_{toe} \times t_{base}$ = **12.7** kN/m

Total shear for toe design — $V_{toe} = V_{toe_wt_base}$ = **12.7** kN/m

Calculate moment for toe design

Moment from weight of base — $M_{toe_wt_base} = (\gamma_{f_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2)$ = **9.4** kNm/m

Total moment for toe design — $M_{toe} = M_{toe_wt_base}$ = **9.4** kNm/m



Check toe in bending

Width of toe — b = **1000** mm/m

Depth of reinforcement — $d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2)$ = **305.0** mm

Constant — $K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu})$ = **0.003**

Compression reinforcement is not required

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

z_{toe} = **290** mm

Area of tension reinforcement required — $A_{s_toe_des} = M_{toe} / (0.87 \times f_y \times z_{toe})$ = **75** mm²/m

Minimum area of tension reinforcement — $A_{s_toe_min} = k \times b \times t_{base}$ = **455** mm²/m

Area of tension reinforcement required — $A_{s_toe_req} = \max(A_{s_toe_des}, A_{s_toe_min})$ = **455** mm²/m

Reinforcement provided — **10 mm dia.bars @ 100 mm centres**

Area of reinforcement provided — $A_{s_toe_prov}$ = **785** mm²/m

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress — $v_{toe} = V_{toe} / (b \times d_{toe})$ = **0.042** N/mm²

Allowable shear stress — $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1\ \text{N/mm}^2)}, 5) \times 1\ \text{N/mm}^2$ = **4.733** N/mm²

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} = **0.481** N/mm²

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

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

Material properties

Characteristic strength of concrete f_{cu} = **35** N/mm²

Characteristic strength of reinforcement f_y = **500** N/mm²

Base details

Minimum area of reinforcement k = **0.13** %

Cover to reinforcement in heel c_{heel} = **40** mm

Calculate shear for heel design

Shear from weight of base $V_{heel_wt_base} = \gamma_{f_d} \times \gamma_{base} \times l_{heel} \times t_{base}$ = **3.5** kN/m

Shear from weight of moist backfill $V_{heel_wt_m} = w_{m_w_f}$ = **22.1** kN/m

Shear from surcharge $V_{heel_sur} = w_{sur_f}$ = **4.8** kN/m

Total shear for heel design $V_{heel} = V_{heel_wt_base} + V_{heel_wt_m} + V_{heel_sur}$ = **30.3** kN/m

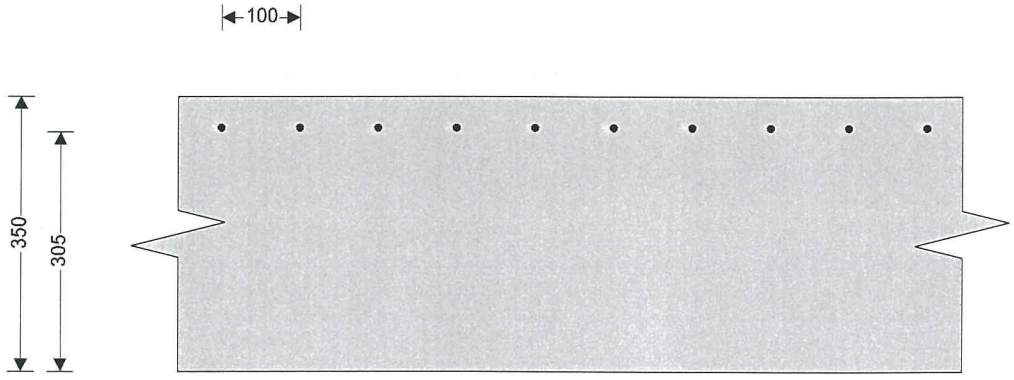
Calculate moment for heel design

Moment from weight of base $M_{heel_wt_base} = (\gamma_{f_d} \times \gamma_{base} \times t_{base} \times (l_{heel} + t_{wall} / 2)^2 / 2)$ = **1.3** kNm/m

Moment from weight of moist backfill $M_{heel_wt_m} = w_{m_w_f} \times (l_{heel} + t_{wall}) / 2$ = **7.2** kNm/m

Moment from surcharge $M_{heel_sur} = w_{sur_f} \times (l_{heel} + t_{wall}) / 2$ = **1.6** kNm/m

Total moment for heel design $M_{heel} = M_{heel_wt_base} + M_{heel_wt_m} + M_{heel_sur}$ = **10** kNm/m



Check heel in bending

Width of heel b = **1000** mm/m

Depth of reinforcement $d_{heel} = t_{base} - c_{heel} - (\phi_{heel} / 2)$ = **305.0** mm

Constant $K_{heel} = M_{heel} / (b \times d_{heel}^2 \times f_{cu})$ = **0.003**

Compression reinforcement is not required

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

z_{heel} = **290** mm

Area of tension reinforcement required $A_{s_heel_des} = M_{heel} / (0.87 \times f_y \times z_{heel})$ = **80** mm²/m

Minimum area of tension reinforcement $A_{s_heel_min} = k \times b \times t_{base}$ = **455** mm²/m

Area of tension reinforcement required $A_{s_heel_req} = \max(A_{s_heel_des}, A_{s_heel_min})$ = **455** mm²/m

Reinforcement provided **10 mm dia.bars @ 100 mm centres**

Area of reinforcement provided $A_{s_heel_prov}$ = **785** mm²/m

PASS - Reinforcement provided at the retaining wall heel is adequate

Check shear resistance at heel

Design shear stress $v_{heel} = V_{heel} / (b \times d_{heel})$ = **0.099** N/mm²

Allowable shear stress $v_{adm} = \min(0.8 \times \sqrt{}(f_{cu} / 1\ \text{N/mm}^2), 5) \times 1\ \text{N/mm}^2$ = **4.733** N/mm²

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} = **0.481** N/mm²

v_{heel} < v_{c_heel} - No shear reinforcement required

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

Material properties

Characteristic strength of concrete f_{cu} = **35** N/mm²

Characteristic strength of reinforcement f_y = **500** N/mm²

Wall details

Minimum area of reinforcement k = **0.13** %

Cover to reinforcement in stem c_{stem} = **40** mm

Cover to reinforcement in wall c_{wall} = **40** mm

Factored horizontal at-rest forces on stem

Surcharge $F_{s_sur_f} = \gamma_{f_l} \times K_0 \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds})$ = **21.8** 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** kN/m

Calculate shear for stem design

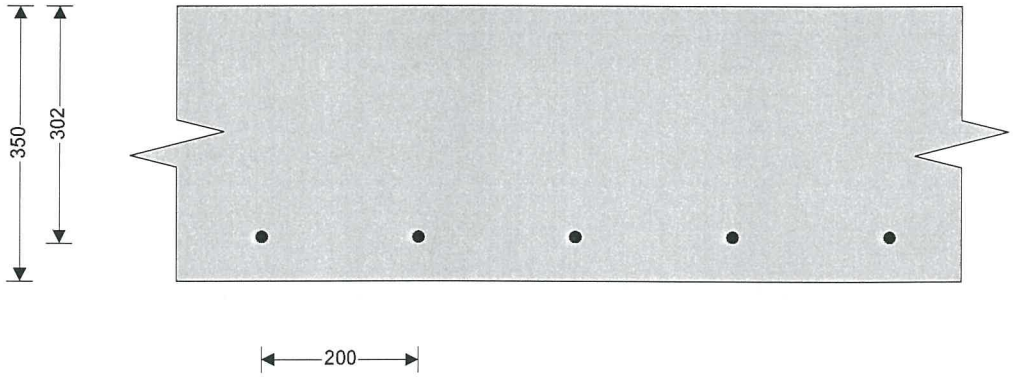
Shear at base of stem $V_{stem} = F_{s_sur_f} + F_{s_m_a_f}$ = **71.8** kN/m

Calculate moment for stem design

Surcharge $M_{s_sur} = F_{s_sur_f} \times (h_{stem} + t_{base}) / 2$ = **36.5** kNm/m

Moist backfill above water table $M_{s_m_a} = F_{s_m_a_f} \times (2 \times h_{sat} + h_{eff} - d_{ds} + t_{base} / 2) / 3$ = **58.8** kNm/m

Total moment for stem design $M_{stem} = M_{s_sur} + M_{s_m_a}$ = **95.3** kNm/m



Check wall stem in bending

Width of wall stem b = **1000** mm/m

Depth of reinforcement $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2)$ = **302.0** mm

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

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} = **287** mm

Area of tension reinforcement required $A_{s_stem_des} = M_{stem} / (0.87 \times f_y \times z_{stem})$ = **764** mm²/m

Minimum area of tension reinforcement $A_{s_stem_min} = k \times b \times t_{wall}$ = **455** mm²/m

Area of tension reinforcement required $A_{s_stem_req} = \text{Max}(A_{s_stem_des}, A_{s_stem_min})$ = **764** mm²/m

Reinforcement provided **16 mm dia.bars @ 200 mm centres**

Area of reinforcement provided $A_{s_stem_prov}$ = **1005** mm²/m

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress $v_{stem} = V_{stem} / (b \times d_{stem}) = \mathbf{0.238}$ N/mm^2

Allowable shear stress $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1\ \text{N/mm}^2)}, 5) \times 1\ \text{N/mm}^2 = \mathbf{4.733}$ 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 $v_{c_stem} = \mathbf{0.526}$ N/mm^2

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

Check retaining wall deflection

Basic span/effective depth ratio $ratio_{bas} = \mathbf{7}$

Design service stress $f_s = 2 \times f_y \times A_{s_stem_req} / (3 \times A_{s_stem_prov}) = \mathbf{253.2}$ N/mm^2

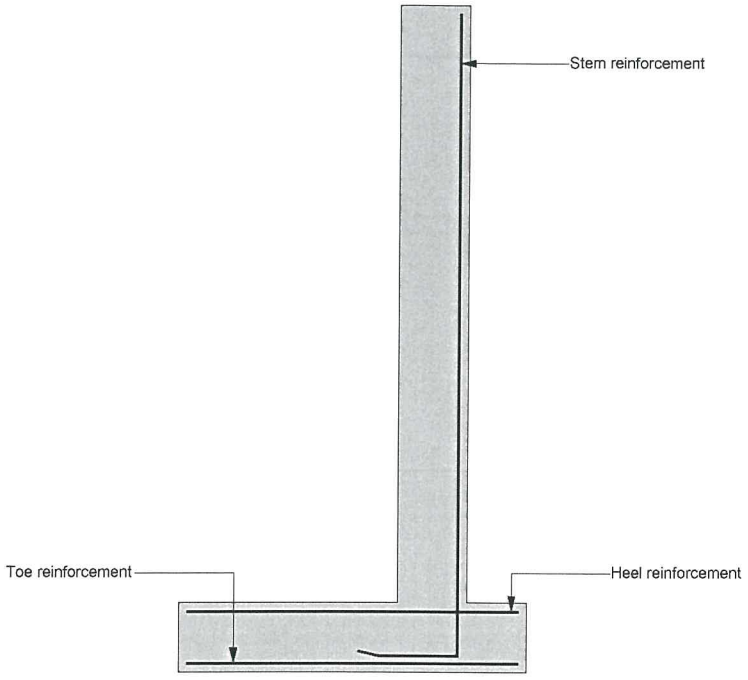
Modification factor $factor_{tens} = \min(0.55 + (477\ \text{N/mm}^2 - f_s)/(120 \times (0.9\ \text{N/mm}^2 + (M_{stem}/(b \times d_{stem}^2)))),2) = \mathbf{1.51}$

Maximum span/effective depth ratio $ratio_{max} = ratio_{bas} \times factor_{tens} = \mathbf{10.56}$

Actual span/effective depth ratio $ratio_{act} = h_{stem} / d_{stem} = \mathbf{9.93}$

PASS - Span to depth ratio is acceptable

Indicative retaining wall reinforcement diagram



Toe bars - 10 mm dia.@ 100 mm centres - (785 mm^2/m)
Heel bars - 10 mm dia.@ 100 mm centres - (785 mm^2/m)
Stem bars - 16 mm dia.@ 200 mm centres - (1005 mm^2/m)