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39a ROSSLYN HILL

APPENDIX G –CALCULATIONS:

- PERMANENT REINFORCED RETAINING WALL CALCULATIONS
- SKETCH PLAN OF CONTIGUOUS WALL AND PROPS
- TEMPORARY WORKS PILED RETAINING WALL ANALYSIS AND OUTLINE CALCULATIONS

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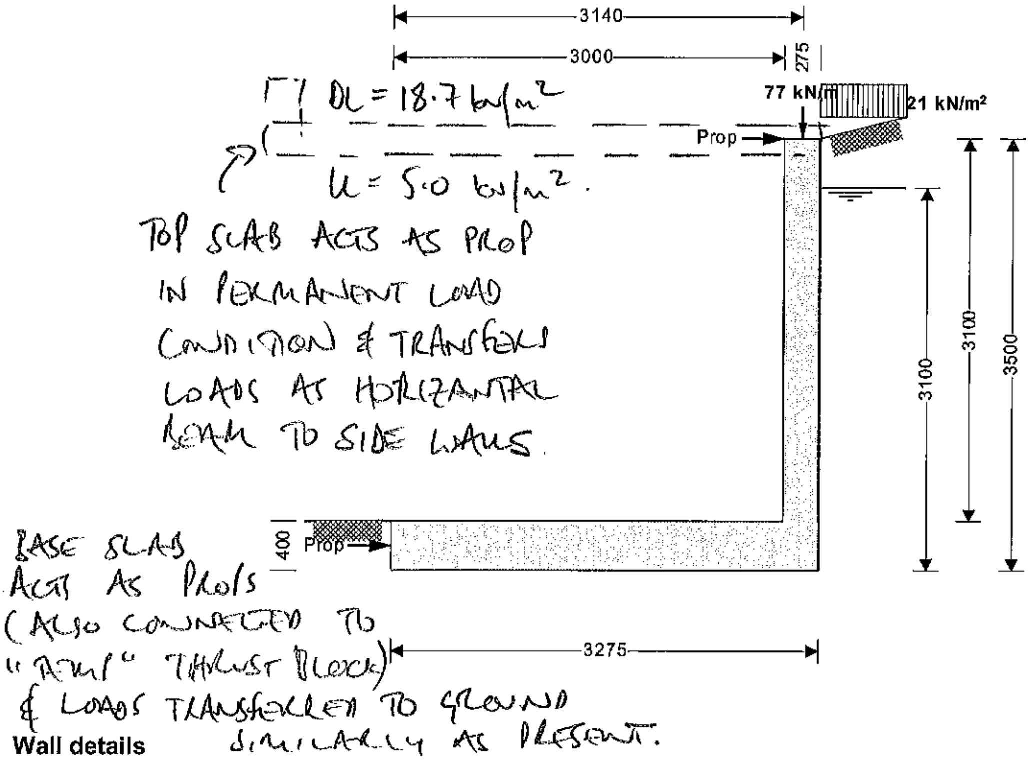
RETAINING WALL ANALYSIS (BS 8002:1994)

TEDDS calculation version 1.2.01.06



Wall details

Retaining wall type	**Cantilever propped at both**
Height of retaining wall stem	h_{stem} = **3100** mm
Thickness of wall stem	t_{wall} = **275** mm
Length of toe	l_{toe} = **3000** mm
Length of heel	l_{heel} = **0** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **3275** mm
Thickness of base	t_{base} = **400** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **900** mm
Thickness of downstand	t_{ds} = **400** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **3500** mm
Depth of cover in front of wall	d_{cover} = **0** mm
Depth of unplanned excavation	d_{exc} = **0** mm
Height of ground water behind wall	h_{water} = **3100** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0\ \text{mm})$ = **2700** mm
Density of wall construction	γ_{wall} = **23.6** kN/m³
Density of base construction	γ_{base} = **23.6** kN/m³
Angle of rear face of wall	α = **90.0** deg
Angle of soil surface behind wall	β = **15.0** deg
Effective height at virtual back of wall	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **3500** mm

Retained material details

Mobilisation factor	M = **1.5**
Moist density of retained material	γ_m = **18.0** kN/m³
Saturated density of retained material	γ_s = **21.0** kN/m³

Design shear strength $\phi' = \mathbf{24.2}$ deg

Angle of wall friction $\delta = \mathbf{18.6}$ deg

Base material details

Firm clay

Moist density $\gamma_{mb} = \mathbf{18.0}$ kN/m^3

Design shear strength $\phi'_b = \mathbf{24.2}$ deg

Design base friction $\delta_b = \mathbf{18.6}$ deg

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

Using Coulomb theory

Active pressure coefficient for retained material

$$K_a = \sin(\alpha + \phi')^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta) \times [1 + \sqrt{(\sin(\phi' + \delta) \times \sin(\phi' - \beta) / (\sin(\alpha - \delta) \times \sin(\alpha + \beta)))}]^2) = \mathbf{0.486}$$

Passive pressure coefficient for base material

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

At-rest pressure

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

Loading details

Surcharge load on plan Surcharge = **20.8** kN/m^2

Applied vertical dead load on wall $W_{dead} = \mathbf{60.0}$ kN/m

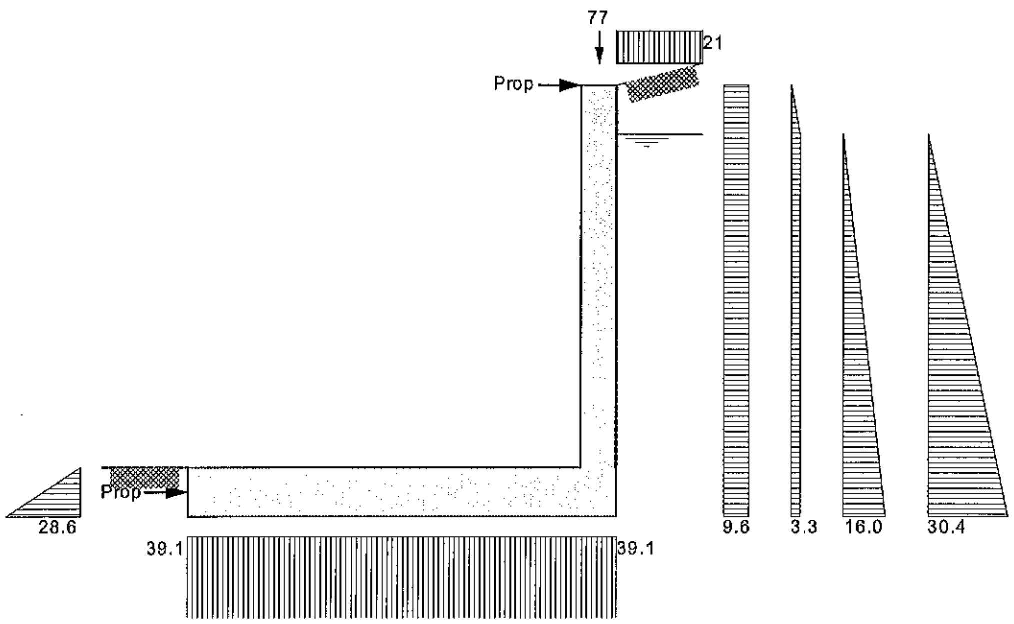
Applied vertical live load on wall $W_{live} = \mathbf{17.0}$ kN/m

Position of applied vertical load on wall $l_{load} = \mathbf{3140}$ mm

Applied horizontal dead load on wall $F_{dead} = \mathbf{0.0}$ kN/m

Applied horizontal live load on wall $F_{live} = \mathbf{0.0}$ kN/m

Height of applied horizontal load on wall $h_{load} = \mathbf{0}$ mm



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

Vertical forces on wall

Wall stem $w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall} = \mathbf{20.1}$ kN/m

Wall base $w_{base} = l_{base} \times t_{base} \times \gamma_{base} = \mathbf{30.9}$ kN/m

Applied vertical load $W_v = W_{dead} + W_{live} = \mathbf{77}$ kN/m

Total vertical load — $W_{total} = w_{wall} + w_{base} + W_v = \mathbf{128}$ kN/m

Horizontal forces on wall

Surcharge — $F_{sur} = K_a \times \cos(90 - \alpha + \delta) \times Surcharge \times h_{eff} = \mathbf{33.5}$ kN/m

Moist backfill above water table — $F_{m\_a} = 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water})^2 = \mathbf{0.7}$ kN/m

Moist backfill below water table — $F_{m\_b} = K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water} = \mathbf{10.3}$ kN/m

Saturated backfill — $F_s = 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times (\gamma_s - \gamma_{water}) \times h_{water}^2 = \mathbf{24.7}$ kN/m

Water — $F_{water} = 0.5 \times h_{water}^2 \times \gamma_{water} = \mathbf{47.1}$ kN/m

Total horizontal load — $F_{total} = F_{sur} + F_{m\_a} + F_{m\_b} + F_s + F_{water} = \mathbf{116.3}$ kN/m

Calculate total propping force

Passive resistance of soil in front of wall — $F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb} = \mathbf{5.7}$ kN/m

Propping force — $F_{prop} = \max(F_{total} - F_p - (W_{total} - W_{live}) \times \tan(\delta_b), 0\ kN/m)$

$F_{prop} = \mathbf{73.2}$ kN/m

Overturning moments

Surcharge — $M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2 = \mathbf{58.6}$ kNm/m

Moist backfill above water table — $M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3 = \mathbf{2.1}$ kNm/m

Moist backfill below water table — $M_{m\_b} = F_{m\_b} \times (h_{water} - 2 \times d_{ds}) / 2 = \mathbf{15.9}$ kNm/m

Saturated backfill — $M_s = F_s \times (h_{water} - 3 \times d_{ds}) / 3 = \mathbf{25.6}$ kNm/m

Water — $M_{water} = F_{water} \times (h_{water} - 3 \times d_{ds}) / 3 = \mathbf{48.7}$ kNm/m

Total overturning moment — $M_{ot} = M_{sur} + M_{m\_a} + M_{m\_b} + M_s + M_{water} = \mathbf{151}$ kNm/m

Restoring moments

Wall stem — $M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2) = \mathbf{63.1}$ kNm/m

Wall base — $M_{base} = w_{base} \times l_{base} / 2 = \mathbf{50.6}$ kNm/m

Design vertical dead load — $M_{dead} = W_{dead} \times l_{load} = \mathbf{188.4}$ kNm/m

Total restoring moment — $M_{rest} = M_{wall} + M_{base} + M_{dead} = \mathbf{302.1}$ kNm/m

Check bearing pressure

Total vertical reaction — $R = W_{total} = \mathbf{128.0}$ kN/m

Distance to reaction — $x_{bar} = l_{base} / 2 = \mathbf{1638}$ mm

Eccentricity of reaction — $e = abs((l_{base} / 2) - x_{bar}) = \mathbf{0}$ mm

Reaction acts within middle third of base

Bearing pressure at toe — $p_{toe} = (R / l_{base}) - (6 \times R \times e / l_{base}^2) = \mathbf{39.1}$ kN/m²

Bearing pressure at heel — $p_{heel} = (R / l_{base}) + (6 \times R \times e / l_{base}^2) = \mathbf{39.1}$ kN/m²

PASS - Maximum bearing pressure is less than allowable bearing pressure

Calculate propping forces to top and base of wall

Propping force to top of wall

$F_{prop\_top} = (M_{ot} - M_{rest} + R \times l_{base} / 2 - F_{prop} \times t_{base} / 2) / (h_{stem} + t_{base} / 2) = \mathbf{13.286}$ kN/m

Propping force to base of wall — $F_{prop\_base} = F_{prop} - F_{prop\_top} = \mathbf{59.960}$ kN/m

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 $w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **28.2** kN/m

Wall base $w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **43.3** kN/m

Applied vertical load $W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live}$ = **111.2** kN/m

Total vertical load $W_{total\_f} = w_{wall\_f} + w_{base\_f} + W_{v\_f}$ = **182.6** kN/m

Factored horizontal at-rest forces on wall

Surcharge $F_{sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times h_{eff}$ = **68.7** kN/m

Moist backfill above water table $F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2$ = **1.2** kN/m

Moist backfill below water table $F_{m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **18.4** kN/m

Saturated backfill $F_{s\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **44.4** kN/m

Water $F_{water\_f} = \gamma_{f\_e} \times 0.5 \times h_{water}^2 \times \gamma_{water}$ = **66** kN/m

Total horizontal load $F_{total\_f} = F_{sur\_f} + F_{m\_a\_f} + F_{m\_b\_f} + F_{s\_f} + F_{water\_f}$ = **198.8** kN/m

Calculate total propping force

Passive resistance of soil in front of wall $F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **8** kN/m

Propping force $F_{prop\_f} = \max(F_{total\_f} - F_{p\_f} - (W_{total\_f} - \gamma_{f\_l} \times W_{live}) \times \tan(\delta_b), 0 \text{ kN/m})$

F_{prop_f} = **138.5** kN/m

Factored overturning moments

Surcharge $M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **120.3** kNm/m

Moist backfill above water table $M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **3.8** kNm/m

Moist backfill below water table $M_{m\_b\_f} = F_{m\_b\_f} \times (h_{water} - 2 \times d_{ds}) / 2$ = **28.6** kNm/m

Saturated backfill $M_{s\_f} = F_{s\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **45.9** kNm/m

Water $M_{water\_f} = F_{water\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **68.2** kNm/m

Total overturning moment $M_{ot\_f} = M_{sur\_f} + M_{m\_a\_f} + M_{m\_b\_f} + M_{s\_f} + M_{water\_f}$ = **266.8** kNm/m

Restoring moments

Wall stem $M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **88.4** kNm/m

Wall base $M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **70.9** kNm/m

Design vertical load $M_{v\_f} = W_{v\_f} \times l_{load}$ = **349.2** kNm/m

Total restoring moment $M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{v\_f}$ = **508.4** kNm/m

Factored bearing pressure

Total vertical reaction $R_f = W_{total\_f}$ = **182.6** kN/m

Distance to reaction $x_{bar\_f} = l_{base} / 2$ = **1638** mm

Eccentricity of reaction $e_f = \text{abs}((l_{base} / 2) - x_{bar\_f})$ = **0** mm

Reaction acts within middle third of base

Bearing pressure at toe $p_{toe\_f} = (R_f / l_{base}) - (6 \times R_f \times e_f / l_{base}^2)$ = **55.8** kN/m²

Bearing pressure at heel $p_{heel\_f} = (R_f / l_{base}) + (6 \times R_f \times e_f / l_{base}^2)$ = **55.8** kN/m²

Rate of change of base reaction rate $= (p_{toe\_f} - p_{heel\_f}) / l_{base}$ = **0.00** kN/m²/m

Bearing pressure at stem / toe $p_{stem\_toe\_f} = \max(p_{toe\_f} - (\text{rate} \times l_{toe}), 0 \text{ kN/m}^2)$ = **55.8** kN/m²

Bearing pressure at mid stem $p_{stem\_mid\_f} = \max(p_{toe\_f} - (\text{rate} \times (l_{toe} + t_{wall} / 2)), 0 \text{ kN/m}^2)$ = **55.8** kN/m²

Bearing pressure at stem / heel $p_{stem\_heel\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall})), 0\ kN/m^2) =$ **55.8** kN/m²

Calculate propping forces to top and base of wall

Propping force to top of wall

$F_{prop\_top\_f} = (M_{ot\_f} - M_{rest\_f} + R_f \times l_{base} / 2 - F_{prop\_f} \times t_{base} / 2) / (h_{stem} + t_{base} / 2) =$ **9.024** kN/m

Propping force to base of wall $F_{prop\_base\_f} = F_{prop\_f} - F_{prop\_top\_f} =$ **129.433** kN/m

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

Material properties

Characteristic strength of concrete $f_{cu} =$ **40** 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 $c_{toe} =$ **75** mm

Calculate shear for toe design

Shear from bearing pressure $V_{toe\_bear} = (p_{toe\_f} + p_{stem\_toe\_f}) \times l_{toe} / 2 =$ **167.3** kN/m

Shear from weight of base $V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base} =$ **39.6** kN/m

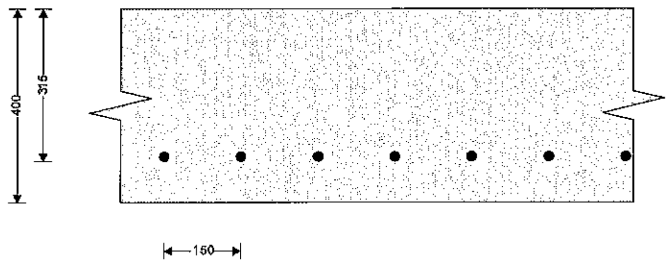
Total shear for toe design $V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base} =$ **127.7** kN/m

Calculate moment for toe design

Moment from bearing pressure $M_{toe\_bear} = (2 \times p_{toe\_f} + p_{stem\_mid\_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6 =$ **274.5** kNm/m

Moment from weight of base $M_{toe\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2) =$ **65** kNm/m

Total moment for toe design $M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base} =$ **209.5** kNm/m



Check toe in bending

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

Depth of reinforcement $d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) =$ **315.0** mm

Constant $K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu}) =$ **0.053**

Compression reinforcement is not required

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

$z_{toe} =$ **295** mm

Area of tension reinforcement required $A_{s\_toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe}) =$ **1631** mm²/m

Minimum area of tension reinforcement $A_{s\_toe\_min} = k \times b \times t_{base} =$ **520** mm²/m

Area of tension reinforcement required $A_{s\_toe\_req} = \max(A_{s\_toe\_des}, A_{s\_toe\_min}) =$ **1631** mm²/m

Reinforcement provided **20 mm dia.bars @ 150 mm centres**

Area of reinforcement provided $A_{s\_toe\_prov} =$ **2094** mm²/m

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress $v_{toe} = V_{toe} / (b \times d_{toe}) =$ **0.405** N/mm²

Allowable shear stress $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1\ N/mm^2)}, 5) \times 1\ N/mm^2 =$ **5.000** 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} = **0.685** N/mm^2

$v_{toe} < v_{c\_toe}$ - No shear reinforcement required

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

Material properties

Characteristic strength of concrete f_{cu} = **40** N/mm^2

Characteristic strength of reinforcement f_y = **500** N/mm^2

Wall details

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

Cover to reinforcement in stem c_{stem} = **30** mm

Cover to reinforcement in wall c_{wall} = **75** mm

Factored horizontal at-rest forces on stem

Surcharge $F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds})$ = **60.9** kN/m

Moist backfill above water table $F_{s\_m\_a\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2$ = **1.2** kN/m

Moist backfill below water table $F_{s\_m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat}) \times h_{sat}$ = **16.1** kN/m

Saturated backfill $F_{s\_s\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{sat}^2$ = **33.7** kN/m

Water $F_{s\_water\_f} = 0.5 \times \gamma_{f\_e} \times \gamma_{water} \times h_{sat}^2$ = **50.1** kN/m

Calculate shear for stem design

Surcharge $V_{s\_sur\_f} = 5 \times F_{s\_sur\_f} / 8$ = **38** kN/m

Moist backfill above water table $V_{s\_m\_a\_f} = F_{s\_m\_a\_f} \times b_l \times ((5 \times L^2) - b_l^2) / (5 \times L^3)$ = **0.1** kN/m

Moist backfill below water table $V_{s\_m\_b\_f} = F_{s\_m\_b\_f} \times (8 - (n^2 \times (4 - n))) / 8$ = **11.2** kN/m

Saturated backfill $V_{s\_s\_f} = F_{s\_s\_f} \times (1 - (a_l^2 \times ((5 \times L) - a_l) / (20 \times L^3)))$ = **28.3** kN/m

Water $V_{s\_water\_f} = F_{s\_water\_f} \times (1 - (a_l^2 \times ((5 \times L) - a_l) / (20 \times L^3)))$ = **42.1** kN/m

Total shear for stem design $V_{stem} = V_{s\_sur\_f} + V_{s\_m\_a\_f} + V_{s\_m\_b\_f} + V_{s\_s\_f} + V_{s\_water\_f}$ = **119.8** kN/m

Calculate moment for stem design

Surcharge $M_{s\_sur} = F_{s\_sur\_f} \times L / 8$ = **25.1** kNm/m

Moist backfill above water table $M_{s\_m\_a} = F_{s\_m\_a\_f} \times b_l \times ((5 \times L^2) - (3 \times b_l^2)) / (15 \times L^2)$ = **0.2** kNm/m

Moist backfill below water table $M_{s\_m\_b} = F_{s\_m\_b\_f} \times a_l \times (2 - n)^2 / 8$ = **7.3** kNm/m

Saturated backfill $M_{s\_s} = F_{s\_s\_f} \times a_l \times ((3 \times a_l^2) - (15 \times a_l \times L) + (20 \times L^2)) / (60 \times L^2)$ = **14.9** kNm/m

Water $M_{s\_water} = F_{s\_water\_f} \times a_l \times ((3 \times a_l^2) - (15 \times a_l \times L) + (20 \times L^2)) / (60 \times L^2)$ = **22.1**
kNm/m

Total moment for stem design $M_{stem} = M_{s\_sur} + M_{s\_m\_a} + M_{s\_m\_b} + M_{s\_s} + M_{s\_water}$ = **69.6** kNm/m

Calculate moment for wall design

Surcharge $M_{w\_sur} = 9 \times F_{s\_sur\_f} \times L / 128$ = **14.1** kNm/m

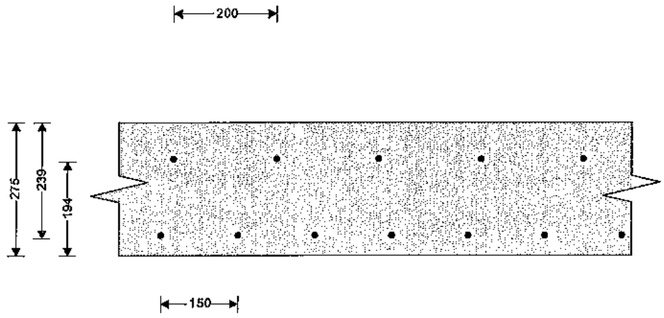
Moist backfill above water table $M_{w\_m\_a} = F_{s\_m\_a\_f} \times 0.577 \times b_l \times [(b_l^3 + 5 \times a_l \times L^2)/(5 \times L^3) - 0.577^2/3]$ = **0.2**
kNm/m

Moist backfill below water table $M_{w\_m\_b} = F_{s\_m\_b\_f} \times a_l \times [((8 - n^2 \times (4-n))^2 / 16) - 4 + n \times (4-n)]/8$ = **4** kNm/m

Saturated backfill $M_{w\_s} = F_{s\_s\_f} \times [a_l^2 \times x \times ((5 \times L) - a_l)/(20 \times L^3) - (x - b_l)^3 / (3 \times a_l^2)]$ = **6.3** kNm/m

Water $M_{w\_water} = F_{s\_water\_f} \times [a_l^2 \times x \times ((5 \times L) - a_l)/(20 \times L^3) - (x - b_l)^3 / (3 \times a_l^2)]$ = **9.3**
kNm/m

Total moment for wall design $M_{wall} = M_{w\_sur} + M_{w\_m\_a} + M_{w\_m\_b} + M_{w\_s} + M_{w\_water}$ = **34** kNm/m



Check wall stem in bending

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

Depth of reinforcement — $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2)$ = **239.0** 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} = **227** mm

Area of tension reinforcement required — $A_{s\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem})$ = **704** mm²/m

Minimum area of tension reinforcement — $A_{s\_stem\_min} = k \times b \times t_{wall}$ = **358** mm²/m

Area of tension reinforcement required — $A_{s\_stem\_req} = \mathrm{Max}(A_{s\_stem\_des}, A_{s\_stem\_min})$ = **704** mm²/m

Reinforcement provided — **12 mm dia.bars @ 150 mm centres**

Area of reinforcement provided — $A_{s\_stem\_prov}$ = **754** mm²/m

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress — $v_{stem} = V_{stem} / (b \times d_{stem})$ = **0.501** N/mm²

Allowable shear stress — $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1 \text{ N/mm}^2)}, 5) \times 1 \text{ N/mm}^2$ = **5.000** 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_stem} = **0.572** N/mm²

$v_{stem} < v_{c\_stem}$ - No shear reinforcement required

Check mid height of wall in bending

Depth of reinforcement — $d_{wall} = t_{wall} - c_{wall} - (\phi_{wall} / 2)$ = **194.0** mm

Constant — $K_{wall} = M_{wall} / (b \times d_{wall}^2 \times f_{cu})$ = **0.023**

Compression reinforcement is not required

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

z_{wall} = **184** mm

Area of tension reinforcement required — $A_{s\_wall\_des} = M_{wall} / (0.87 \times f_y \times z_{wall})$ = **424** mm²/m

Minimum area of tension reinforcement — $A_{s\_wall\_min} = k \times b \times t_{wall}$ = **358** mm²/m

Area of tension reinforcement required — $A_{s\_wall\_req} = \mathrm{Max}(A_{s\_wall\_des}, A_{s\_wall\_min})$ = **424** mm²/m

Reinforcement provided — **12 mm dia.bars @ 200 mm centres**

Area of reinforcement provided — $A_{s\_wall\_prov}$ = **565** mm²/m

PASS - Reinforcement provided to the retaining wall at mid height is adequate

Check retaining wall deflection

Basic span/effective depth ratio — $ratio_{bas}$ = **20**

Design service stress — $f_s = 2 \times f_y \times A_{s\_stem\_req} / (3 \times A_{s\_stem\_prov})$ = **311.4** N/mm²

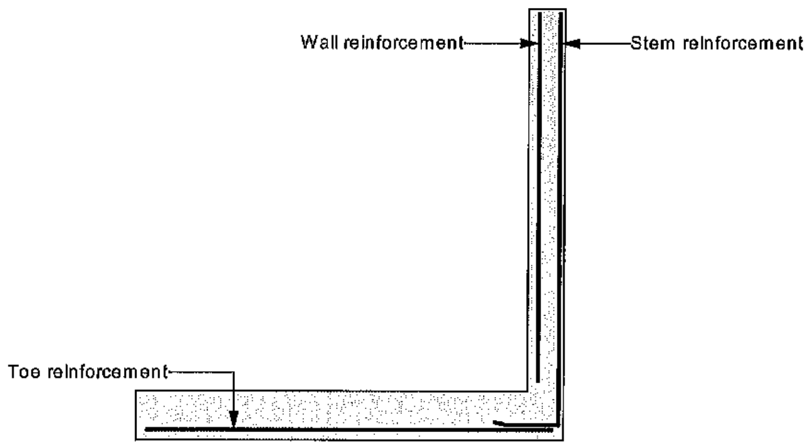
Modification factor — $factor_{tens} = \min(0.55 + (477 \text{ N/mm}^2 - f_s)/(120 \times (0.9 \text{ N/mm}^2 + (M_{stem}/(b \times d_{stem}^2)))), 2)$ = **1.20**

Maximum span/effective depth ratio $ratio_{max} = ratio_{bas} \times factor_{tens}$ = **24.03**

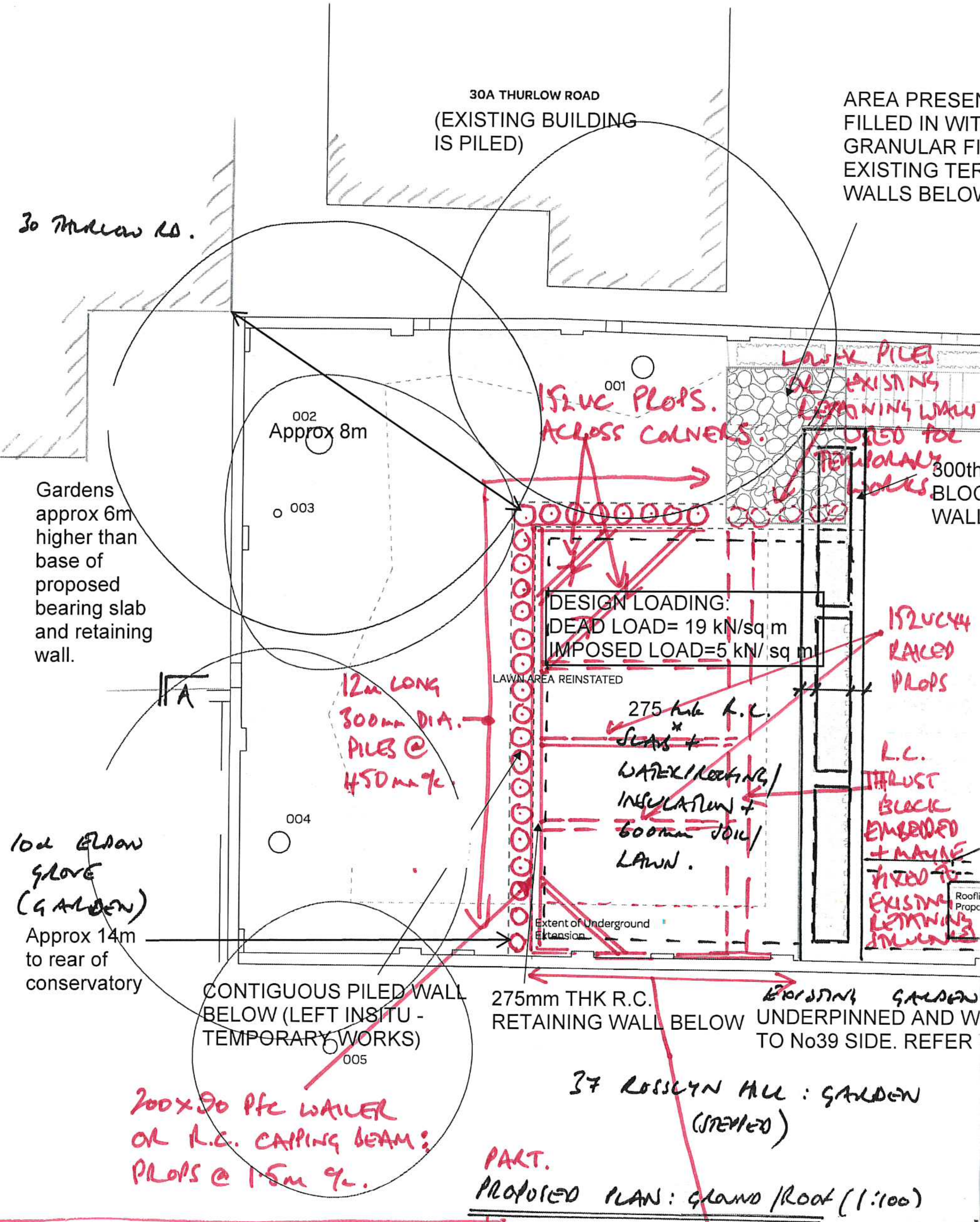
Actual span/effective depth ratio $ratio_{act} = h_{stem} / d_{stem}$ = **12.97**

PASS - Span to depth ratio is acceptable

Indicative retaining wall reinforcement diagram



Toe bars - 20 mm dia.@ 150 mm centres - (2094 mm²/m)
Wall bars - 12 mm dia.@ 200 mm centres - (565 mm²/m)
Stem bars - 12 mm dia.@ 150 mm centres - (754 mm²/m)



MARK-UP TO SHOW SUGGESTED TEMPORARY WORKS PROPPING ARRANGEMENTS: FINAL SEQUENCE, METHODOLOGY & DESIGN BY CONTRACTOR & SPECIALIST SUB-CONTRACTORS.

EXISTING GARDEN WALL UNDERPINNED PRIOR TO REAR WALL FORMATION ∴ MAY BE USED TO PROP AGAINST BETWEEN NEW R.C. & WALERS/CAPPING.

39A ROSSLYN HILL # 140321. SSK007.

TEKLA Tedds Conisbee 1-5 Offord Street London N1 1DH	Project 39a Rosslyn Hill				Job no. 140321	
	Calcs for temp piled wall design - analysis				Start page no./Revision 1	
	Calcs by HH	Calcs date 09/11/2015	Checked by	Checked date	Approved by	Approved date

STEEL SHEET PILING DESIGN

NOTE: ANALYSIS IS ONLY: A CONTIGUOUS PILED WALL IS PROPOSED, NOT A SHEET PILED WALL.

In accordance with BS 8002:1994 - Code of practice for earth retaining structures

Tedds calculation version 1.0.05

Tied wall with free earth support

Geometry

Length of sheet pile for equilibrium (for analysis)	$H = \mathbf{9488}$ mm
Total length of sheet pile provided	$H_{pile} = \mathbf{12000}$ mm
Number of different types of soil	$N_s = \mathbf{2}$
Retained height	$d_{ret} = \mathbf{4300}$ mm
Depth of unplanned excavation	$d_{ex} = \mathbf{0}$ mm
Total retained height	$d_s = d_{ret} + d_{ex} = \mathbf{4300}$ mm
Angle of retained slope	$\beta = \mathbf{19.0}$ deg
Depth from GL to top of water table retained side	$d_w = \mathbf{4300}$ mm
Depth from GL to top of water table retaining side	$d_{wp} = \mathbf{4300}$ mm

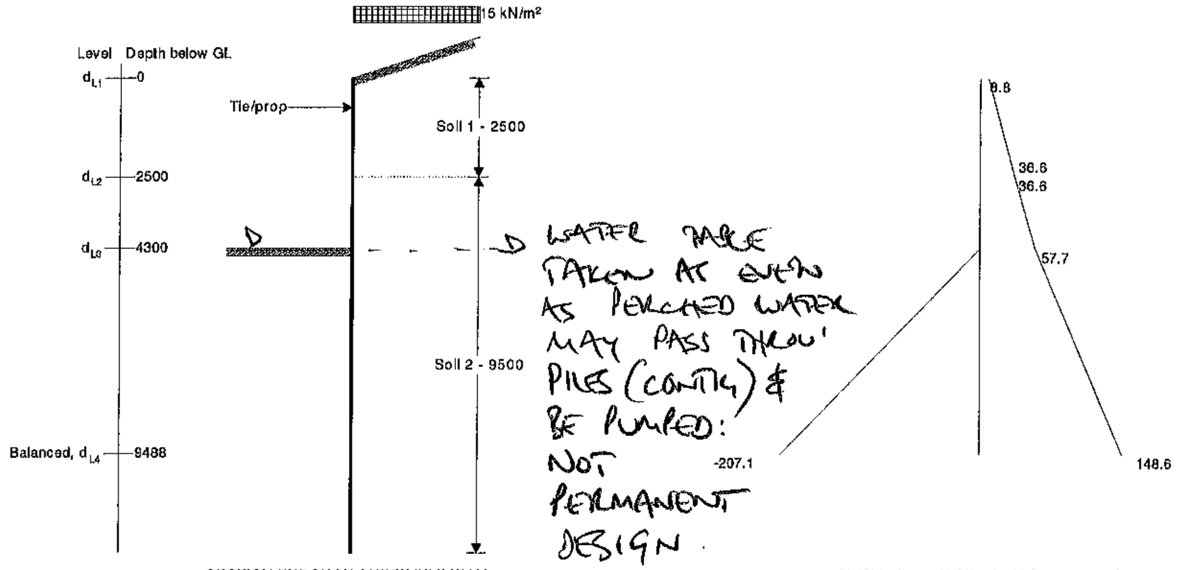
Soil layer 1

Moist density of soil	$\gamma_{m1} = \mathbf{19.0}$ kN/m^3
Dry density of soil	$\gamma_{d1} = \mathbf{12.2}$ kN/m^3
Mobilization factor	$M_{soil} = \mathbf{1.2}$
Design shear strength	$\phi'_1 = \mathbf{23.0}$ deg
Active pressure coefficient	$k_{a1} = \cos(\phi'_1)^2 / (1 + \sqrt{(\sin(\phi'_1) \times \sin(\phi'_1 - \beta) / \cos(\beta))})^2 = \mathbf{0.619}$
Passive pressure coefficient	$k_{p1} = \cos(\phi'_1)^2 / (1 - \sqrt{(\sin(\phi'_1) \times \sin(\phi'_1))})^2 = \mathbf{2.283}$
Height of soil layer 1	$h_1 = \mathbf{2500}$ mm
Depth from GL to bottom of layer1	$d_1 = \mathbf{2500}$ mm

Soil layer 2

Moist density of soil	$\gamma_{m2} = \mathbf{20.0}$ kN/m^3
Dry density of soil	$\gamma_{d2} = \mathbf{13.2}$ kN/m^3
Mobilization factor	$M_{soil} = \mathbf{1.2}$
Design shear strength	$\phi'_2 = \mathbf{23.0}$ deg
Active pressure coefficient	$k_{a2} = \cos(\phi'_2)^2 / (1 + \sqrt{(\sin(\phi'_2) \times \sin(\phi'_2 - \beta) / \cos(\beta))})^2 = \mathbf{0.619}$
Passive pressure coefficient	$k_{p2} = \cos(\phi'_2)^2 / (1 - \sqrt{(\sin(\phi'_2) \times \sin(\phi'_2))})^2 = \mathbf{2.283}$
Height of soil layer 2	$h_2 = \mathbf{6988}$ mm

TEKLA Tedds Conisbee 1-5 Offord Street London N1 1DH	Project 39a Rosslyn Hill				Job no. 140321	
	Calcs for temp piled wall design - analysis				Start page no./Revision 2	
	Calcs by HH	Calcs date 09/11/2015	Checked by	Checked date	Approved by	Approved date



SECTION THROUGH SHEET PILE WALL

BALANCED PRESSURE DIAGRAM (kN/m²)

Overburden on active side

Overburden at 0 mm below GL in soil 1 — $OB_{a11} = Q = \mathbf{15.0}$ kN/m²

Overburden at 2500 mm below GL in soil 1 — $OB_{a21} = \gamma_{m1} \times h_{a1} + OB_{a11} = \mathbf{62.5}$ kN/m²

Overburden at 2500 mm below GL in soil 2 — $OB_{a22} = \gamma_{m1} \times h_{a1} + OB_{a11} = \mathbf{62.5}$ kN/m²

Overburden at 4300 mm below GL in soil 2 — $OB_{a31} = \gamma_{m2} \times h_{a2} + OB_{a22} = \mathbf{98.5}$ kN/m²

Overburden at 9488 mm below GL in soil 2 — $OB_{a41} = \gamma_{d2} \times h_{a3} + OB_{a31} = \mathbf{166.9}$ kN/m²

Overburden on passive side

Overburden at 4300 mm below GL in soil 2 — $OB_{p31} = 0$ kN/m² $= \mathbf{0.0}$ kN/m²

Overburden at 9488 mm below GL in soil 2 — $OB_{p41} = \gamma_{d2} \times h_{p3} + OB_{p31} = \mathbf{68.4}$ kN/m²

Pressure on active side

Active pressure at 0 mm below GL in soil 1 — $p_{a11} = k_{a1} \times OB_{a11} \times \cos(\beta) = \mathbf{8.8}$ kN/m²

Active pressure at 2500 mm below GL in soil 1 — $p_{a21} = k_{a1} \times OB_{a21} \times \cos(\beta) = \mathbf{36.6}$ kN/m²

Active pressure at 2500 mm below GL in soil 2 — $p_{a22} = k_{a2} \times OB_{a22} \times \cos(\beta) = \mathbf{36.6}$ kN/m²

Active pressure at 4300 mm below GL in soil 2 — $p_{a31} = k_{a2} \times OB_{a31} \times \cos(\beta) = \mathbf{57.7}$ kN/m²

Active pressure at 9488 mm below GL in soil 2 — $p_{a41} = k_{a2} \times OB_{a41} \times \cos(\beta) + \gamma_w \times (d_{L4} - d_w) = \mathbf{148.6}$ kN/m²

Pressure on passive side

Passive pressure at 4300 mm below GL in soil 2 — $p_{p31} = k_{p2} \times OB_{p31} = \mathbf{0.0}$ kN/m²

Passive pressure at 9488 mm below GL in soil 2 — $p_{p41} = k_{p2} \times OB_{p41} + \gamma_w \times (d_{L4} - \max(d_s, d_w)) = \mathbf{207.1}$ kN/m²

Active forces

Active force at level 1 — $F_{a11} = 0.5 \times p_{a11} \times h_{a1} = \mathbf{11.0}$ kN/m

Active force at level 1 — $F_{a12} = 0.5 \times p_{a21} \times h_{a1} = \mathbf{45.7}$ kN/m

Active force at level 2 — $F_{a21} = 0.5 \times p_{a22} \times h_{a2} = \mathbf{32.9}$ kN/m

Active force at level 2 — $F_{a22} = 0.5 \times p_{a31} \times h_{a2} = \mathbf{51.9}$ kN/m

Active force at level 3 — $F_{a31} = 0.5 \times p_{a31} \times h_{a3} = \mathbf{149.6}$ kN/m

Active force at level 3 — $F_{a32} = 0.5 \times p_{a41} \times h_{a3} = \mathbf{385.5}$ kN/m

Passive forces

Passive force at level 3 — $F_{p31} = 0.5 \times p_{p31} \times h_{p3} = \mathbf{0.0}$ kN/m

TEKLA Tedds Conisbee 1-5 Offord Street London N1 1DH	Project 39a Rosslyn Hill				Job no. 140321	
	Calcs for temp piled wall design - analysis				Start page no./Revision 3	
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Passive force at level 3 $F_{p32} = 0.5 \times p_{p41} \times h_{p3} = \mathbf{537.2}$ kN/m

Total forces in tie

Total active forces $\Sigma F_a = \mathbf{676.7}$ kN/m

Total passive forces $\Sigma F_p = \mathbf{537.2}$ kN/m

Active moments about tie

Moment about tie level 1 $M_{a11} = 0.5 \times p_{a11} \times h_{a1} \times [(d_{L2} - d_t) - 2/3 \times h_{a1}] = \mathbf{0.9}$ kNm/m

Moment about tie level 1 $M_{a12} = 0.5 \times p_{a21} \times h_{a1} \times [(d_{L2} - d_t) - 1/3 \times h_{a1}] = \mathbf{41.9}$ kNm/m

Moment about tie level 2 $M_{a21} = 0.5 \times p_{a22} \times h_{a2} \times [(d_{L3} - d_t) - 2/3 \times h_{a2}] = \mathbf{77.4}$ kNm/m

Moment about tie level 2 $M_{a22} = 0.5 \times p_{a31} \times h_{a2} \times [(d_{L3} - d_t) - 1/3 \times h_{a2}] = \mathbf{153.1}$ kNm/m

Moment about tie level 3 $M_{a31} = 0.5 \times p_{a31} \times h_{a3} \times [(d_{L4} - d_t) - 2/3 \times h_{a3}] = \mathbf{789.8}$ kNm/m

Moment about tie level 3 $M_{a32} = 0.5 \times p_{a41} \times h_{a3} \times [(d_{L4} - d_t) - 1/3 \times h_{a3}] = \mathbf{2702.1}$ kNm/m

Passive moments about tie

Moment about tie level 3 $M_{p31} = 0.5 \times p_{p31} \times h_{p3} \times [(d_{L4} - d_t) - 2/3 \times h_{p3}] = \mathbf{0.0}$ kNm/m

Moment about tie level 3 $M_{p32} = 0.5 \times p_{p41} \times h_{p3} \times [(d_{L4} - d_t) - 1/3 \times h_{p3}] = \mathbf{3765.1}$ kNm/m

Total moments about tie

Total active moment $\Sigma M_a = \mathbf{3765.2}$ kNm/m

Total passive moment $\Sigma M_p = \mathbf{3765.1}$ kNm/m

Required pile length

Length of pile required to balance moments $H_{total} = \mathbf{9488}$ mm

Pass - Provided length of sheet pile greater than minimum required length of pile

Required section modulus

Maximum moment in pile (from analysis) $M_{pile} = \max(ABS(M_{min}), ABS(M_{max})) = \mathbf{265.9}$ kNm → DESIGN OF CONTIG PILE.

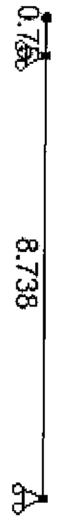
Permissible stress of pile ~~$\sigma_{pile} = 270$ N/mm²~~ N/A

Material factor $\gamma_{ms} = \mathbf{1.2}$

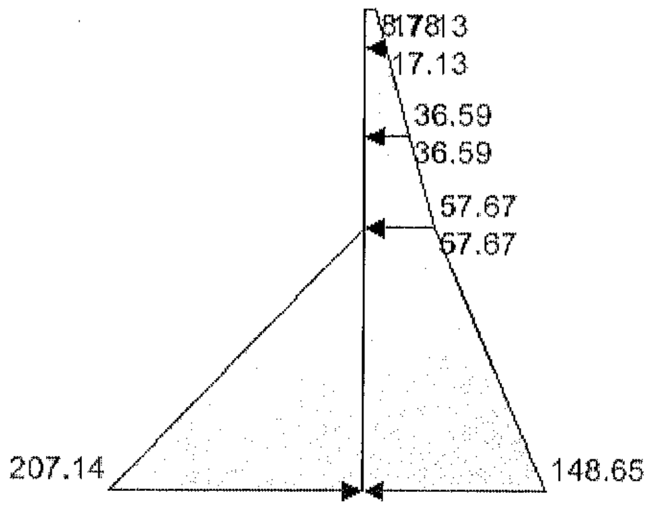
Min req'd plastic section modulus (per metre run) $Z = \gamma_{ms} \times M_{pile} / \sigma_{pile} = \mathbf{1182}$ cm³

Load in tie/strut

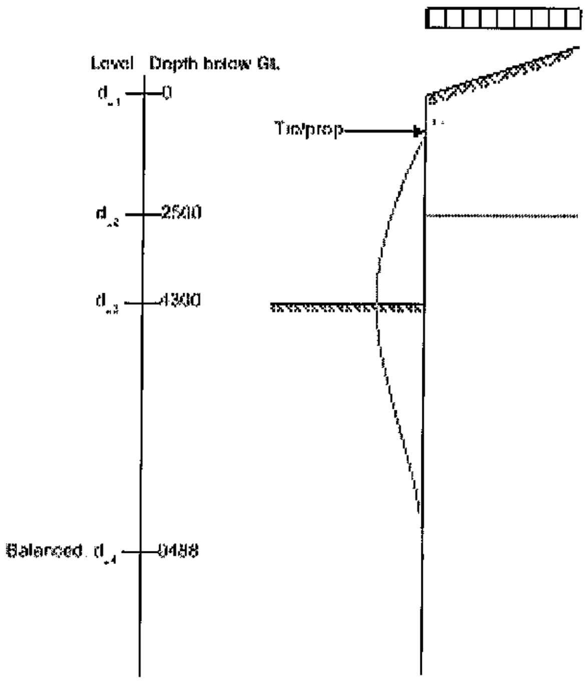
Tie/strut load $T = \Sigma F_a - \Sigma F_p = \mathbf{139.5}$kN/m



Analysis model



Analysis loading diagram



Bending moment diagram

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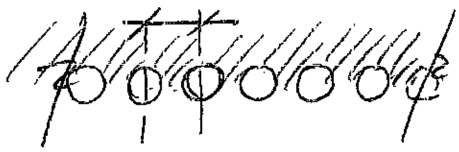
project	job no.
39 A ROSSLYN HILL	140321
title	sheet no.
CONTIGUOUS PILED WALL DESIGN	date NOV '15 · engineer [initials] · checked

rev.	date	

CONTIGUOUS PILED WALL

450 mm c/c



300 mm ϕ PILES @ 450 mm c/c

a) DESIGN OF PILE (FINAL DESIGN BY SPECIALIST SUB-CONTRACTOR)

MOMENT = 266 kNm / m.

∴ PER PILE = 266 × 0.45 = 120 kNm

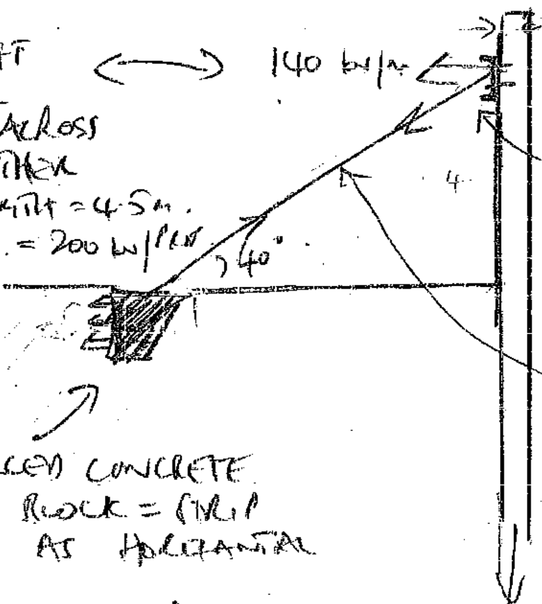
DESIGN PILE AS PER 300 ϕ COLUMN

→ OK 8 No H25 BARS, REFER TO SPREADSHEET

SEE ATTACHED

b) PROPPING

300 ϕ PILES (8H25)



PILES AT CORNER PROPPED ACROSS EACH OTHER
MAX. LENGTH = 4.5 m.
@ 1.5 m c/c = 200 kN / PROP
152 UC 23
CAPACITY = 236 kN
OK

200 × 90 PFC 'WALER' ANCHORED TO PILES (OR CAPPING BEAM ARMED: CONTRACTORS PREFERENCE)

190 kN/m × 1.5 m = 275 kN / PROP @ 1.5 m c/c.
→ 152 × 152 × 44 UC
(CAP = 284 kN @ Le = 7 m)

REINFORCED CONCRETE THRUST BLOCK = STRIP ∴ ACTS AS HORIZONTAL BEAM

12 m LONG (TOTAL)

APPROX 1 m × 1 m R.C. EMBEDDED BEAM TO SPREAD LOADS TO ACCEPTABLE PASSIVE EARTH PRESSURES.

∴ CORNER PROPS = 152 × 152 × 23 UC
RAKING PROPS = 152 × 152 × 44 UC

OR SLIMSHORS @ CLOSER C/C : FINAL TO CONTRACTORS' DESIGN.

Project	Spreadsheets to BS 8110	**The Concrete Centre**			
Client	Advisory Group	Made by	Date	Page
Location	Columns at A1, A2 etc	HH	10-Nov-15	124
	COLUMN CHART FOR CIRCULAR COLUMNS TO BS 8110:2005	Checked	Revision	Job No
	Originated from 'RCC54.xls' v3.1 on CD © 2006 TCC	chg	-	0

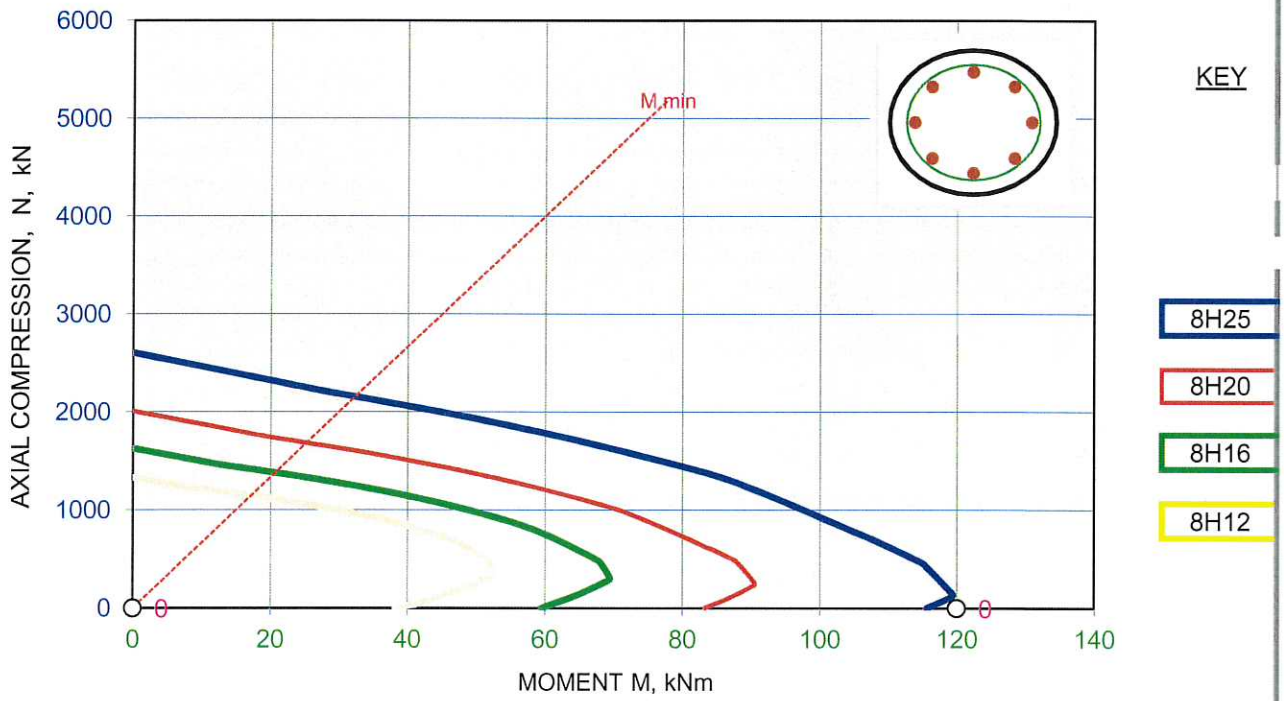
MATERIALS

fcu	30	N/mm²	γm	1.15	steel	Cover	30	mm
fy	500	N/mm²	γm	1.5	concrete	h agg	20	mm
steel class	A							
SECTION l	300	mm	with	8	bars			

BAR ARRANGEMENTS

Type	Bar Ø	Asc %	Link Ø	Bar c/c	Nbal (kN)	Nuz (kN)	Checks
H	40	14.22	10	70.7			Asc > 6 %
H	32	9.10	8	75.4			Asc > 6 %
H	25	5.56	8	78.1	123	2602	ok
H	20	3.56	6	81.7	256	2006	ok
H	16	2.28	6	83.3	307	1625	ok
H	12	1.28	6	84.8	347	1328	ok

N:M INTERACTION CHART for 300 diameter column, grade C30, 30 mm cover and 8 bars



LOADCASES

Load case	N (kN)	M (kNm)		Load case	N (kN)	M (kNm)	
1	0	120	No Fit	4	0	0	No Fit
2	0	0	No Fit	5	0	0	No Fit
3	0	0	No Fit	6	0	0	No Fit