Project name:

South Lodge

Project number: 2170605

Sheet:

Revision:

Date:

Engineer:

Checked:

elliottwood

Retaining Wall Design Calculation

- → 350mm RC Retaining wall
- → 350mm toe dowelled into slab
- → Proped top + bottom in temporary case
- → New ground floor slab props top
- → Ground retained across full height
- → Design input from site investigation
- → Line load acting upon stem from new RC ground slab

  DL = 70 kN/m

  LL = 10 kN/m

- → At rest pressure coefficient applied to soil

SEE TEDDS CALCULATION OVERLEAF

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RETAINING WALL ANALYSIS

In accordance with EN1997-1:2004 incorporating Corrigendum dated February 2009 and the UK National Annex incorporating Corrigendum No.1

Tedds calculation version 2.9.00

Retaining wall details

Stem type	Propped cantilever
Stem height	h_{stem} = **3300** mm
Prop height	h_{prop} = **3300** mm
Stem thickness	t_{stem} = **350** mm
Angle to rear face of stem	α = **90** deg
Stem density	γ_{stem} = **25** kN/m^3
Toe length	l_{toe} = **1500** mm
Base thickness	t_{base} = **350** mm
Base density	γ_{base} = **25** kN/m^3
Height of retained soil	h_{ret} = **3300** mm
Angle of soil surface	β = **0** deg
Depth of cover	d_{cover} = **0** mm

Retained soil properties

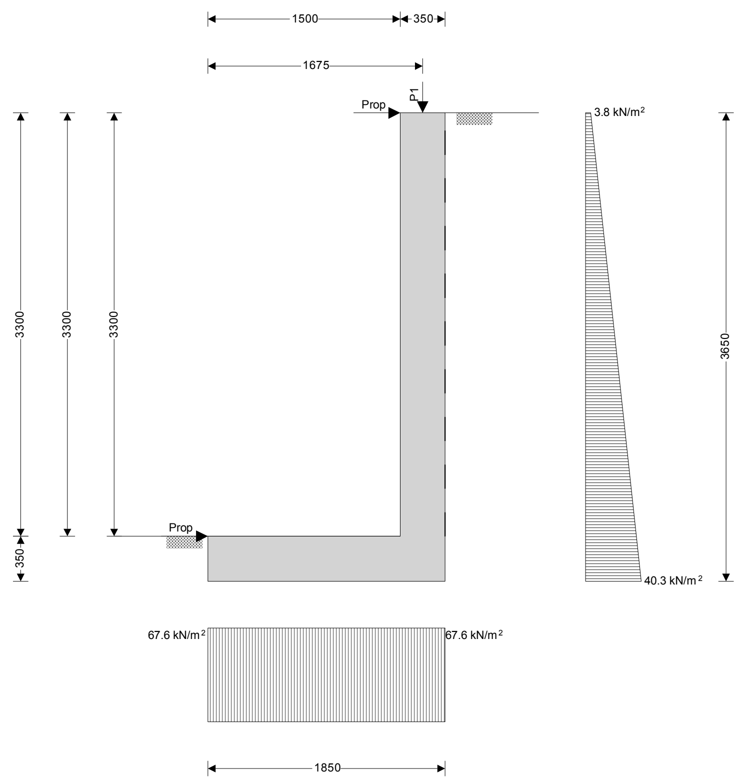
Moist density	γ_{mr} = **20** kN/m^3
Saturated density	γ_{sr} = **22.3** kN/m^3

Base soil properties

Soil type	Medium dense well graded sand and gravel
Soil density	γ_b = **20** kN/m^3
Presumed bearing capacity	$P_{bearing}$ = **90** kN/m^2

Loading details

Permanent surcharge load	$Surcharge_G$ = **2.5** kN/m^2
Variable surcharge load	$Surcharge_Q$ = **5** kN/m^2
Vertical line load at 1675 mm	P_{G1} = **70** kN/m
	P_{Q1} = **10** kN/m



General arrangement

Calculate retaining wall geometry

Base length	$l_{base} = l_{toe} + t_{stem}$ = **1850** mm
Moist soil height	$h_{moist} = h_{soil}$ = **3300** mm
Length of surcharge load	$l_{sur} = l_{heel}$ = **0** mm
- Distance to vertical component	$x_{sur\_v} = l_{base} - l_{heel} / 2$ = **1850** mm
Effective height of wall	$h_{eff} = h_{base} + d_{cover} + h_{ret}$ = **3650** mm
- Distance to horizontal component	$x_{sur\_h} = h_{eff} / 2$ = **1825** mm
Area of wall stem	$A_{stem} = h_{stem} \times t_{stem}$ = **1.155** m^2
- Distance to vertical component	$x_{stem} = l_{toe} + t_{stem} / 2$ = **1675** mm
Area of wall base	$A_{base} = l_{base} \times t_{base}$ = **0.648** m^2
- Distance to vertical component	$x_{base} = l_{base} / 2$ = **925** mm

Soil coefficients

Coefficient of friction to back of wall	K_{fr} = **0.325**
Coefficient of friction to front of wall	K_{fb} = **0.325**
Coefficient of friction beneath base	K_{fbb} = **0.325**
At rest pressure coefficient	K_0 = **0.500**
Passive pressure coefficient	K_P = **4.977**

Bearing pressure check

Vertical forces on wall

Wall stem	$F_{stem} = A_{stem} \times \gamma_{stem}$ = **28.9** kN/m
Wall base	$F_{base} = A_{base} \times \gamma_{base}$ = **16.2** kN/m

Line loads $F_{P\_v} = P_{G1} + P_{Q1} =$ **80** kN/m

Total $F_{total\_v} = F_{stem} + F_{base} + F_{P\_v} =$ **125.1** kN/m

Horizontal forces on wall

Surcharge load $F_{sur\_h} = K_0 \times (Surcharge_G + Surcharge_Q) \times h_{eff} =$ **13.7** kN/m

Moist retained soil $F_{moist\_h} = K_0 \times \gamma_{mr}' \times h_{eff}^2 / 2 =$ **66.6** kN/m

Base soil $F_{pass\_h} = -K_P \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2 =$ **-6.1** kN/m

Total $F_{total\_h} = F_{moist\_h} + F_{pass\_h} + F_{sur\_h} =$ **74.2** kN/m

Moments on wall

Wall stem $M_{stem} = F_{stem} \times x_{stem} =$ **48.4** kNm/m

Wall base $M_{base} = F_{base} \times x_{base} =$ **15** kNm/m

Surcharge load $M_{sur} = -F_{sur\_h} \times x_{sur\_h} =$ **-25** kNm/m

Line loads $M_P = (P_{G1} + P_{Q1}) \times p_1 =$ **134** kNm/m

Moist retained soil $M_{moist} = -F_{moist\_h} \times x_{moist\_h} =$ **-81** kNm/m

Total $M_{total} = M_{stem} + M_{base} + M_{moist} + M_{sur} + M_P =$ **91.3** kNm/m

Check bearing pressure

Propping force to stem $F_{prop\_stem} = (F_{total\_v} \times l_{base} / 2 - M_{total}) / (h_{prop} + t_{base}) =$ **6.7** kN/m

Propping force to base $F_{prop\_base} = F_{total\_h} - F_{prop\_stem} =$ **67.5** kN/m

Moment from propping force $M_{prop} = F_{prop\_stem} \times (h_{prop} + t_{base}) =$ **24.4** kNm/m

Distance to reaction $\bar{x} = (M_{total} + M_{prop}) / F_{total\_v} =$ **925** mm

Eccentricity of reaction $e = \bar{x} - l_{base} / 2 =$ **0** mm

Loaded length of base $l_{load} = l_{base} =$ **1850** mm

Bearing pressure at toe $q_{toe} = F_{total\_v} / l_{base} \times (1 - 6 \times e / l_{base}) =$ **67.6** kN/m²

Bearing pressure at heel $q_{heel} = F_{total\_v} / l_{base} \times (1 + 6 \times e / l_{base}) =$ **67.6** kN/m²

Factor of safety $FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel}) =$ **1.331**

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

RETAINING WALL DESIGN

In accordance with EN1992-1-1:2004 incorporating Corrigendum dated January 2008 and the UK National Annex incorporating National Amendment No.1

Tedds calculation version 2.9.00

Concrete details - Table 3.1 - Strength and deformation characteristics for concrete

Concrete strength class C32/40

Characteristic compressive cylinder strength $f_{ck} =$ **32** N/mm²

Characteristic compressive cube strength $f_{ck,cube} =$ **40** N/mm²

Mean value of compressive cylinder strength $f_{cm} = f_{ck} + 8$ N/mm² $=$ **40** N/mm²

Mean value of axial tensile strength $f_{ctm} = 0.3 \text{ N/mm}^2 \times (f_{ck} / 1 \text{ N/mm}^2)^{2/3} =$ **3.0** N/mm²

5% fractile of axial tensile strength $f_{ctk,0.05} = 0.7 \times f_{ctm} =$ **2.1** N/mm²

Secant modulus of elasticity of concrete $E_{cm} = 22 \text{ kN/mm}^2 \times (f_{cm} / 10 \text{ N/mm}^2)^{0.3} =$ **33346** N/mm²

Partial factor for concrete - Table 2.1N $\gamma_C =$ **1.50**

Compressive strength coefficient - cl.3.1.6(1) $\alpha_{cc} =$ **0.85**

Design compressive concrete strength - exp.3.15 $f_{cd} = \alpha_{cc} \times f_{ck} / \gamma_C =$ **18.1** N/mm²

Maximum aggregate size $h_{agg} =$ **20** mm

Reinforcement details

Characteristic yield strength of reinforcement $f_{yk} =$ **500** N/mm²

Modulus of elasticity of reinforcement $E_s =$ **200000** N/mm²

Partial factor for reinforcing steel - Table 2.1N γ_S = **1.15**

Design yield strength of reinforcement $f_{yd} = f_{yk} / \gamma_S$ = **435** N/mm^2

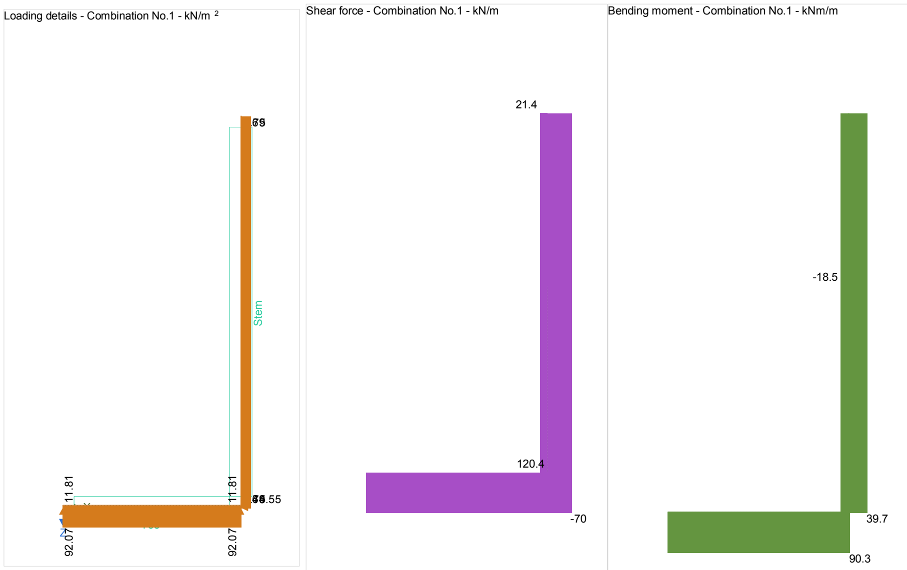
Cover to reinforcement

Front face of stem c_{sf} = **40** mm

Rear face of stem c_{sr} = **50** mm

Top face of base c_{bt} = **50** mm

Bottom face of base c_{bb} = **75** mm



Check stem design at 1876 mm

Depth of section h = **350** mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 1 M = **18.5** kNm/m

Depth to tension reinforcement $d = h - c_{sf} - \phi_{sx} - \phi_{sfM} / 2$ = **292** mm

$K = M / (d^2 \times f_{ck})$ = **0.007**

K' = **0.207**

K' > K - No compression reinforcement is required

Lever arm $z = \min(0.5 + 0.5 \times (1 - 3.53 \times K)^{0.5}, 0.95) \times d$ = **277** mm

Depth of neutral axis $x = 2.5 \times (d – z)$ = **37** mm

Area of tension reinforcement required $A_{sfM.req} = M / (f_{yd} \times z)$ = **153** mm^2/m

Tension reinforcement provided 12 dia.bars @ 200 c/c

Area of tension reinforcement provided $A_{sfM.prov} = \pi \times \phi_{sfM}^2 / (4 \times s_{sfM})$ = **565** mm^2/m

Minimum area of reinforcement - exp.9.1N $A_{sfM.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d$ = **459** mm^2/m

Maximum area of reinforcement - cl.9.2.1.1(3) $A_{sfM.max} = 0.04 \times h$ = **14000** mm^2/m

$\max(A_{sfM.req}, A_{sfM.min}) / A_{sfM.prov}$ = **0.812**

PASS - Area of reinforcement provided is greater than area of reinforcement required

Deflection control - Section 7.4

Reference reinforcement ratio $\rho_0 = \sqrt{}(f_{ck} / 1 \text{ N/mm}^2) / 1000$ = **0.006**

Required tension reinforcement ratio $\rho = A_{sfM.req} / d$ = **0.001**

Required compression reinforcement ratio $\rho' = A_{sfM.2.req} / d_2$ = **0.000**

Structural system factor - Table 7.4N $K_b = \mathbf{1}$

Reinforcement factor - exp.7.17 $K_s = \min(500\ N/mm^2 / (f_{yk} \times A_{sfM.req} / A_{sfM.prov}), 1.5) = \mathbf{1.5}$

Limiting span to depth ratio - exp.7.16.a $K_s \times K_b \times [11 + 1.5 \times \sqrt{(f_{ck} / 1\ N/mm^2)} \times \rho_0 / \rho + 3.2 \times \sqrt{(f_{ck} / 1\ N/mm^2)} \times (\rho_0 / \rho - 1)^{3/2}] = \mathbf{982}$

Actual span to depth ratio $h_{prop} / d = \mathbf{11.3}$

PASS - Span to depth ratio is less than deflection control limit

Check stem design at base of stem

Depth of section $h = \mathbf{350}$ mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 1 $M = \mathbf{39.7}$ kNm/m

Depth to tension reinforcement $d = h - c_{sr} - \phi_{sr} / 2 = \mathbf{294}$ mm

$K = M / (d^2 \times f_{ck}) = \mathbf{0.014}$

$K' = \mathbf{0.207}$

K' > K - No compression reinforcement is required

Lever arm $z = \min(0.5 + 0.5 \times (1 - 3.53 \times K)^{0.5}, 0.95) \times d = \mathbf{279}$ mm

Depth of neutral axis $x = 2.5 \times (d - z) = \mathbf{37}$ mm

Area of tension reinforcement required $A_{sr.req} = M / (f_{yd} \times z) = \mathbf{327}$ mm²/m

Tension reinforcement provided 12 dia.bars @ 200 c/c

Area of tension reinforcement provided $A_{sr.prov} = \pi \times \phi_{sr}^2 / (4 \times s_{sr}) = \mathbf{565}$ mm²/m

Minimum area of reinforcement - exp.9.1N $A_{sr.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = \mathbf{462}$ mm²/m

Maximum area of reinforcement - cl.9.2.1.1(3) $A_{sr.max} = 0.04 \times h = \mathbf{14000}$ mm²/m

$\max(A_{sr.req}, A_{sr.min}) / A_{sr.prov} = \mathbf{0.817}$

PASS - Area of reinforcement provided is greater than area of reinforcement required

Deflection control - Section 7.4

Reference reinforcement ratio $\rho_0 = \sqrt{(f_{ck} / 1\ N/mm^2)} / 1000 = \mathbf{0.006}$

Required tension reinforcement ratio $\rho = A_{sr.req} / d = \mathbf{0.001}$

Required compression reinforcement ratio $\rho' = A_{sr.2.req} / d_2 = \mathbf{0.000}$

Structural system factor - Table 7.4N $K_b = \mathbf{1}$

Reinforcement factor - exp.7.17 $K_s = \min(500\ N/mm^2 / (f_{yk} \times A_{sr.req} / A_{sr.prov}), 1.5) = \mathbf{1.5}$

Limiting span to depth ratio - exp.7.16.a $K_s \times K_b \times [11 + 1.5 \times \sqrt{(f_{ck} / 1\ N/mm^2)} \times \rho_0 / \rho + 3.2 \times \sqrt{(f_{ck} / 1\ N/mm^2)} \times (\rho_0 / \rho - 1)^{3/2}] = \mathbf{305.1}$

Actual span to depth ratio $h_{prop} / d = \mathbf{11.2}$

PASS - Span to depth ratio is less than deflection control limit

Rectangular section in shear - Section 6.2

Design shear force $V = \mathbf{70}$ kN/m

$C_{Rd.c} = 0.18 / \gamma_C = \mathbf{0.120}$

$k = \min(1 + \sqrt{(200\ mm / d)}, 2) = \mathbf{1.825}$

Longitudinal reinforcement ratio $\rho_l = \min(A_{sr.prov} / d, 0.02) = \mathbf{0.002}$

$v_{min} = 0.035\ N^{1/2}/mm \times k^{3/2} \times f_{ck}^{0.5} = \mathbf{0.488}\ N/mm^2$

Design shear resistance - exp.6.2a & 6.2b $V_{Rd.c} = \max(C_{Rd.c} \times k \times (100\ N^2/mm^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$

$V_{Rd.c} = \mathbf{143.5}$ kN/m

$V / V_{Rd.c} = \mathbf{0.488}$

PASS - Design shear resistance exceeds design shear force

Check stem design at prop

Depth of section $h = \mathbf{350}$ mm

Rectangular section in shear - Section 6.2

Design shear force $V = \mathbf{21.4}$ kN/m

$C_{Rd.c} = 0.18 / \gamma_C = \mathbf{0.120}$

$k = \min(1 + \sqrt{(200\ mm / d)}, 2) = \mathbf{1.825}$

Longitudinal reinforcement ratio $\rho_l = \min(A_{sr1.prov} / d, 0.02) = \mathbf{0.002}$

$v_{min} = 0.035\ N^{1/2}/mm \times k^{3/2} \times f_{ck}^{0.5} = \mathbf{0.488}\ N/mm^2$

Design shear resistance - exp.6.2a & 6.2b $V_{Rd.c} = \max(C_{Rd.c} \times k \times (100\ N^2/mm^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$

$V_{Rd.c} = \mathbf{143.5}$ kN/m

$V / V_{Rd.c} = \mathbf{0.149}$

PASS - Design shear resistance exceeds design shear force

Horizontal reinforcement parallel to face of stem - Section 9.6

Minimum area of reinforcement – cl.9.6.3(1) $A_{sx.req} = \max(0.25 \times A_{sr.prov}, 0.001 \times t_{stem}) = \mathbf{350}\ mm^2/m$

Maximum spacing of reinforcement – cl.9.6.3(2) $s_{sx\_max} = \mathbf{400}$ mm

Transverse reinforcement provided 12 dia.bars @ 200 c/c

Area of transverse reinforcement provided $A_{sx.prov} = \pi \times \phi_{sx}^2 / (4 \times s_{sx}) = \mathbf{565}\ mm^2/m$

PASS - Area of reinforcement provided is greater than area of reinforcement required

Check base design at toe

Depth of section $h = \mathbf{350}$ mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 1 $M = \mathbf{90.3}$ kNm/m

Depth to tension reinforcement $d = h - c_{bb} - \phi_{bb} / 2 = \mathbf{267}$ mm

$K = M / (d^2 \times f_{ck}) = \mathbf{0.040}$

$K' = \mathbf{0.207}$

K' > K - No compression reinforcement is required

Lever arm $z = \min(0.5 + 0.5 \times (1 - 3.53 \times K)^{0.5}, 0.95) \times d = \mathbf{254}$ mm

Depth of neutral axis $x = 2.5 \times (d - z) = \mathbf{33}$ mm

Area of tension reinforcement required $A_{bb.req} = M / (f_{yd} \times z) = \mathbf{819}\ mm^2/m$

Tension reinforcement provided 16 dia.bars @ 200 c/c

Area of tension reinforcement provided $A_{bb.prov} = \pi \times \phi_{bb}^2 / (4 \times s_{bb}) = \mathbf{1005}\ mm^2/m$

Minimum area of reinforcement - exp.9.1N $A_{bb.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = \mathbf{420}\ mm^2/m$

Maximum area of reinforcement - cl.9.2.1.1(3) $A_{bb.max} = 0.04 \times h = \mathbf{14000}\ mm^2/m$

$\max(A_{bb.req}, A_{bb.min}) / A_{bb.prov} = \mathbf{0.814}$

PASS - Area of reinforcement provided is greater than area of reinforcement required

Rectangular section in shear - Section 6.2

Design shear force $V = \mathbf{120.4}$ kN/m

$C_{Rd.c} = 0.18 / \gamma_C = \mathbf{0.120}$

$k = \min(1 + \sqrt{(200\ mm / d)}, 2) = \mathbf{1.865}$

Longitudinal reinforcement ratio $\rho_l = \min(A_{bb.prov} / d, 0.02) = \mathbf{0.004}$

$v_{min} = 0.035\ N^{1/2}/mm \times k^{3/2} \times f_{ck}^{0.5} = \mathbf{0.504}\ N/mm^2$

Design shear resistance - exp.6.2a & 6.2b $V_{Rd.c} = \max(C_{Rd.c} \times k \times (100\ N^2/mm^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$

$V_{Rd.c} = \mathbf{137}$ kN/m

$V / V_{Rd.c} = \mathbf{0.879}$

PASS - Design shear resistance exceeds design shear force

Secondary transverse reinforcement to base - Section 9.3

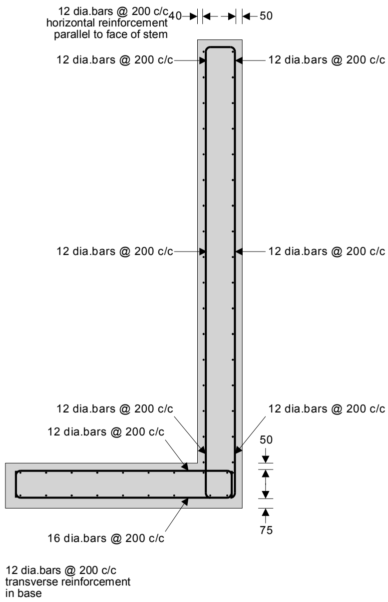
Minimum area of reinforcement – cl.9.3.1.1(2) $A_{bx.req} = 0.2 \times A_{bb.prov} = \mathbf{201}\ mm^2/m$

Maximum spacing of reinforcement – cl.9.3.1.1(3) s_{bx_max} = **450** mm

Transverse reinforcement provided 12 dia.bars @ 200 c/c

Area of transverse reinforcement provided $A_{bx.prov} = \pi \times \phi_{bx}^2 / (4 \times s_{bx})$ = **565** mm²/m

PASS - Area of reinforcement provided is greater than area of reinforcement required



Reinforcement details