APPENDIX C

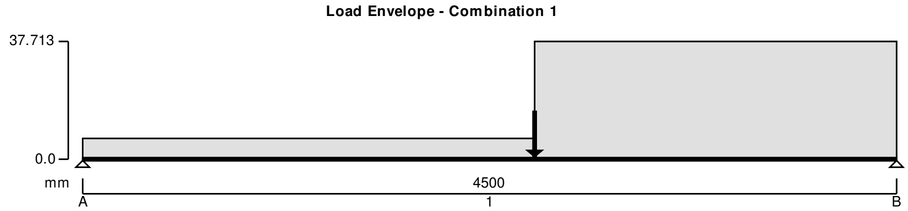
CALCULATIONS

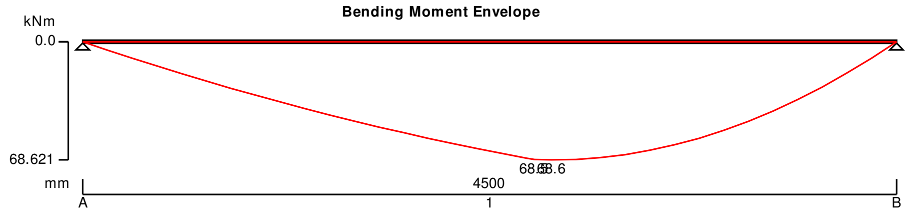
Conisbee 1-5 Offord Street London N1 1DH	Project 1 St. Marks Crescent				Job no. 180507	
	Calcs for new beam at rear				Start page no./Revision 1	
	Calcs by HH	Calcs date 13/06/2018	Checked by	Checked date	Approved by	Approved date

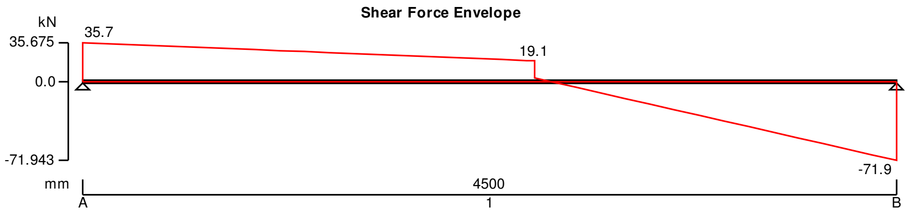
STEEL BEAM ANALYSIS & DESIGN (BS5950)

In accordance with BS5950-1:2000 incorporating Corrigendum No.1

TEDDS calculation version 3.0.05







Support conditions

Support A	Vertically restrained Rotationally free
Support B	Vertically restrained Rotationally free

Applied loading

Beam loads	Dead full UDL 2 kN/m Imposed full UDL 2 kN/m Dead point load 11.15 kN at 2500 mm Dead partial UDL 19 kN/m from 2500 mm to 4500 mm Dead partial UDL 3.2 kN/m from 2500 mm to 4500 mm Dead self weight of beam × 1

Load combinations

Load combination 1	Support A	Dead × 1.40 Imposed × 1.60
	Span 1	Dead × 1.40 Imposed × 1.60
	Support B	Dead × 1.40

Imposed × 1.60

Analysis results

Maximum moment	M_{max} = **68.6** kNm	M_{min} = **0** kNm
Maximum moment span 1 segment 1	$M_{s1\_seg1\_max}$ = **63.5** kNm	$M_{s1\_seg1\_min}$ = **0** kNm
Maximum moment span 1 segment 2	$M_{s1\_seg2\_max}$ = **68.6** kNm	$M_{s1\_seg2\_min}$ = **0** kNm
Maximum shear	V_{max} = **35.7** kN	V_{min} = **-71.9** kN
Maximum shear span 1 segment 1	$V_{s1\_seg1\_max}$ = **35.7** kN	$V_{s1\_seg1\_min}$ = **0** kN
Maximum shear span 1 segment 2	$V_{s1\_seg2\_max}$ = **20.8** kN	$V_{s1\_seg2\_min}$ = **-71.9** kN
Deflection segment 3	δ_{max} = **10** mm	δ_{min} = **0** mm
Maximum reaction at support A	R_{A_max} = **35.7** kN	R_{A_min} = **35.7** kN
Unfactored dead load reaction at support A	R_{A_Dead} = **20.3** kN	
Unfactored imposed load reaction at support A	$R_{A\_Imposed}$ = **4.5** kN	
Maximum reaction at support B	R_{B_max} = **71.9** kN	R_{B_min} = **71.9** kN
Unfactored dead load reaction at support B	R_{B_Dead} = **46.2** kN	
Unfactored imposed load reaction at support B	$R_{B\_Imposed}$ = **4.5** kN	

Section details

Section type **UC 203x203x46 (BS4-1)**

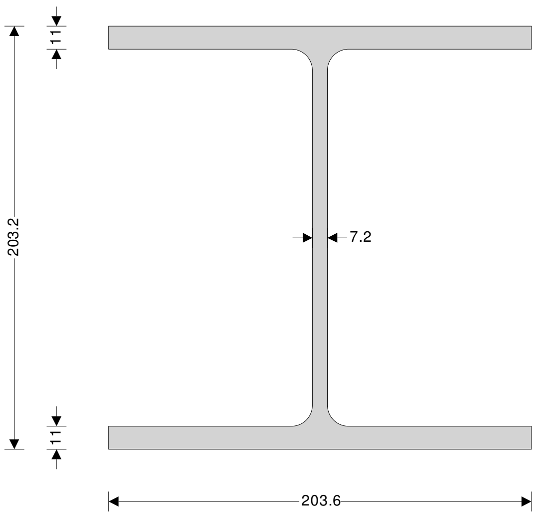
Steel grade **S355**

From table 9: Design strength p_y

Thickness of element max(T, t) = **11.0** mm

Design strength p_y = **355** N/mm^2

Modulus of elasticity E = **205000** N/mm^2



Lateral restraint

Span 1 has lateral restraint at supports plus midspan

Effective length factors

Effective length factor in major axis K_x = **1.00**

Effective length factor in minor axis K_y = **1.00**

Effective length factor for lateral-torsional buckling $K_{LT.A}$ = **1.00**

$K_{LT.B}$ = **1.00**

Classification of cross sections - Section 3.5

$\varepsilon = \sqrt{[275 \text{ N/mm}^2 / p_y]}$ = **0.88**

Internal compression parts - Table 11

Depth of section $d = \mathbf{160.8}$ mm

$d / t = 25.4 \times \varepsilon <= 80 \times \varepsilon$ Class 1 plastic

Outstand flanges - Table 11

Width of section $b = B / 2 = \mathbf{101.8}$ mm

$b / T = 10.5 \times \varepsilon <= 15 \times \varepsilon$ Class 3 semi-compact

Section is class 3 semi-compact

Shear capacity - Section 4.2.3

Design shear force $F_v = \max(\text{abs}(V_{max}), \text{abs}(V_{min})) = \mathbf{71.9}$ kN

$d / t < 70 \times \varepsilon$

Web does not need to be checked for shear buckling

Shear area $A_v = t \times D = \mathbf{1463}$ mm^2

Design shear resistance $P_v = 0.6 \times p_y \times A_v = \mathbf{311.6}$ kN

PASS - Design shear resistance exceeds design shear force

Moment capacity at span 1 segment 2 - Section 4.2.5

Design bending moment $M = \max(\text{abs}(M_{s1\_seg2\_max}), \text{abs}(M_{s1\_seg2\_min})) = \mathbf{68.6}$ kNm

Effective plastic modulus - Section 3.5.6

Limiting value for class 2 compact flange $\beta_{2f} = 10 \times \varepsilon = \mathbf{8.801}$

Limiting value for class 3 semi-compact flange $\beta_{3f} = 15 \times \varepsilon = \mathbf{13.202}$

Limiting value for class 2 compact web $\beta_{2w} = 100 \times \varepsilon = \mathbf{88.014}$

Limiting value for class 3 semi-compact web $\beta_{3w} = 120 \times \varepsilon = \mathbf{105.617}$

Effective plastic modulus - cl.3.5.6.2

$S_{eff} = \min(Z_{xx} + (S_{xx} - Z_{xx}) \times \min([((\beta_{3w} / (d / t))^2 - 1) / ((\beta_{3w} / \beta_{2w})^2 - 1)], [(\beta_{3f} / (b / T) - 1) / (\beta_{3f} / \beta_{2f} - 1)]), S_{xx}) = \mathbf{490411}$ mm^3

Moment capacity low shear - cl.4.2.5.2 $M_c = \min(p_y \times S_{eff}, 1.2 \times p_y \times Z_{xx}) = \mathbf{174.1}$ kNm

Effective length for lateral-torsional buckling - Section 4.3.5

Effective length for lateral torsional buckling $L_E = 1.0 \times L_{s1\_seg2} = \mathbf{2250}$ mm

Slenderness ratio $\lambda = L_E / r_{yy} = \mathbf{43.823}$

Equivalent slenderness - Section 4.3.6.7

Buckling parameter $u = \mathbf{0.847}$

Torsional index $x = \mathbf{17.713}$

Slenderness factor $v = 1 / [1 + 0.05 \times (\lambda / x)^2]^{0.25} = \mathbf{0.935}$

Ratio - cl.4.3.6.9 $\beta_W = S_{eff} / S_{xx} = \mathbf{0.986}$

Equivalent slenderness - cl.4.3.6.7 $\lambda_{LT} = u \times v \times \lambda \times \sqrt{[\beta_W]} = \mathbf{34.455}$

Limiting slenderness - Annex B.2.2 $\lambda_{L0} = 0.4 \times (\pi^2 \times E / p_y)^{0.5} = \mathbf{30.198}$

$\lambda_{LT} > \lambda_{L0}$ - Allowance should be made for lateral-torsional buckling

Bending strength - Section 4.3.6.5

Robertson constant $\alpha_{LT} = \mathbf{7.0}$

Perry factor $\eta_{LT} = \max(\alpha_{LT} \times (\lambda_{LT} - \lambda_{L0}) / 1000, 0) = \mathbf{0.030}$

Euler stress $p_E = \pi^2 \times E / \lambda_{LT}^2 = \mathbf{1704.3}$ N/mm^2

$\phi_{LT} = (p_y + (\eta_{LT} + 1) \times p_E) / 2 = \mathbf{1055}$ N/mm^2

Bending strength - Annex B.2.1 $p_b = p_E \times p_y / (\phi_{LT} + (\phi_{LT}^2 - p_E \times p_y)^{0.5}) = \mathbf{342.2}$ N/mm^2

Equivalent uniform moment factor - Section 4.3.6.6

Moment at quarter point of segment $M_2 = \mathbf{67.7}$ kNm

Moment at centre-line of segment $M_3 = \mathbf{57.1}$ kNm

Moment at three quarter point of segment M_4 = **34.5** kNm

Maximum moment in segment M_{abs} = **68.6** kNm

Maximum moment governing buckling resistance $M_{LT} = M_{abs}$ = **68.6** kNm

Equivalent uniform moment factor for lateral-torsional buckling

$m_{LT} = \max(0.2 + (0.15 \times M_2 + 0.5 \times M_3 + 0.15 \times M_4) / M_{abs}, 0.44)$ = **0.839**

Buckling resistance moment - Section 4.3.6.4

Buckling resistance moment $M_b = p_b \times S_{eff}$ = **167.8** kNm

M_b / m_{LT} = **200** kNm

PASS - Moment capacity exceeds design bending moment

Check vertical deflection - Section 2.5.2

Consider deflection due to dead and imposed loads

Limiting deflection $\delta_{lim} = L_{s1} / 250$ = **18** mm

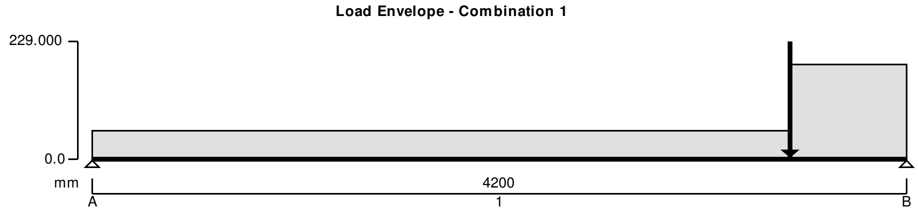
Maximum deflection span 1 $\delta = \max(\text{abs}(\delta_{max}), \text{abs}(\delta_{min}))$ = **10.016** mm

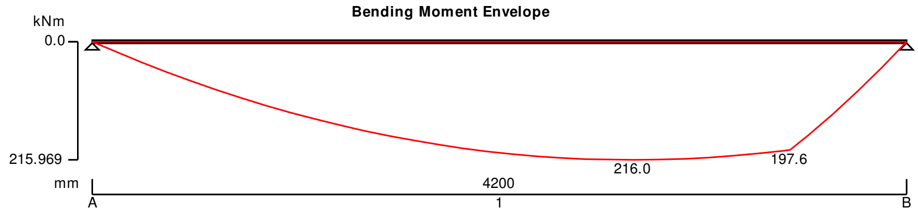
PASS - Maximum deflection does not exceed deflection limit

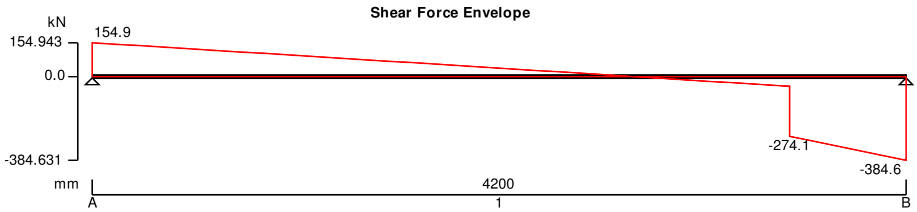
STEEL BEAM ANALYSIS & DESIGN (BS5950)

In accordance with BS5950-1:2000 incorporating Corrigendum No.1

TEDDS calculation version 3.0.05







Support conditions

Support A	Vertically restrained
	Rotationally free
Support B	Vertically restrained
	Rotationally free

Applied loading

Beam loads	Dead partial UDL 80 kN/m from 3600 mm to 4200 mm
	Imposed partial UDL 10.35 kN/m from 3600 mm to 4200 mm
	Dead point load 135 kN at 3600 mm
	Imposed point load 25 kN at 3600 mm
	Dead full UDL 32 kN/m
	Imposed full UDL 6 kN/m
	Dead self weight of beam × 1

Load combinations

Load combination 1	Support A	Dead × 1.40
		Imposed × 1.60
	Span 1	Dead × 1.40
		Imposed × 1.60

	Support B	Dead × 1.40
		Imposed × 1.60

Analysis results

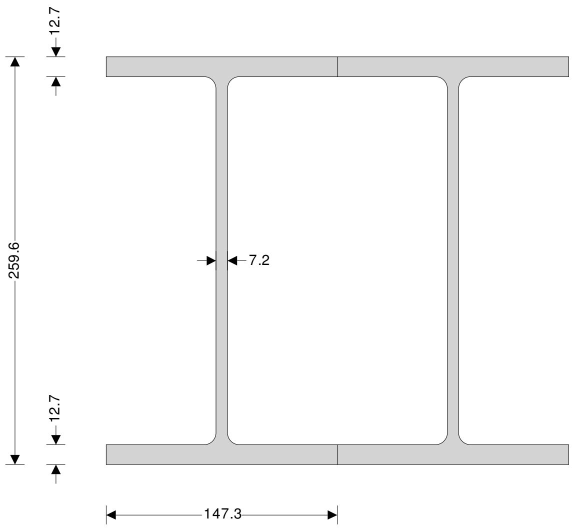
Maximum moment	M_{max} = **216** kNm	M_{min} = **0** kNm
Maximum shear	V_{max} = **154.9** kN	V_{min} = **-384.6** kN
Deflection	δ_{max} = **1.6** mm	δ_{min} = **0** mm
Maximum reaction at support A	R_{A_max} = **154.9** kN	R_{A_min} = **154.9** kN
Unfactored dead load reaction at support A	R_{A_Dead} = **91.7** kN	
Unfactored imposed load reaction at support A	$R_{A\_Imposed}$ = **16.6** kN	
Maximum reaction at support B	R_{B_max} = **384.6** kN	R_{B_min} = **384.6** kN
Unfactored dead load reaction at support B	R_{B_Dead} = **229.3** kN	
Unfactored imposed load reaction at support B	$R_{B\_Imposed}$ = **39.8** kN	

Section details

Section type	**2 x UB 254x146x43 (BS4-1)**
Steel grade	**S355**

From table 9: Design strength p_y

Thickness of element	max(T, t) = **12.7** mm
Design strength	p_y = **355** N/mm^2
Modulus of elasticity	E = **205000** N/mm^2



Lateral restraint

Span 1 has lateral restraint at supports only

Effective length factors

Effective length factor in major axis	K_x = **1.00**
Effective length factor in minor axis	K_y = **1.00**
Effective length factor for lateral-torsional buckling	$K_{LT.A}$ = **1.00**
	$K_{LT.B}$ = **1.00**

Classification of cross sections - Section 3.5

$\varepsilon = \sqrt{[275 \text{ N/mm}^2 / p_y]}$ = **0.88**

Internal compression parts - Table 11

Depth of section	d = **219** mm	
	$d / t = 34.6 \times \varepsilon <= 80 \times \varepsilon$	Class 1 plastic

Outstand flanges - Table 11

Width of section — $b = B / 2 = \mathbf{73.7}$ mm

$b / T = 6.6 \times \varepsilon <= 9 \times \varepsilon$ — Class 1 plastic

Section is class 1 plastic

Shear capacity - Section 4.2.3

Design shear force — $F_v = max(abs(V_{max}), abs(V_{min})) = \mathbf{384.6}$ kN

$d / t < 70 \times \varepsilon$

Web does not need to be checked for shear buckling

Shear area — $A_v = t \times D = \mathbf{1869}$ mm^2

Design shear resistance — $P_v = 0.6 \times N \times p_y \times A_v = \mathbf{796.2}$ kN

PASS - Design shear resistance exceeds design shear force

Moment capacity - Section 4.2.5

Design bending moment — $M = max(abs(M_{s1\_max}), abs(M_{s1\_min})) = \mathbf{216}$ kNm

Moment capacity low shear - cl.4.2.5.2 — $M_c = N \times min(p_y \times S_{xx}, 1.2 \times p_y \times Z_{xx}) = \mathbf{402.1}$ kNm

Effective length for lateral-torsional buckling - Section 4.3.5

Effective length for lateral torsional buckling — $L_E = 1.0 \times L_{s1} = \mathbf{4200}$ mm

Slenderness ratio — $\lambda = L_E / r_{yy} = \mathbf{119.431}$

Equivalent slenderness - Section 4.3.6.7

Buckling parameter — $u = \mathbf{0.891}$

Torsional index — $x = \mathbf{21.162}$

Slenderness factor — $v = 1 / [1 + 0.05 \times (\lambda / x)^2]^{0.25} = \mathbf{0.788}$

Ratio - cl.4.3.6.9 — $\beta_W = \mathbf{1.000}$

Equivalent slenderness - cl.4.3.6.7 — $\lambda_{LT} = u \times v \times \lambda \times \sqrt{[\beta_W]} = \mathbf{83.817}$

Limiting slenderness - Annex B.2.2 — $\lambda_{L0} = 0.4 \times (\pi^2 \times E / p_y)^{0.5} = \mathbf{30.198}$

$\lambda_{LT} > \lambda_{L0}$ - Allowance should be made for lateral-torsional buckling

Bending strength - Section 4.3.6.5

Robertson constant — $\alpha_{LT} = \mathbf{7.0}$

Perry factor — $\eta_{LT} = max(\alpha_{LT} \times (\lambda_{LT} - \lambda_{L0}) / 1000, 0) = \mathbf{0.375}$

Euler stress — $p_E = \pi^2 \times E / \lambda_{LT}^2 = \mathbf{288}$ N/mm^2

$\phi_{LT} = (p_y + (\eta_{LT} + 1) \times p_E) / 2 = \mathbf{375.5}$ N/mm^2

Bending strength - Annex B.2.1 — $p_b = p_E \times p_y / (\phi_{LT} + (\phi_{LT}^2 - p_E \times p_y)^{0.5}) = \mathbf{178.6}$ N/mm^2

Equivalent uniform moment factor - Section 4.3.6.6

Moment at quarter point of segment — $M_2 = \mathbf{132.1}$ kNm

Moment at centre-line of segment — $M_3 = \mathbf{202.8}$ kNm

Moment at three quarter point of segment — $M_4 = \mathbf{212.3}$ kNm

Maximum moment in segment — $M_{abs} = \mathbf{216}$ kNm

Maximum moment governing buckling resistance — $M_{LT} = M_{abs} = \mathbf{216}$ kNm

Equivalent uniform moment factor for lateral-torsional buckling

$m_{LT} = max(0.2 + (0.15 \times M_2 + 0.5 \times M_3 + 0.15 \times M_4) / M_{abs}, 0.44) = \mathbf{0.909}$

Buckling resistance moment - Section 4.3.6.4

Buckling resistance moment — $M_b = N \times p_b \times S_{xx} = \mathbf{202.3}$ kNm

$M_b / m_{LT} = \mathbf{222.6}$ kNm

PASS - Buckling resistance moment exceeds design bending moment

Check vertical deflection - Section 2.5.2

Consider deflection due to imposed loads

Limiting deflection $\delta_{lim} = L_{s1} / 360 =$ **11.667** mm

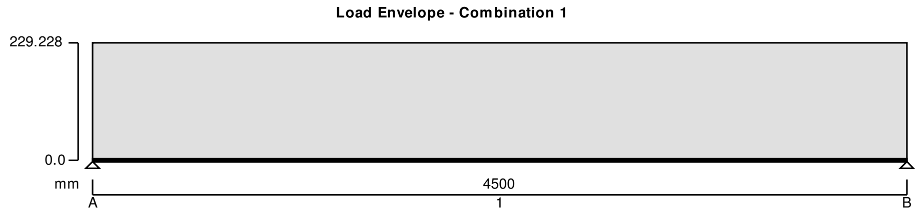
Maximum deflection span 1 $\delta = max(abs(\delta_{max}), abs(\delta_{min})) =$ **1.588** mm

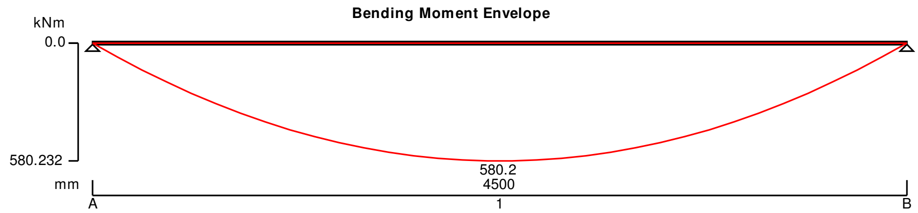
PASS - Maximum deflection does not exceed deflection limit

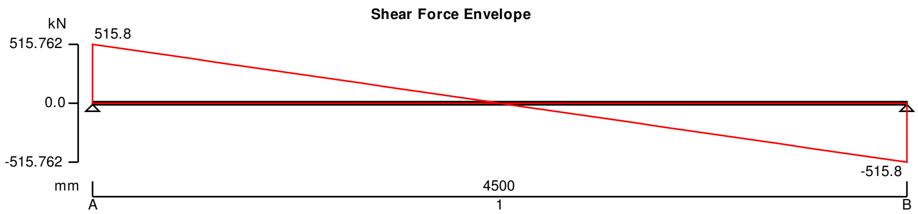
Conisbee 1-5 Offord Street London N1 1DH	Project 1 St Marks Crescent				Job no. 180507	
	Calcs for NEW LOWER BOOM R.C. BASEMENT				Start page no./Revision 1	
	Calcs by HH	Calcs date 12/06/2018	Checked by	Checked date	Approved by	Approved date

RC BEAM ANALYSIS & DESIGN BS8110

TEDDS calculation version 2.1.12







Support conditions

Support A	Vertically restrained
	Rotationally free
Support B	Vertically restrained
	Rotationally free

Applied loading

Dead self weight of beam × 1

Dead full UDL 100 kN/m

Imposed full UDL 40 kN/m

Load combinations

Load combination 1	Support A	Dead × 1.40
		Imposed × 1.60
	Span 1	Dead × 1.40
		Imposed × 1.60
	Support B	Dead × 1.40
		Imposed × 1.60

Analysis results

Maximum moment support A M_{A_max} = **0** kNm M_{A_red} = **0** kNm

Maximum moment span 1 at 2250 mm	M_{s1_max} = **580** kNm	M_{s1_red} = **580** kNm
Maximum moment support B	M_{B_max} = **0** kNm	M_{B_red} = **0** kNm
Maximum shear support A	V_{A_max} = **516** kN	V_{A_red} = **516** kN
Maximum shear support A span 1 at 450 mm	$V_{A\_s1\_max}$ = **413** kN	$V_{A\_s1\_red}$ = **413** kN
Maximum shear support B	V_{B_max} = **-516** kN	V_{B_red} = **-516** kN
Maximum shear support B span 1 at 4050 mm	$V_{B\_s1\_max}$ = **-413** kN	$V_{B\_s1\_red}$ = **-413** kN
Maximum reaction at support A	R_A = **516** kN	
Unfactored dead load reaction at support A	R_{A_Dead} = **266** kN	
Unfactored imposed load reaction at support A	$R_{A\_Imposed}$ = **90** kN	
Maximum reaction at support B	R_B = **516** kN	
Unfactored dead load reaction at support B	R_{B_Dead} = **266** kN	
Unfactored imposed load reaction at support B	$R_{B\_Imposed}$ = **90** kN	

Rectangular section details

Section width b = **1500** mm

Section depth h = **500** mm

Concrete details

Concrete strength class **C40/50**

Characteristic compressive cube strength f_{cu} = **50** N/mm^2

Modulus of elasticity of concrete E_c = 20kN/mm^2 + 200 × f_{cu} = **30000** N/mm^2

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

Reinforcement details

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

Characteristic yield strength of shear reinforcement f_{yv} = **500** N/mm^2

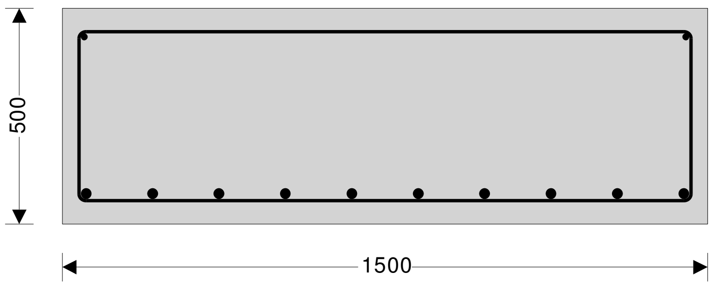
Nominal cover to reinforcement

Nominal cover to top reinforcement c_{nom_t} = **50** mm

Nominal cover to bottom reinforcement c_{nom_b} = **50** mm

Nominal cover to side reinforcement c_{nom_s} = **35** mm

Mid span 1



2 x 16ϕ bars

3 x 8ϕ shear legs at 100 c/c

10 x 25ϕ bars

Design moment resistance of rectangular section (cl. 3.4.4) - Positive moment

Design bending moment — $M = abs(M_{s1\_red})$ = **580** kNm

Depth to tension reinforcement — $d = h - c_{nom\_b} - \phi_v - \phi_{bot} / 2$ = **430** mm

Redistribution ratio — $\beta_b = \min(1 - m_{rs1}, 1)$ = **1.000**

$K = M / (b \times d^2 \times f_{cu})$ = **0.042**

$K' = 0.156$

K' > K - No compression reinforcement is required

Lever arm — $z = \min(d \times (0.5 + (0.25 - K / 0.9)^{0.5}), 0.95 \times d)$ = **408** mm

Depth of neutral axis — $x = (d - z) / 0.45$ = **48** mm

Area of tension reinforcement required — $A_{s,req} = M / (0.87 \times f_y \times z)$ = **3269** mm^2

Tension reinforcement provided — $10 \times 25\phi$ bars

Area of tension reinforcement provided — $A_{s,prov}$ = **4909** mm^2

Minimum area of reinforcement — $A_{s,min} = 0.0013 \times b \times h$ = **975** mm^2

Maximum area of reinforcement — $A_{s,max} = 0.04 \times b \times h$ = **30000** mm^2

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

Rectangular section in shear

Shear reinforcement provided — $3 \times 8\phi$ legs at 100 c/c

Area of shear reinforcement provided — $A_{sv,prov}$ = **1508** mm^2/m

Minimum area of shear reinforcement (Table 3.7) — $A_{sv,min} = 0.4N/mm^2 \times b / (0.87 \times f_{yv})$ = **1379** mm^2/m

PASS - Area of shear reinforcement provided exceeds minimum required

Maximum longitudinal spacing (cl. 3.4.5.5) — $s_{vl,max} = 0.75 \times d$ = **322** mm

PASS - Longitudinal spacing of shear reinforcement provided is less than maximum

Design concrete shear stress — $v_c = 0.79N/mm^2 \times \min(3,[100 \times A_{s,prov} / (b \times d)]^{1/3}) \times \max(1, (400mm / d)^{1/4}) \times (\min(f_{cu}, 40N/mm^2) / 25N/mm^2)^{1/3} / \gamma_m$ = **0.675** N/mm^2

Design shear resistance provided — $v_{s,prov} = A_{sv,prov} \times 0.87 \times f_{yv} / b$ = **0.437** N/mm^2

Design shear stress provided — $v_{prov} = v_{s,prov} + v_c$ = **1.112** N/mm^2

Design shear resistance — $V_{prov} = v_{prov} \times (b \times d)$ = **716.7** kN

Shear links provided valid between 0 mm and 4500 mm with tension reinforcement of 4909 mm^2

Spacing of reinforcement (cl 3.12.11)

Actual distance between bars in tension — $s = (b - 2 \times (c_{nom\_s} + \phi_v + \phi_{bot}/2)) /(N_{bot} - 1) - \phi_{bot}$ = **129** mm

Minimum distance between bars in tension (cl 3.12.11.1)

Minimum distance between bars in tension — $s_{min} = h_{agg} + 5$ mm = **25** mm

PASS - Satisfies the minimum spacing criteria

Maximum distance between bars in tension (cl 3.12.11.2)

Design service stress — $f_s = (2 \times f_y \times A_{s,req}) / (3 \times A_{s,prov} \times \beta_b)$ = **222.0** N/mm^2

Maximum distance between bars in tension — $s_{max} = \min(47000 N/mm / f_s, 300 mm)$ = **212** mm

PASS - Satisfies the maximum spacing criteria

Span to depth ratio (cl. 3.4.6)

Basic span to depth ratio (Table 3.9) — $span\_to\_depth_{basic}$ = **20.0**

Design service stress in tension reinforcement — $f_s = (2 \times f_y \times A_{s,req})/ (3 \times A_{s,prov} \times \beta_b)$ = **222.0** N/mm^2

Modification for tension reinforcement

$f_{tens} = \min(2.0, 0.55 + (477N/mm^2 - f_s) / (120 \times (0.9N/mm^2 + (M / (b \times d^2)))))$ = **1.259**

Modification for compression reinforcement

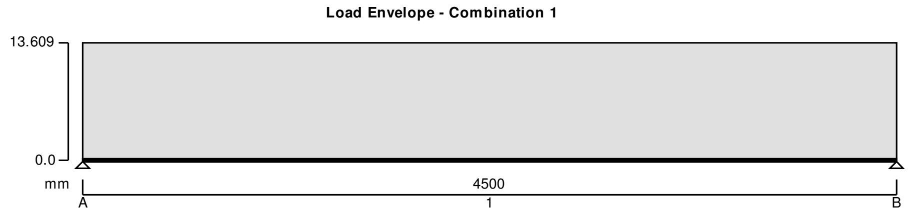
$f_{comp} = \min(1.5, 1 + (100 \times A_{s2,prov} / (b \times d)) / (3 + (100 \times A_{s2,prov} / (b \times d))))$ = **1.020**

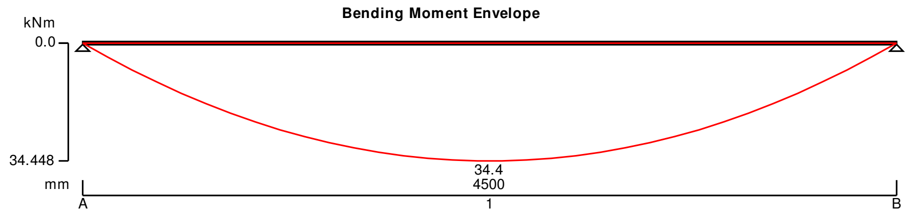
Modification for span length	f_{long} = 1.000
Allowable span to depth ratio	$span\_to\_depth_{allow} = span\_to\_depth_{basic} \times f_{tens} \times f_{comp}$ = **25.7**
Actual span to depth ratio	$span\_to\_depth_{actual} = L_{s1} / d$ = **10.5**

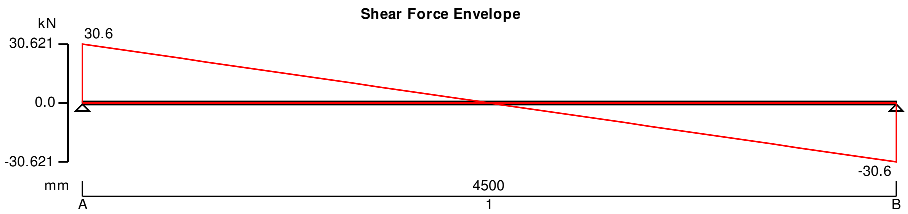
PASS - Actual span to depth ratio is within the allowable limit

RC BEAM ANALYSIS & DESIGN BS8110

TEDDS calculation version 2.1.12







Support conditions

Support A	Vertically restrained
	Rotationally free
Support B	Vertically restrained
	Rotationally free

Applied loading

Dead self weight of beam × 1

Dead full UDL 2 kN/m

Imposed full UDL 1.5 kN/m

Load combinations

Load combination 1	Support A	Dead × 1.40
		Imposed × 1.60
	Span 1	Dead × 1.40
		Imposed × 1.60
	Support B	Dead × 1.40
		Imposed × 1.60

Analysis results

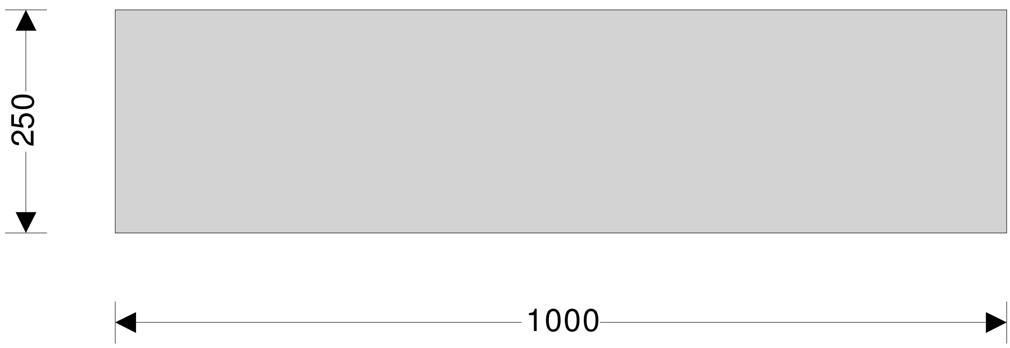
Maximum moment support A	M_{A_max} = **0** kNm	M_{A_red} = **0** kNm

Maximum moment span 1 at 2250 mm	M_{s1_max} = **34** kNm	M_{s1_red} = **34** kNm
Maximum moment support B	M_{B_max} = **0** kNm	M_{B_red} = **0** kNm
Maximum shear support A	V_{A_max} = **31** kN	V_{A_red} = **31** kN
Maximum shear support A span 1 at 200 mm	$V_{A\_s1\_max}$ = **28** kN	$V_{A\_s1\_red}$ = **28** kN
Maximum shear support B	V_{B_max} = **-31** kN	V_{B_red} = **-31** kN
Maximum shear support B span 1 at 4300 mm	$V_{B\_s1\_max}$ = **-28** kN	$V_{B\_s1\_red}$ = **-28** kN
Maximum reaction at support A	R_A = **31** kN	
Unfactored dead load reaction at support A	R_{A_Dead} = **18** kN	
Unfactored imposed load reaction at support A	$R_{A\_Imposed}$ = **3** kN	
Maximum reaction at support B	R_B = **31** kN	
Unfactored dead load reaction at support B	R_{B_Dead} = **18** kN	
Unfactored imposed load reaction at support B	$R_{B\_Imposed}$ = **3** kN	

Rectangular section details

Section width b = **1000** mm

Section depth h = **250** mm



Concrete details

Concrete strength class **C40/50**

Characteristic compressive cube strength f_{cu} = **50** N/mm^2

Modulus of elasticity of concrete $E_c = 20kN/mm^2 + 200 \times f_{cu}$ = **30000** N/mm^2

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

Reinforcement details

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

Characteristic yield strength of shear reinforcement f_{yv} = **500** N/mm^2

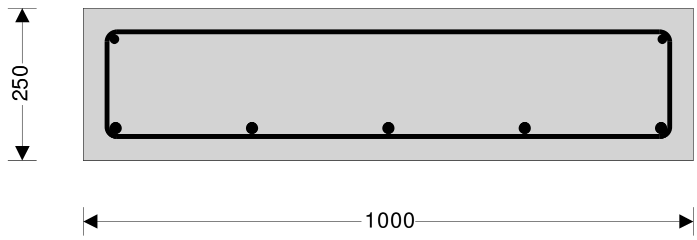
Nominal cover to reinforcement

Nominal cover to top reinforcement c_{nom_t} = **35** mm

Nominal cover to bottom reinforcement c_{nom_b} = **35** mm

Nominal cover to side reinforcement c_{nom_s} = **35** mm

Mid span 1



2 x 16ϕ bars

2 x 8ϕ shear legs at 100 c/c

5 x 20ϕ bars

Design moment resistance of rectangular section (cl. 3.4.4) - Positive moment

Design bending moment	$M = abs(M_{s1\_red})$ = **34** kNm
Depth to tension reinforcement	$d = h - c_{nom\_b} - \phi_v - \phi_{bot} / 2$ = **197** mm
Redistribution ratio	$\beta_b = min(1 - m_{rs1}, 1)$ = **1.000**
	$K = M / (b \times d^2 \times f_{cu})$ = **0.018**
	K' = 0.156

K' > K - No compression reinforcement is required

Lever arm	$z = min(d \times (0.5 + (0.25 - K / 0.9)^{0.5}), 0.95 \times d)$ = **187** mm
Depth of neutral axis	$x = (d - z) / 0.45$ = **22** mm
Area of tension reinforcement required	$A_{s,req} = M / (0.87 \times f_y \times z)$ = **423** mm^2
Tension reinforcement provided	$5 \times 20\phi$ bars
Area of tension reinforcement provided	$A_{s,prov}$ = **1571** mm^2
Minimum area of reinforcement	$A_{s,min} = 0.0013 \times b \times h$ = **325** mm^2
Maximum area of reinforcement	$A_{s,max} = 0.04 \times b \times h$ = **10000** mm^2

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

Rectangular section in shear

Shear reinforcement provided	$2 \times 8\phi$ legs at 100 c/c
Area of shear reinforcement provided	$A_{sv,prov}$ = **1005** mm^2/m
Minimum area of shear reinforcement (Table 3.7)	$A_{sv,min} = 0.4N/mm^2 \times b / (0.87 \times f_{yv})$ = **920** mm^2/m

PASS - Area of shear reinforcement provided exceeds minimum required

Maximum longitudinal spacing (cl. 3.4.5.5)	$s_{vl,max} = 0.75 \times d$ = **148** mm

PASS - Longitudinal spacing of shear reinforcement provided is less than maximum

Design concrete shear stress	$v_c = 0.79N/mm^2 \times min(3,[100 \times A_{s,prov} / (b \times d)]^{1/3}) \times max(1, (400mm /d)^{1/4}) \times (min(f_{cu}, 40N/mm^2) / 25N/mm^2)^{1/3} / \gamma_m$ = **0.818** N/mm^2
Design shear resistance provided	$v_{s,prov} = A_{sv,prov} \times 0.87 \times f_{yv} / b$ = **0.437** N/mm^2
Design shear stress provided	$v_{prov} = v_{s,prov} + v_c$ = **1.256** N/mm^2
Design shear resistance	$V_{prov} = v_{prov} \times (b \times d)$ = **247.3** kN

Shear links provided valid between 0 mm and 4500 mm with tension reinforcement of 1571 mm^2

Spacing of reinforcement (cl 3.12.11)

Actual distance between bars in tension	$s = (b - 2 \times (c_{nom\_s} + \phi_v + \phi_{bot}/2)) /(N_{bot} - 1) - \phi_{bot}$ = **204** mm

Minimum distance between bars in tension (cl 3.12.11.1)

Minimum distance between bars in tension	$s_{min} = h_{agg} + 5$ mm = **25** mm

PASS - Satisfies the minimum spacing criteria

Maximum distance between bars in tension (cl 3.12.11.2)

Design service stress	$f_s = (2 \times f_y \times A_{s,req}) / (3 \times A_{s,prov} \times \beta_b)$ = **89.8** N/mm^2
Maximum distance between bars in tension	$s_{max} = min(47000 N/mm / f_s, 300 mm)$ = **300** mm

PASS - Satisfies the maximum spacing criteria

Span to depth ratio (cl. 3.4.6)

Basic span to depth ratio (Table 3.9)	$span\_to\_depth_{basic}$ = **20.0**
Design service stress in tension reinforcement	$f_s = (2 \times f_y \times A_{s,req})/ (3 \times A_{s,prov} \times \beta_b)$ = **89.8** N/mm^2

Modification for tension reinforcement

$f_{tens} = min(2.0, 0.55 + (477N/mm^2 - f_s) / (120 \times (0.9N/mm^2 + (M / (b \times d^2)))))$ = **2.000**

Modification for compression reinforcement

$f_{comp} = min(1.5, 1 + (100 \times A_{s2,prov} / (b \times d)) / (3 + (100 \times A_{s2,prov} / (b \times d))))$ = **1.064**

Modification for span length	f_{long} = 1.000

Allowable span to depth ratio $span\_to\_depth_{allow} = span\_to\_depth_{basic} \times f_{tens} \times f_{comp}$ = **42.5**

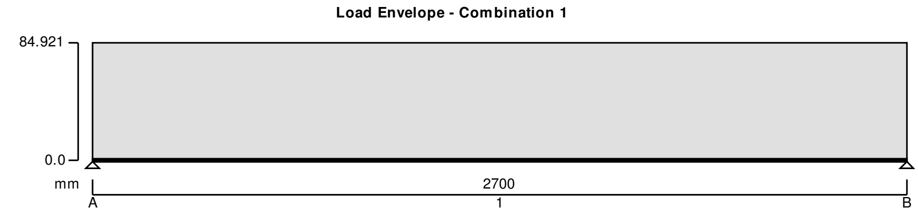
Actual span to depth ratio $span\_to\_depth_{actual} = L_{s1} / d$ = **22.8**

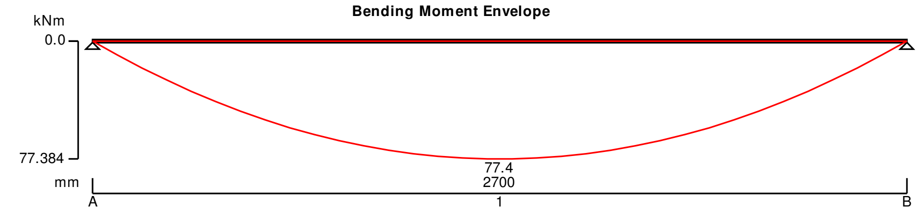
PASS - Actual span to depth ratio is within the allowable limit

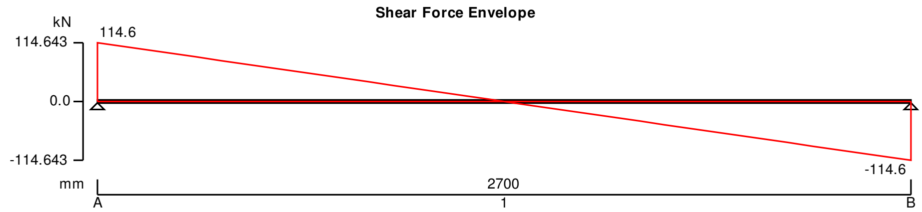
Conisbee 1-5 Offord Street London N1 1DH	Project 1 St Marks Crescent				Job no. 180507	
	Calcs for R.C capping beam stair				Start page no./Revision 1	
	Calcs by HH	Calcs date 13/06/2018	Checked by	Checked date	Approved by	Approved date

RC BEAM ANALYSIS & DESIGN BS8110

TEDDS calculation version 2.1.12







Support conditions

Support A	Vertically restrained Rotationally free
Support B	Vertically restrained Rotationally free

Applied loading

Dead self weight of beam × 1
Imposed full UDL 50.5 kN/m

Load combinations

Load combination 1	Support A	Dead × 1.40
		Imposed × 1.60
	Span 1	Dead × 1.40
		Imposed × 1.60
	Support B	Dead × 1.40
		Imposed × 1.60

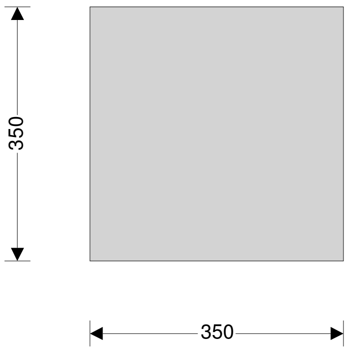
Analysis results

Maximum moment support A	M_{A_max} = **0** kNm	M_{A_red} = **0** kNm
Maximum moment span 1 at 1350 mm	M_{s1_max} = **77** kNm	M_{s1_red} = **77** kNm

Maximum moment support B M_{B_max} = **0** kNm M_{B_red} = **0** kNm
Maximum shear support A V_{A_max} = **115** kN V_{A_red} = **115** kN
Maximum shear support A span 1 at 300 mm $V_{A\_s1\_max}$ = **89** kN $V_{A\_s1\_red}$ = **89** kN
Maximum shear support B V_{B_max} = **-115** kN V_{B_red} = **-115** kN
Maximum shear support B span 1 at 2400 mm $V_{B\_s1\_max}$ = **-89** kN $V_{B\_s1\_red}$ = **-89** kN
Maximum reaction at support A R_A = **115** kN
Unfactored dead load reaction at support A R_{A_Dead} = **4** kN
Unfactored imposed load reaction at support A $R_{A\_Imposed}$ = **68** kN
Maximum reaction at support B R_B = **115** kN
Unfactored dead load reaction at support B R_{B_Dead} = **4** kN
Unfactored imposed load reaction at support B $R_{B\_Imposed}$ = **68** kN

Rectangular section details

Section width b = **350** mm
Section depth h = **350** mm



Concrete details

Concrete strength class **C40/50**
Characteristic compressive cube strength f_{cu} = **50** N/mm^2
Modulus of elasticity of concrete $E_c = 20kN/mm^2 + 200 \times f_{cu}$ = **30000** N/mm^2
Maximum aggregate size h_{agg} = **20** mm

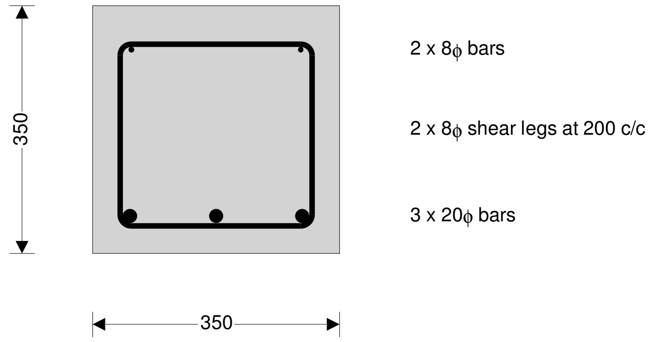
Reinforcement details

Characteristic yield strength of reinforcement f_y = **500** N/mm^2
Characteristic yield strength of shear reinforcement f_{yv} = **500** N/mm^2

Nominal cover to reinforcement

Nominal cover to top reinforcement c_{nom_t} = **50** mm
Nominal cover to bottom reinforcement c_{nom_b} = **35** mm
Nominal cover to side reinforcement c_{nom_s} = **35** mm

Mid span 1



Design moment resistance of rectangular section (cl. 3.4.4) - Positive moment

Design bending moment — $M = abs(M_{s1\_red}) = \mathbf{77}$ kNm

Depth to tension reinforcement — $d = h - c_{nom\_b} - \phi_v - \phi_{bot} / 2 = \mathbf{297}$ mm

Redistribution ratio — $\beta_b = min(1 - m_{rs1}, 1) = \mathbf{1.000}$

$K = M / (b \times d^2 \times f_{cu}) = \mathbf{0.050}$

$K' = 0.156$

K' > K - No compression reinforcement is required

Lever arm — $z = min(d \times (0.5 + (0.25 - K / 0.9)^{0.5}), 0.95 \times d) = \mathbf{279}$ mm

Depth of neutral axis — $x = (d - z) / 0.45 = \mathbf{39}$ mm

Area of tension reinforcement required — $A_{s,req} = M / (0.87 \times f_y \times z) = \mathbf{637}$ mm^2

Tension reinforcement provided — 3 × 20ϕ bars

Area of tension reinforcement provided — $A_{s,prov} = \mathbf{942}$ mm^2

Minimum area of reinforcement — $A_{s,min} = 0.0013 \times b \times h = \mathbf{159}$ mm^2

Maximum area of reinforcement — $A_{s,max} = 0.04 \times b \times h = \mathbf{4900}$ mm^2

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

Rectangular section in shear

Shear reinforcement provided — 2 × 8ϕ legs at 200 c/c

Area of shear reinforcement provided — $A_{sv,prov} = \mathbf{503}$ mm^2/m

Minimum area of shear reinforcement (Table 3.7) — $A_{sv,min} = 0.4N/mm^2 \times b / (0.87 \times f_{yv}) = \mathbf{322}$ mm^2/m

PASS - Area of shear reinforcement provided exceeds minimum required

Maximum longitudinal spacing (cl. 3.4.5.5) — $s_{vl,max} = 0.75 \times d = \mathbf{223}$ mm

PASS - Longitudinal spacing of shear reinforcement provided is less than maximum

Design concrete shear stress — $v_c = 0.79N/mm^2 \times min(3,[100 \times A_{s,prov} / (b \times d)]^{1/3}) \times max(1, (400mm /d)^{1/4}) \times (min(f_{cu}, 40N/mm^2) / 25N/mm^2)^{1/3} / \gamma_m = \mathbf{0.771}$ N/mm^2

Design shear resistance provided — $v_{s,prov} = A_{sv,prov} \times 0.87 \times f_{yv} / b = \mathbf{0.625}$ N/mm^2

Design shear stress provided — $v_{prov} = v_{s,prov} + v_c = \mathbf{1.395}$ N/mm^2

Design shear resistance — $V_{prov} = v_{prov} \times (b \times d) = \mathbf{145.1}$ kN

Shear links provided valid between 0 mm and 2700 mm with tension reinforcement of 942 mm^2

Spacing of reinforcement (cl 3.12.11)

Actual distance between bars in tension — $s = (b - 2 \times (c_{nom\_s} + \phi_v + \phi_{bot}/2)) /(N_{bot} - 1) - \phi_{bot} = \mathbf{102}$ mm

Minimum distance between bars in tension (cl 3.12.11.1)

Minimum distance between bars in tension — $s_{min} = h_{agg} + 5\ mm = \mathbf{25}$ mm

PASS - Satisfies the minimum spacing criteria

Maximum distance between bars in tension (cl 3.12.11.2)

Design service stress $f_s = (2 \times f_y \times A_{s,req}) / (3 \times A_{s,prov} \times \beta_b) =$ **225.2** N/mm^2

Maximum distance between bars in tension $s_{max} = min(47000\ N/mm / f_s, 300\ mm) =$ **209** mm

PASS - Satisfies the maximum spacing criteria

Span to depth ratio (cl. 3.4.6)

Basic span to depth ratio (Table 3.9) $span\_to\_depth_{basic} =$ **20.0**

Design service stress in tension reinforcement $f_s = (2 \times f_y \times A_{s,req})/ (3 \times A_{s,prov} \times \beta_b) =$ **225.2** N/mm^2

Modification for tension reinforcement

$f_{tens} = min(2.0, 0.55 + (477N/mm^2 - f_s) / (120 \times (0.9N/mm^2 + (M / (b \times d^2))))) =$ **1.166**

Modification for compression reinforcement

$f_{comp} = min(1.5, 1 + (100 \times A_{s2,prov} / (b \times d)) / (3 + (100 \times A_{s2,prov} / (b \times d)))) =$ **1.031**

Modification for span length $f_{long} = 1.000$

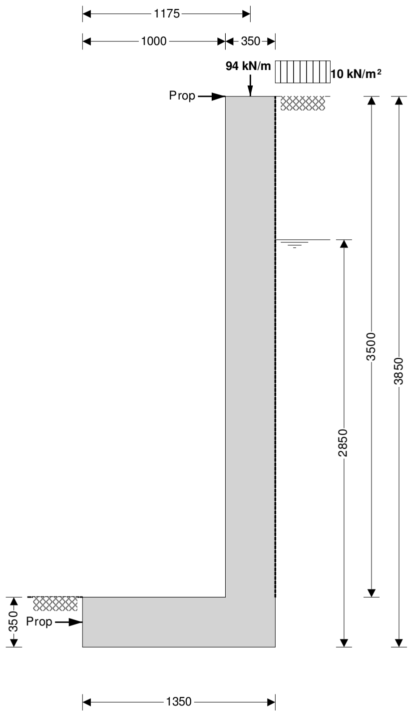
Allowable span to depth ratio $span\_to\_depth_{allow} = span\_to\_depth_{basic} \times f_{tens} \times f_{comp} =$ **24.0**

Actual span to depth ratio $span\_to\_depth_{actual} = L_{s1} / d =$ **9.1**

PASS - Actual span to depth ratio is within the allowable limit

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} = **3500** mm
Thickness of wall stem	t_{wall} = **350** mm
Length of toe	l_{toe} = **1000** mm
Length of heel	l_{heel} = **0** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **1350** mm
Thickness of base	t_{base} = **350** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **900** mm
Thickness of downstand	t_{ds} = **350** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **3850** 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} = **2850** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0\text{ mm})$ = **2500** 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	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **3850** mm

Retained material details

Mobilisation factor	M = **1.5**
Moist density of retained material	γ_m = **18.0** kN/m^3

Saturated density of retained material γ_s = **21.0** kN/m^3

Design shear strength ϕ' = **24.2** deg

Angle of wall friction δ = **18.6** deg

Base material details

Firm clay

Moist density γ_{mb} = **18.0** kN/m^3

Design shear strength ϕ'_b = **24.2** deg

Design base friction δ_b = **18.6** deg

Allowable bearing pressure $P_{bearing}$ = **125** kN/m^2

Using Coulomb theory

Active pressure coefficient for retained material

$K_a = \sin(\alpha + \phi')^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta) \times [1 + \sqrt{(\sin(\phi' + \delta) \times \sin(\phi' - \beta) / (\sin(\alpha - \delta) \times \sin(\alpha + \beta)))}]^2) =$ **0.369**

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**

Loading details

Surcharge load on plan Surcharge = **10.0** kN/m^2

Applied vertical dead load on wall W_{dead} = **80.2** kN/m

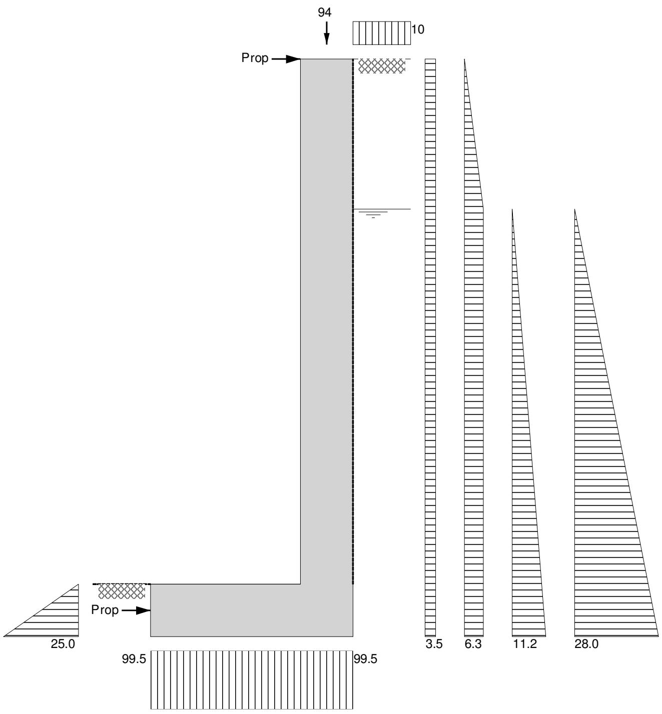
Applied vertical live load on wall W_{live} = **14.0** kN/m

Position of applied vertical load on wall l_{load} = **1175** 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 $w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **28.9** kN/m

Wall base $w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **11.2** kN/m

Applied vertical load $W_v = W_{dead} + W_{live}$ = **94.2** kN/m

Total vertical load $W_{total} = w_{wall} + w_{base} + W_v$ = **134.3** kN/m

Horizontal forces on wall

Surcharge $F_{sur} = K_a \times \cos(90 - \alpha + \delta) \times Surcharge \times h_{eff}$ = **13.5** kN/m

Moist backfill above water table $F_{m\_a} = 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water})^2$ = **3.1** kN/m

Moist backfill below water table $F_{m\_b} = K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **17.9** kN/m

Saturated backfill $F_s = 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **15.9** kN/m

Water $F_{water} = 0.5 \times h_{water}^2 \times \gamma_{water}$ = **39.8** kN/m

Total horizontal load $F_{total} = F_{sur} + F_{m\_a} + F_{m\_b} + F_s + F_{water}$ = **90.3** kN/m

Calculate total propping force

Passive resistance of soil in front of wall $F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **4.4** kN/m

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

F_{prop} = **45.5** kN/m

Overturning moments

Surcharge $M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **25.9** kNm/m

Moist backfill above water table $M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **10** kNm/m

Moist backfill below water table $M_{m\_b} = F_{m\_b} \times (h_{water} - 2 \times d_{ds}) / 2$ = **25.6** kNm/m

Saturated backfill $M_s = F_s \times (h_{water} - 3 \times d_{ds}) / 3$ = **15.1** kNm/m

Water $M_{water} = F_{water} \times (h_{water} - 3 \times d_{ds}) / 3$ = **37.8** kNm/m

Total overturning moment $M_{ot} = M_{sur} + M_{m\_a} + M_{m\_b} + M_s + M_{water}$ = **114.5** kNm/m

Restoring moments

Wall stem $M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2)$ = **34** kNm/m

Wall base $M_{base} = w_{base} \times l_{base} / 2$ = **7.5** kNm/m

Design vertical dead load $M_{dead} = W_{dead} \times l_{load}$ = **94.2** kNm/m

Total restoring moment $M_{rest} = M_{wall} + M_{base} + M_{dead}$ = **135.7** kNm/m

Check bearing pressure

Total vertical reaction $R = W_{total}$ = **134.3** kN/m

Distance to reaction $x_{bar} = l_{base} / 2$ = **675** mm

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

Reaction acts within middle third of base

Bearing pressure at toe $p_{toe} = (R / l_{base}) - (6 \times R \times e / l_{base}^2)$ = **99.5** kN/m²

Bearing pressure at heel $p_{heel} = (R / l_{base}) + (6 \times R \times e / l_{base}^2)$ = **99.5** 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

$F_{prop\_top} = (M_{ot} - M_{rest} + R \times l_{base} / 2 - F_{prop} \times t_{base} / 2) / (h_{stem} + t_{base} / 2)$ = **16.713** kN/m

Propping force to base of wall $F_{prop\_base} = F_{prop} - F_{prop\_top}$ = **28.746** 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	$w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **40.5** kN/m
Wall base	$w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **15.6** kN/m
Applied vertical load	$W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live}$ = **134.7** kN/m
Total vertical load	$W_{total\_f} = w_{wall\_f} + w_{base\_f} + W_{v\_f}$ = **190.8** kN/m

Factored horizontal at-rest forces on wall

Surcharge	$F_{sur\_f} = \gamma_{f\_l} \times K_0 \times Surcharge \times h_{eff}$ = **36.3** kN/m
Moist backfill above water table	$F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2$ = **7.4** kN/m
Moist backfill below water table	$F_{m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **42.4** kN/m
Saturated backfill	$F_{s\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **37.5** kN/m
Water	$F_{water\_f} = \gamma_{f\_e} \times 0.5 \times h_{water}^2 \times \gamma_{water}$ = **55.8** kN/m
Total horizontal load	$F_{total\_f} = F_{sur\_f} + F_{m\_a\_f} + F_{m\_b\_f} + F_{s\_f} + F_{water\_f}$ = **179.5** kN/m

Calculate total propping force

Passive resistance of soil in front of wall	$F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **6.1** 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} = **116.7** kN/m

Factored overturning moments

Surcharge	$M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **70** kNm/m
Moist backfill above water table	$M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **23.7** kNm/m
Moist backfill below water table	$M_{m\_b\_f} = F_{m\_b\_f} \times (h_{water} - 2 \times d_{ds}) / 2$ = **60.4** kNm/m
Saturated backfill	$M_{s\_f} = F_{s\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **35.7** kNm/m
Water	$M_{water\_f} = F_{water\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **53** kNm/m
Total overturning moment	$M_{ot\_f} = M_{sur\_f} + M_{m\_a\_f} + M_{m\_b\_f} + M_{s\_f} + M_{water\_f}$ = **242.7** kNm/m

Restoring moments

Wall stem	$M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **47.6** kNm/m
Wall base	$M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **10.5** kNm/m
Design vertical load	$M_{v\_f} = W_{v\_f} \times l_{load}$ = **158.2** kNm/m
Total restoring moment	$M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{v\_f}$ = **216.3** kNm/m

Factored bearing pressure

Total vertical reaction	$R_f = W_{total\_f}$ = **190.8** kN/m
Distance to reaction	$x_{bar\_f} = l_{base} / 2$ = **675** 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	$p_{toe\_f} = (R_f / l_{base}) - (6 \times R_f \times e_f / l_{base}^2)$ = **141.3** kN/m²
Bearing pressure at heel	$p_{heel\_f} = (R_f / l_{base}) + (6 \times R_f \times e_f / l_{base}^2)$ = **141.3** 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	$p_{stem\_toe\_f} = \max(p_{toe\_f} - (rate \times l_{toe}), 0 \text{ kN/m}^2)$ = **141.3** kN/m²

Bearing pressure at mid stem $p_{stem\_mid\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall} / 2)), 0\ kN/m^2) =$ **141.3** kN/m²

Bearing pressure at stem / heel $p_{stem\_heel\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall})), 0\ kN/m^2) =$ **141.3** kN/m²

Calculate propping forces to top and base of wall

Propping force to top of wall

$F_{prop\_top\_f} = (M_{ot\_f} - M_{rest\_f} + R_f \times l_{base} / 2 - F_{prop\_f} \times t_{base} / 2) / (h_{stem} + t_{base} / 2) =$ **36.649** kN/m

Propping force to base of wall $F_{prop\_base\_f} = F_{prop\_f} - F_{prop\_top\_f} =$ **80.049** 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 $c_{toe} =$ **50** mm

Calculate shear for toe design

Shear from bearing pressure $V_{toe\_bear} = (p_{toe\_f} + p_{stem\_toe\_f}) \times l_{toe} / 2 =$ **141.3** kN/m

Shear from weight of base $V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base} =$ **11.6** kN/m

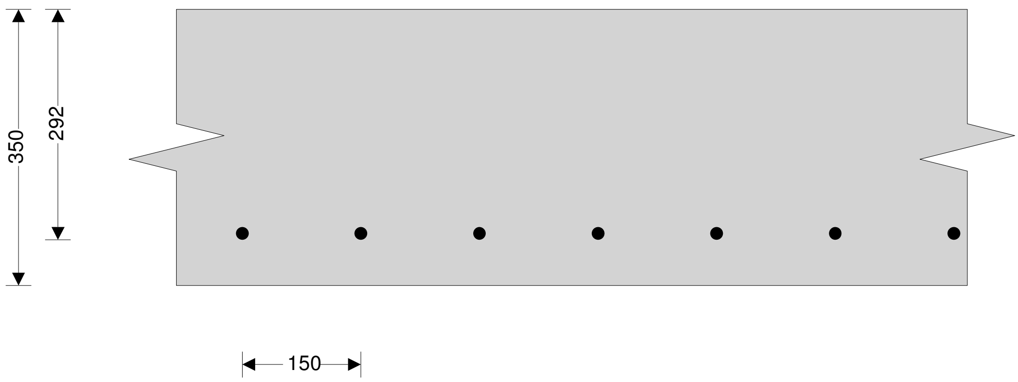
Total shear for toe design $V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base} =$ **129.7** kN/m

Calculate moment for toe design

Moment from bearing pressure $M_{toe\_bear} = (2 \times p_{toe\_f} + p_{stem\_mid\_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6 =$ **97.5** kNm/m

Moment from weight of base $M_{toe\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2) =$ **8** kNm/m

Total moment for toe design $M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base} =$ **89.6** kNm/m



Check toe in bending

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

Depth of reinforcement $d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) =$ **292.0** mm

Constant $K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu}) =$ **0.026**

Compression reinforcement is not required

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

$z_{toe} =$ **277** mm

Area of tension reinforcement required $A_{s\_toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe}) =$ **742** 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 $A_{s\_toe\_req} = \mathrm{Max}(A_{s\_toe\_des}, A_{s\_toe\_min}) =$ **742** mm²/m

Reinforcement provided **16 mm dia.bars @ 150 mm centres**

Area of reinforcement provided $A_{s\_toe\_prov} =$ **1340** mm²/m

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress $v_{toe} = V_{toe} / (b \times d_{toe}) = \mathbf{0.444}$ N/mm^2

Allowable shear stress $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1 \text{ N/mm}^2)}, 5) \times 1 \text{ N/mm}^2 = \mathbf{5.000}$ 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 $v_{c\_toe} = \mathbf{0.617}$ 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 $f_{cu} = \mathbf{40}$ N/mm^2

Characteristic strength of reinforcement $f_y = \mathbf{500}$ N/mm^2

Wall details

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

Cover to reinforcement in stem $c_{stem} = \mathbf{50}$ mm

Cover to reinforcement in wall $c_{wall} = \mathbf{50}$ mm

Factored horizontal at-rest forces on stem

Surcharge $F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds}) = \mathbf{33}$ kN/m

Moist backfill above water table $F_{s\_m\_a\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2 = \mathbf{7.4}$ kN/m

Moist backfill below water table $F_{s\_m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat}) \times h_{sat} = \mathbf{37.2}$ kN/m

Saturated backfill $F_{s\_s\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{sat}^2 = \mathbf{28.9}$ kN/m

Water $F_{s\_water\_f} = 0.5 \times \gamma_{f\_e} \times \gamma_{water} \times h_{sat}^2 = \mathbf{42.9}$ kN/m

Calculate shear for stem design

Surcharge $V_{s\_sur\_f} = 5 \times F_{s\_sur\_f} / 8 = \mathbf{20.7}$ kN/m

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

Moist backfill below water table $V_{s\_m\_b\_f} = F_{s\_m\_b\_f} \times (8 - (n^2 \times (4 - n))) / 8 = \mathbf{29.1}$ kN/m

Saturated backfill $V_{s\_s\_f} = F_{s\_s\_f} \times (1 - (a_l^2 \times ((5 \times L) - a_l) / (20 \times L^3))) = \mathbf{25.6}$ kN/m

Water $V_{s\_water\_f} = F_{s\_water\_f} \times (1 - (a_l^2 \times ((5 \times L) - a_l) / (20 \times L^3))) = \mathbf{38.1}$ kN/m

Total shear for stem design $V_{stem} = V_{s\_sur\_f} + V_{s\_m\_a\_f} + V_{s\_m\_b\_f} + V_{s\_s\_f} + V_{s\_water\_f} = \mathbf{115.4}$ kN/m

Calculate moment for stem design

Surcharge $M_{s\_sur} = F_{s\_sur\_f} \times L / 8 = \mathbf{15.2}$ kNm/m

Moist backfill above water table $M_{s\_m\_a} = F_{s\_m\_a\_f} \times b_l \times ((5 \times L^2) - (3 \times b_l^2)) / (15 \times L^2) = \mathbf{2.4}$ kNm/m

Moist backfill below water table $M_{s\_m\_b} = F_{s\_m\_b\_f} \times a_l \times (2 - n)^2 / 8 = \mathbf{20.1}$ kNm/m

Saturated backfill $M_{s\_s} = F_{s\_s\_f} \times a_l \times ((3 \times a_l^2) - (15 \times a_l \times L) + (20 \times L^2)) / (60 \times L^2) = \mathbf{13.7}$ kNm/m

Water $M_{s\_water} = F_{s\_water\_f} \times a_l \times ((3 \times a_l^2) - (15 \times a_l \times L) + (20 \times L^2)) / (60 \times L^2) = \mathbf{20.4}$
kNm/m

Total moment for stem design $M_{stem} = M_{s\_sur} + M_{s\_m\_a} + M_{s\_m\_b} + M_{s\_s} + M_{s\_water} = \mathbf{71.8}$ kNm/m

Calculate moment for wall design

Surcharge $M_{w\_sur} = 9 \times F_{s\_sur\_f} \times L / 128 = \mathbf{8.5}$ kNm/m

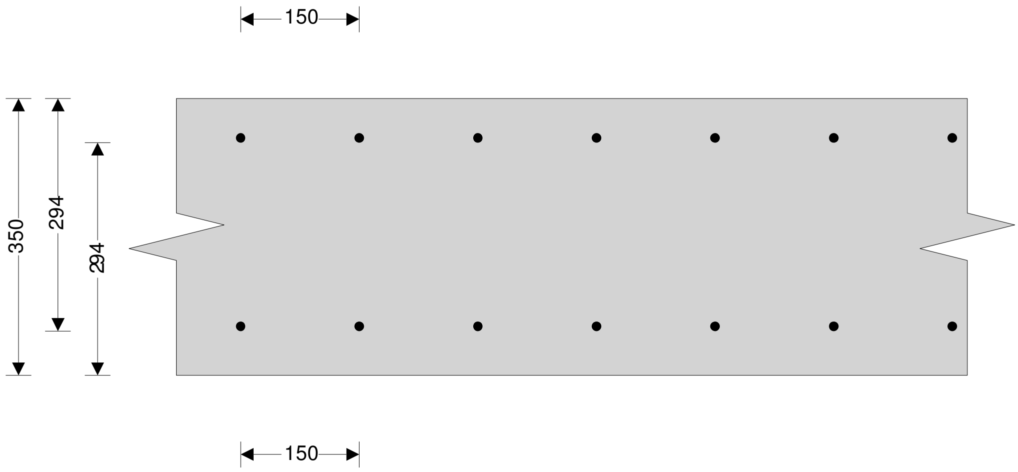
Moist backfill above water table $M_{w\_m\_a} = F_{s\_m\_a\_f} \times 0.577 \times b_l \times [(b_l^3 + 5 \times a_l \times L^2)/(5 \times L^3) - 0.577^2/3] = \mathbf{2.7}$
kNm/m

Moist backfill below water table $M_{w\_m\_b} = F_{s\_m\_b\_f} \times a_l \times [((8 - n^2 \times (4-n))^2 / 16) - 4 + n \times (4-n)]/8 = \mathbf{10.4}$ kNm/m

Saturated backfill $M_{w\_s} = F_{s\_s\_f} \times [a_l^2 \times x \times ((5 \times L) - a_l)/(20 \times L^3) - (x - b_l)^3 / (3 \times a_l^2)] = \mathbf{5.2}$ kNm/m

Water $M_{w\_water} = F_{s\_water\_f} \times [a_l^2 \times x \times ((5 \times L) - a_l)/(20 \times L^3) - (x - b_l)^3 / (3 \times a_l^2)] = \mathbf{7.8}$
kNm/m

Total moment for wall design $M_{wall} = M_{w\_sur} + M_{w\_m\_a} + M_{w\_m\_b} + M_{w\_s} + M_{w\_water} = \mathbf{34.6}$ kNm/m



Check wall stem in bending

Width of wall stem $b = \mathbf{1000}$ mm/m

Depth of reinforcement $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2) = \mathbf{294.0}$ mm

Constant $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu}) = \mathbf{0.021}$

Compression reinforcement is not required

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

$z_{stem} = \mathbf{279}$ mm

Area of tension reinforcement required $A_{s\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem}) = \mathbf{591}$ mm^2/m

Minimum area of tension reinforcement $A_{s\_stem\_min} = k \times b \times t_{wall} = \mathbf{455}$ mm^2/m

Area of tension reinforcement required $A_{s\_stem\_req} = \mathrm{Max}(A_{s\_stem\_des}, A_{s\_stem\_min}) = \mathbf{591}$ mm^2/m

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

Area of reinforcement provided $A_{s\_stem\_prov} = \mathbf{754}$ mm^2/m

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress $v_{stem} = V_{stem} / (b \times d_{stem}) = \mathbf{0.393}$ N/mm^2

Allowable shear stress $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1 \text{ N/mm}^2)}, 5) \times 1 \text{ N/mm}^2 = \mathbf{5.000}$ 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 $v_{c\_stem} = \mathbf{0.507}$ N/mm^2

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

Check mid height of wall in bending

Depth of reinforcement $d_{wall} = t_{wall} - c_{wall} - (\phi_{wall} / 2) = \mathbf{294.0}$ mm

Constant $K_{wall} = M_{wall} / (b \times d_{wall}^2 \times f_{cu}) = \mathbf{0.010}$

Compression reinforcement is not required

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

$z_{wall} = \mathbf{279}$ mm

Area of tension reinforcement required $A_{s\_wall\_des} = M_{wall} / (0.87 \times f_y \times z_{wall}) = \mathbf{285}$ mm^2/m

Minimum area of tension reinforcement $A_{s\_wall\_min} = k \times b \times t_{wall} = \mathbf{455}$ mm^2/m

Area of tension reinforcement required $A_{s\_wall\_req} = \mathrm{Max}(A_{s\_wall\_des}, A_{s\_wall\_min}) = \mathbf{455}$ mm^2/m

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

Area of reinforcement provided $A_{s\_wall\_prov} = \mathbf{754}$ mm^2/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 $f_s = 2 \times f_y \times A_{s\_stem\_req} / (3 \times A_{s\_stem\_prov})$ = **261.4** N/mm^2

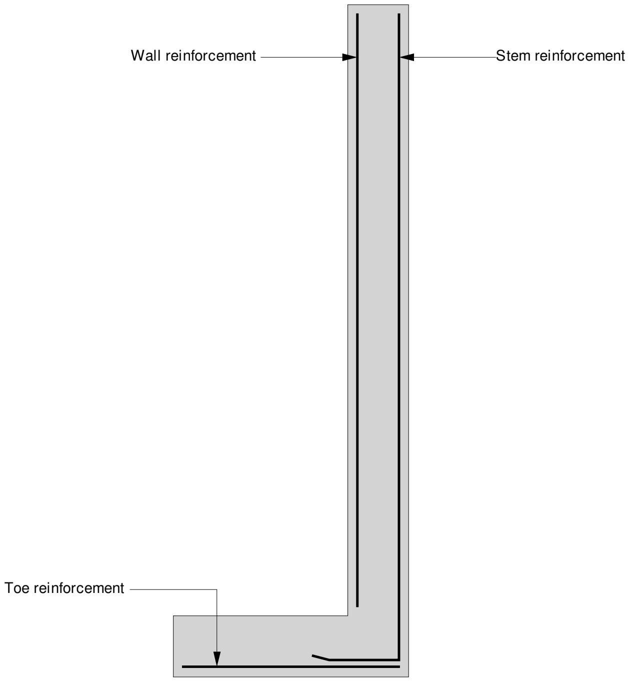
Modification factor $factor_{tens} = \min(0.55 + (477 \text{ N/mm}^2 - f_s)/(120 \times (0.9 \text{ N/mm}^2 + (M_{stem}/(b \times d_{stem}^2)))),2)$ = **1.59**

Maximum span/effective depth ratio $ratio_{max} = ratio_{bas} \times factor_{tens}$ = **31.76**

Actual span/effective depth ratio $ratio_{act} = h_{stem} / d_{stem}$ = **11.90**

PASS - Span to depth ratio is acceptable

Indicative retaining wall reinforcement diagram

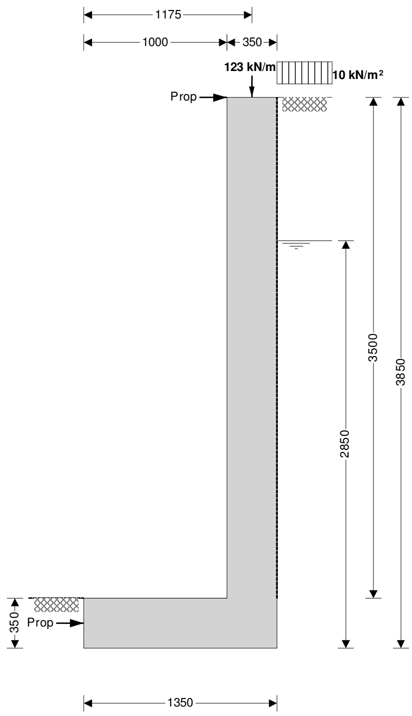


Toe bars - 16 mm dia.@ 150 mm centres - (1340 mm^2/m)
Wall bars - 12 mm dia.@ 150 mm centres - (754 mm^2/m)
Stem bars - 12 mm dia.@ 150 mm centres - (754 mm^2/m)

Conisbee 1-5 Offord Street London N1 1DH	Project 1 St Marks Crescent			Job no. 180507	
	Calcs for Retaining wall No. 1/2			Start page no./Revision 1	
	Calcs by HH	Calcs date 12/06/2018	Checked by	Checked date	Approved by	Approved date

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} = **3500** mm
Thickness of wall stem	t_{wall} = **350** mm
Length of toe	l_{toe} = **1000** mm
Length of heel	l_{heel} = **0** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **1350** mm
Thickness of base	t_{base} = **350** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **900** mm
Thickness of downstand	t_{ds} = **350** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **3850** 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} = **2850** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0\ mm)$ = **2500** 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	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **3850** mm

Retained material details

Mobilisation factor	M = **1.5**
Moist density of retained material	γ_m = **18.0** kN/m^3

Saturated density of retained material γ_s = **21.0** kN/m^3

Design shear strength ϕ' = **24.2** deg

Angle of wall friction δ = **18.6** deg

Base material details

Firm clay

Moist density γ_{mb} = **18.0** kN/m^3

Design shear strength ϕ'_b = **24.2** deg

Design base friction δ_b = **18.6** deg

Allowable bearing pressure $P_{bearing}$ = **125** kN/m^2

Using Coulomb theory

Active pressure coefficient for retained material

$$K_a = \sin(\alpha + \phi')^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta) \times [1 + \sqrt{(\sin(\phi' + \delta) \times \sin(\phi' - \beta) / (\sin(\alpha - \delta) \times \sin(\alpha + \beta)))}]^2) = \mathbf{0.369}$$

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 $K_0 = 1 - \sin(\phi')$ = **0.590**

Loading details

Surcharge load on plan Surcharge = **10.0** kN/m^2

Applied vertical dead load on wall W_{dead} = **110.0** kN/m

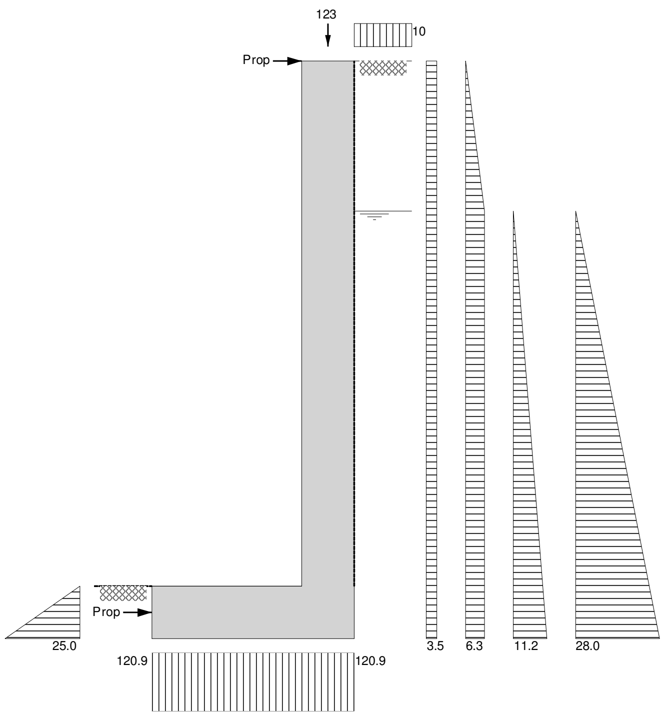
Applied vertical live load on wall W_{live} = **13.1** kN/m

Position of applied vertical load on wall l_{load} = **1175** 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 $w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **28.9** kN/m

Wall base $w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **11.2** kN/m

Applied vertical load $W_v = W_{dead} + W_{live}$ = **123.1** kN/m

Total vertical load $W_{total} = w_{wall} + w_{base} + W_v$ = **163.2** kN/m

Horizontal forces on wall

Surcharge $F_{sur} = K_a \times \cos(90 - \alpha + \delta) \times Surcharge \times h_{eff}$ = **13.5** kN/m

Moist backfill above water table $F_{m\_a} = 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water})^2$ = **3.1** kN/m

Moist backfill below water table $F_{m\_b} = K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **17.9** kN/m

Saturated backfill $F_s = 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **15.9** kN/m

Water $F_{water} = 0.5 \times h_{water}^2 \times \gamma_{water}$ = **39.8** kN/m

Total horizontal load $F_{total} = F_{sur} + F_{m\_a} + F_{m\_b} + F_s + F_{water}$ = **90.3** kN/m

Calculate total propping force

Passive resistance of soil in front of wall $F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **4.4** kN/m

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

F_{prop} = **35.4** kN/m

Overturning moments

Surcharge $M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **25.9** kNm/m

Moist backfill above water table $M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **10** kNm/m

Moist backfill below water table $M_{m\_b} = F_{m\_b} \times (h_{water} - 2 \times d_{ds}) / 2$ = **25.6** kNm/m

Saturated backfill $M_s = F_s \times (h_{water} - 3 \times d_{ds}) / 3$ = **15.1** kNm/m

Water $M_{water} = F_{water} \times (h_{water} - 3 \times d_{ds}) / 3$ = **37.8** kNm/m

Total overturning moment $M_{ot} = M_{sur} + M_{m\_a} + M_{m\_b} + M_s + M_{water}$ = **114.5** kNm/m

Restoring moments

Wall stem $M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2)$ = **34** kNm/m

Wall base $M_{base} = w_{base} \times l_{base} / 2$ = **7.5** kNm/m

Design vertical dead load $M_{dead} = W_{dead} \times l_{load}$ = **129.3** kNm/m

Total restoring moment $M_{rest} = M_{wall} + M_{base} + M_{dead}$ = **170.7** kNm/m

Check bearing pressure

Total vertical reaction $R = W_{total}$ = **163.2** kN/m

Distance to reaction $x_{bar} = l_{base} / 2$ = **675** mm

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

Reaction acts within middle third of base

Bearing pressure at toe $p_{toe} = (R / l_{base}) - (6 \times R \times e / l_{base}^2)$ = **120.9** kN/m²

Bearing pressure at heel $p_{heel} = (R / l_{base}) + (6 \times R \times e / l_{base}^2)$ = **120.9** 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

$F_{prop\_top} = (M_{ot} - M_{rest} + R \times l_{base} / 2 - F_{prop} \times t_{base} / 2) / (h_{stem} + t_{base} / 2)$ = **12.975** kN/m

Propping force to base of wall $F_{prop\_base} = F_{prop} - F_{prop\_top}$ = **22.454** 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 $w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **40.5** kN/m

Wall base $w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **15.6** kN/m

Applied vertical load $W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live}$ = **175** kN/m

Total vertical load $W_{total\_f} = w_{wall\_f} + w_{base\_f} + W_{v\_f}$ = **231.1** kN/m

Factored horizontal at-rest forces on wall

Surcharge $F_{sur\_f} = \gamma_{f\_l} \times K_0 \times Surcharge \times h_{eff}$ = **36.3** kN/m

Moist backfill above water table $F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2$ = **7.4** kN/m

Moist backfill below water table $F_{m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **42.4** kN/m

Saturated backfill $F_{s\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **37.5** kN/m

Water $F_{water\_f} = \gamma_{f\_e} \times 0.5 \times h_{water}^2 \times \gamma_{water}$ = **55.8** kN/m

Total horizontal load $F_{total\_f} = F_{sur\_f} + F_{m\_a\_f} + F_{m\_b\_f} + F_{s\_f} + F_{water\_f}$ = **179.5** kN/m

Calculate total propping force

Passive resistance of soil in front of wall $F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **6.1** 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} = **102.7** kN/m

Factored overturning moments

Surcharge $M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **70** kNm/m

Moist backfill above water table $M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **23.7** kNm/m

Moist backfill below water table $M_{m\_b\_f} = F_{m\_b\_f} \times (h_{water} - 2 \times d_{ds}) / 2$ = **60.4** kNm/m

Saturated backfill $M_{s\_f} = F_{s\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **35.7** kNm/m

Water $M_{water\_f} = F_{water\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **53** kNm/m

Total overturning moment $M_{ot\_f} = M_{sur\_f} + M_{m\_a\_f} + M_{m\_b\_f} + M_{s\_f} + M_{water\_f}$ = **242.7** kNm/m

Restoring moments

Wall stem $M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **47.6** kNm/m

Wall base $M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **10.5** kNm/m

Design vertical load $M_{v\_f} = W_{v\_f} \times l_{load}$ = **205.6** kNm/m

Total restoring moment $M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{v\_f}$ = **263.7** kNm/m

Factored bearing pressure

Total vertical reaction $R_f = W_{total\_f}$ = **231.1** kN/m

Distance to reaction $x_{bar\_f} = l_{base} / 2$ = **675** mm

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

Reaction acts within middle third of base

Bearing pressure at toe $p_{toe\_f} = (R_f / l_{base}) - (6 \times R_f \times e_f / l_{base}^2)$ = **171.2** kN/m²

Bearing pressure at heel $p_{heel\_f} = (R_f / l_{base}) + (6 \times R_f \times e_f / l_{base}^2)$ = **171.2** 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 $p_{stem\_toe\_f} = \max(p_{toe\_f} - (rate \times l_{toe}), 0 \text{ kN/m}^2)$ = **171.2** kN/m²

Bearing pressure at mid stem $p_{stem\_mid\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall} / 2)), 0\ kN/m^2) =$ **171.2** kN/m^2

Bearing pressure at stem / heel $p_{stem\_heel\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall})), 0\ kN/m^2) =$ **171.2** kN/m^2

Calculate propping forces to top and base of wall

Propping force to top of wall

$F_{prop\_top\_f} = (M_{ot\_f} - M_{rest\_f} + R_f \times l_{base} / 2 - F_{prop\_f} \times t_{base} / 2) / (h_{stem} + t_{base} / 2) =$ **31.832** kN/m

Propping force to base of wall $F_{prop\_base\_f} = F_{prop\_f} - F_{prop\_top\_f} =$ **70.825** kN/m

Design of reinforced concrete retaining wall toe (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

Base details

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

Cover to reinforcement in toe $c_{toe} =$ **50** mm

Calculate shear for toe design

Shear from bearing pressure $V_{toe\_bear} = (p_{toe\_f} + p_{stem\_toe\_f}) \times l_{toe} / 2 =$ **171.2** kN/m

Shear from weight of base $V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base} =$ **11.6** kN/m

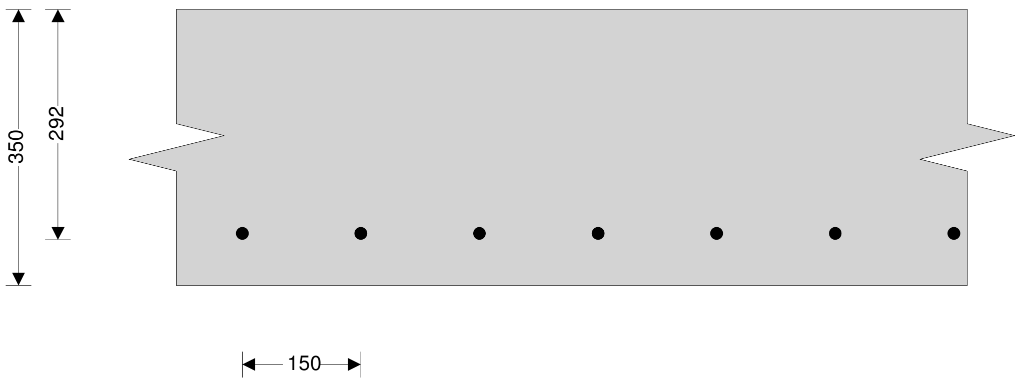
Total shear for toe design $V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base} =$ **159.6** kN/m

Calculate moment for toe design

Moment from bearing pressure $M_{toe\_bear} = (2 \times p_{toe\_f} + p_{stem\_mid\_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6 =$ **118.2** kNm/m

Moment from weight of base $M_{toe\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2) =$ **8** kNm/m

Total moment for toe design $M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base} =$ **110.2** kNm/m



Check toe in bending

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

Depth of reinforcement $d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) =$ **292.0** mm

Constant $K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu}) =$ **0.032**

Compression reinforcement is not required

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

$z_{toe} =$ **277** mm

Area of tension reinforcement required $A_{s\_toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe}) =$ **913** mm^2/m

Minimum area of tension reinforcement $A_{s\_toe\_min} = k \times b \times t_{base} =$ **455** mm^2/m

Area of tension reinforcement required $A_{s\_toe\_req} = \max(A_{s\_toe\_des}, A_{s\_toe\_min}) =$ **913** mm^2/m

Reinforcement provided **16 mm dia.bars @ 150 mm centres**

Area of reinforcement provided $A_{s\_toe\_prov} =$ **1340** mm^2/m

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress $v_{toe} = V_{toe} / (b \times d_{toe}) = \mathbf{0.547}$ N/mm^2

Allowable shear stress $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1 \text{ N/mm}^2)}, 5) \times 1 \text{ N/mm}^2 = \mathbf{5.000}$ 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 $v_{c\_toe} = \mathbf{0.617}$ 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 $f_{cu} = \mathbf{40}$ N/mm^2

Characteristic strength of reinforcement $f_y = \mathbf{500}$ N/mm^2

Wall details

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

Cover to reinforcement in stem $c_{stem} = \mathbf{50}$ mm

Cover to reinforcement in wall $c_{wall} = \mathbf{50}$ mm

Factored horizontal at-rest forces on stem

Surcharge $F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds}) = \mathbf{33}$ kN/m

Moist backfill above water table $F_{s\_m\_a\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2 = \mathbf{7.4}$ kN/m

Moist backfill below water table $F_{s\_m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat}) \times h_{sat} = \mathbf{37.2}$ kN/m

Saturated backfill $F_{s\_s\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{sat}^2 = \mathbf{28.9}$ kN/m

Water $F_{s\_water\_f} = 0.5 \times \gamma_{f\_e} \times \gamma_{water} \times h_{sat}^2 = \mathbf{42.9}$ kN/m

Calculate shear for stem design

Surcharge $V_{s\_sur\_f} = 5 \times F_{s\_sur\_f} / 8 = \mathbf{20.7}$ kN/m

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

Moist backfill below water table $V_{s\_m\_b\_f} = F_{s\_m\_b\_f} \times (8 - (n^2 \times (4 - n))) / 8 = \mathbf{29.1}$ kN/m

Saturated backfill $V_{s\_s\_f} = F_{s\_s\_f} \times (1 - (a_l^2 \times ((5 \times L) - a_l) / (20 \times L^3))) = \mathbf{25.6}$ kN/m

Water $V_{s\_water\_f} = F_{s\_water\_f} \times (1 - (a_l^2 \times ((5 \times L) - a_l) / (20 \times L^3))) = \mathbf{38.1}$ kN/m

Total shear for stem design $V_{stem} = V_{s\_sur\_f} + V_{s\_m\_a\_f} + V_{s\_m\_b\_f} + V_{s\_s\_f} + V_{s\_water\_f} = \mathbf{115.4}$ kN/m

Calculate moment for stem design

Surcharge $M_{s\_sur} = F_{s\_sur\_f} \times L / 8 = \mathbf{15.2}$ kNm/m

Moist backfill above water table $M_{s\_m\_a} = F_{s\_m\_a\_f} \times b_l \times ((5 \times L^2) - (3 \times b_l^2)) / (15 \times L^2) = \mathbf{2.4}$ kNm/m

Moist backfill below water table $M_{s\_m\_b} = F_{s\_m\_b\_f} \times a_l \times (2 - n)^2 / 8 = \mathbf{20.1}$ kNm/m

Saturated backfill $M_{s\_s} = F_{s\_s\_f} \times a_l \times ((3 \times a_l^2) - (15 \times a_l \times L) + (20 \times L^2)) / (60 \times L^2) = \mathbf{13.7}$ kNm/m

Water $M_{s\_water} = F_{s\_water\_f} \times a_l \times ((3 \times a_l^2) - (15 \times a_l \times L) + (20 \times L^2)) / (60 \times L^2) = \mathbf{20.4}$
kNm/m

Total moment for stem design $M_{stem} = M_{s\_sur} + M_{s\_m\_a} + M_{s\_m\_b} + M_{s\_s} + M_{s\_water} = \mathbf{71.8}$ kNm/m

Calculate moment for wall design

Surcharge $M_{w\_sur} = 9 \times F_{s\_sur\_f} \times L / 128 = \mathbf{8.5}$ kNm/m

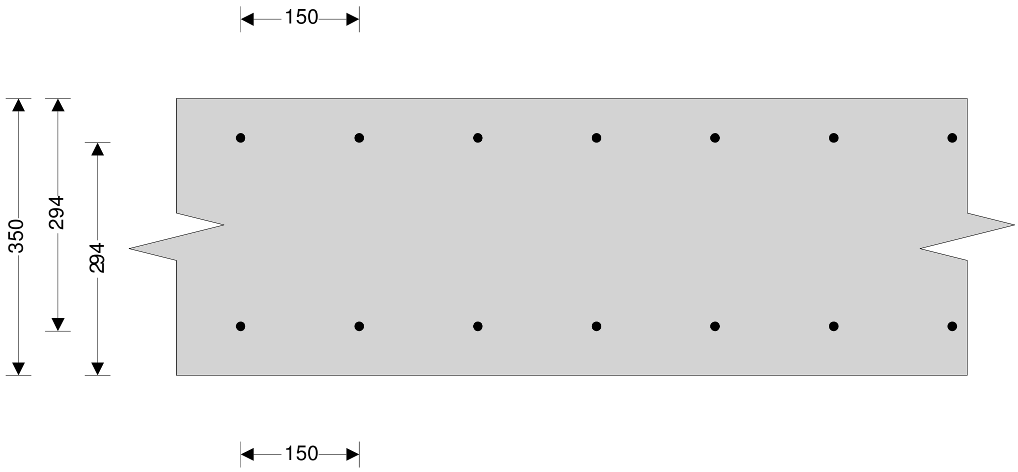
Moist backfill above water table $M_{w\_m\_a} = F_{s\_m\_a\_f} \times 0.577 \times b_l \times [(b_l^3 + 5 \times a_l \times L^2)/(5 \times L^3) - 0.577^2/3] = \mathbf{2.7}$
kNm/m

Moist backfill below water table $M_{w\_m\_b} = F_{s\_m\_b\_f} \times a_l \times [((8 - n^2 \times (4-n))^2 / 16) - 4 + n \times (4-n)]/8 = \mathbf{10.4}$ kNm/m

Saturated backfill $M_{w\_s} = F_{s\_s\_f} \times [a_l^2 \times x \times ((5 \times L) - a_l)/(20 \times L^3) - (x - b_l)^3 / (3 \times a_l^2)] = \mathbf{5.2}$ kNm/m

Water $M_{w\_water} = F_{s\_water\_f} \times [a_l^2 \times x \times ((5 \times L) - a_l)/(20 \times L^3) - (x - b_l)^3 / (3 \times a_l^2)] = \mathbf{7.8}$
kNm/m

Total moment for wall design $M_{wall} = M_{w\_sur} + M_{w\_m\_a} + M_{w\_m\_b} + M_{w\_s} + M_{w\_water} =$ **34.6** kNm/m



Check wall stem in bending

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

Depth of reinforcement: $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2) =$ **294.0** mm

Constant: $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu}) =$ **0.021**

Compression reinforcement is not required

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

$z_{stem} =$ **279** mm

Area of tension reinforcement required: $A_{s\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem}) =$ **591** 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: $A_{s\_stem\_req} = \mathrm{Max}(A_{s\_stem\_des}, A_{s\_stem\_min}) =$ **591** 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: $v_{stem} = V_{stem} / (b \times d_{stem}) =$ **0.393** 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: $v_{c\_stem} =$ **0.507** N/mm²

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

Check mid height of wall in bending

Depth of reinforcement: $d_{wall} = t_{wall} - c_{wall} - (\phi_{wall} / 2) =$ **294.0** mm

Constant: $K_{wall} = M_{wall} / (b \times d_{wall}^2 \times f_{cu}) =$ **0.010**

Compression reinforcement is not required

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

$z_{wall} =$ **279** mm

Area of tension reinforcement required: $A_{s\_wall\_des} = M_{wall} / (0.87 \times f_y \times z_{wall}) =$ **285** mm²/m

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

Area of tension reinforcement required: $A_{s\_wall\_req} = \mathrm{Max}(A_{s\_wall\_des}, A_{s\_wall\_min}) =$ **455** mm²/m

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

Area of reinforcement provided: $A_{s\_wall\_prov} =$ **754** 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 $f_s = 2 \times f_y \times A_{s\_stem\_req} / (3 \times A_{s\_stem\_prov})$ = **261.4** N/mm²

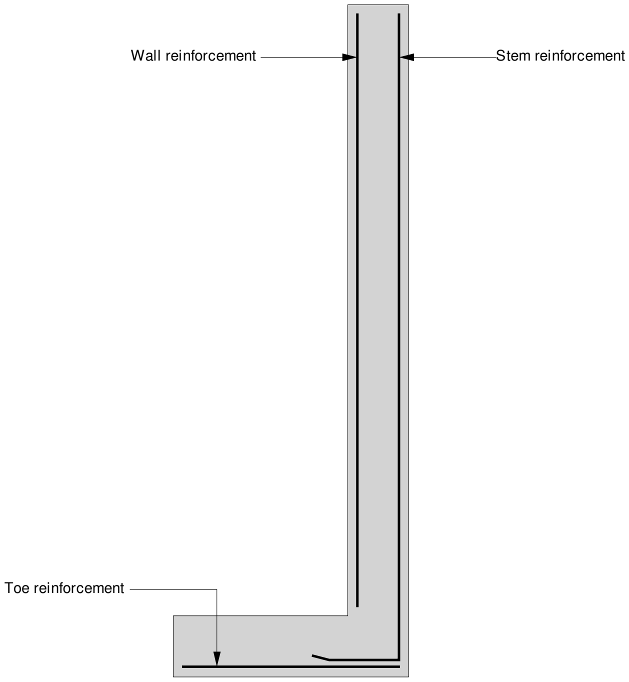
Modification factor $factor_{tens} = \min(0.55 + (477 \text{ N/mm}^2 - f_s)/(120 \times (0.9 \text{ N/mm}^2 + (M_{stem}/(b \times d_{stem}^2)))),2)$ = **1.59**

Maximum span/effective depth ratio $ratio_{max} = ratio_{bas} \times factor_{tens}$ = **31.76**

Actual span/effective depth ratio $ratio_{act} = h_{stem} / d_{stem}$ = **11.90**

PASS - Span to depth ratio is acceptable

Indicative retaining wall reinforcement diagram

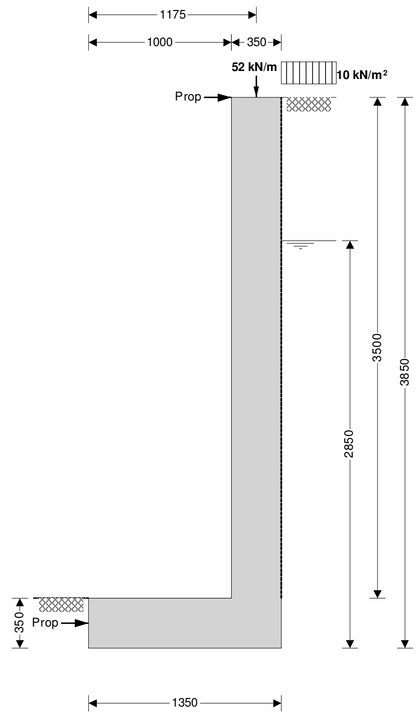


Toe bars - 16 mm dia.@ 150 mm centres - (1340 mm^2/m)
Wall bars - 12 mm dia.@ 150 mm centres - (754 mm^2/m)
Stem bars - 12 mm dia.@ 150 mm centres - (754 mm^2/m)

Conisbee 1-5 Offord Street London N1 1DH	Project 1 St Marks Crescent				Job no. 180507	
	Calcs for Retaining wall No. 1/2 Rear				Start page no./Revision 1	
	Calcs by HH	Calcs date 13/06/2018	Checked by	Checked date	Approved by	Approved date

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} = **3500** mm
Thickness of wall stem	t_{wall} = **350** mm
Length of toe	l_{toe} = **1000** mm
Length of heel	l_{heel} = **0** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **1350** mm
Thickness of base	t_{base} = **350** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **900** mm
Thickness of downstand	t_{ds} = **350** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **3850** 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} = **2850** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0\text{ mm})$ = **2500** 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	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **3850** mm

Retained material details

Mobilisation factor	M = **1.5**
Moist density of retained material	γ_m = **18.0** kN/m^3

Saturated density of retained material γ_s = **21.0** kN/m^3

Design shear strength ϕ' = **24.2** deg

Angle of wall friction δ = **18.6** deg

Base material details

Firm clay

Moist density γ_{mb} = **18.0** kN/m^3

Design shear strength ϕ'_b = **24.2** deg

Design base friction δ_b = **18.6** deg

Allowable bearing pressure $P_{bearing}$ = **125** kN/m^2

Using Coulomb theory

Active pressure coefficient for retained material

$$K_a = \sin(\alpha + \phi')^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta) \times [1 + \sqrt{(\sin(\phi' + \delta) \times \sin(\phi' - \beta) / (\sin(\alpha - \delta) \times \sin(\alpha + \beta)))}]^2) = \mathbf{0.369}$$

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 $K_0 = 1 - \sin(\phi')$ = **0.590**

Loading details

Surcharge load on plan Surcharge = **10.0** kN/m^2

Applied vertical dead load on wall W_{dead} = **47.6** kN/m

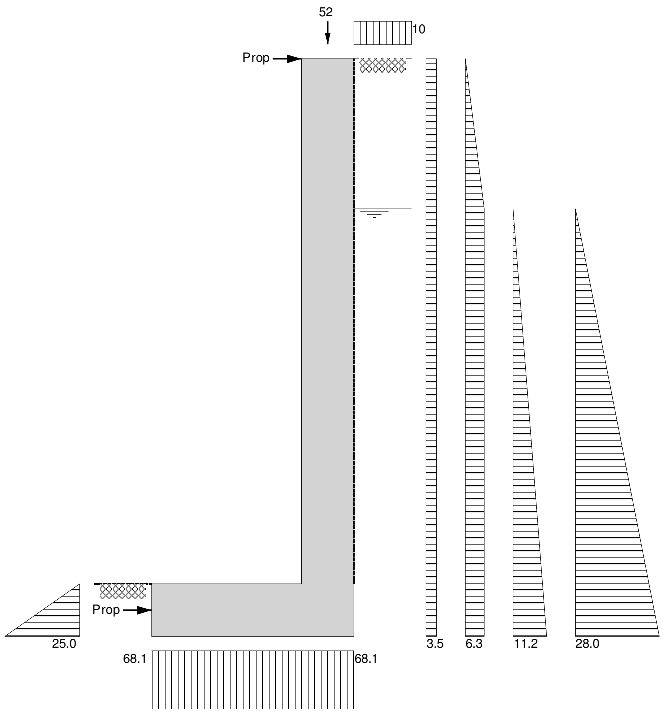
Applied vertical live load on wall W_{live} = **4.2** kN/m

Position of applied vertical load on wall l_{load} = **1175** 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 — $w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **28.9** kN/m

Wall base — $w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **11.2** kN/m

Applied vertical load — $W_v = W_{dead} + W_{live}$ = **51.8** kN/m

Total vertical load — $W_{total} = w_{wall} + w_{base} + W_v$ = **91.9** kN/m

Horizontal forces on wall

Surcharge — $F_{sur} = K_a \times \cos(90 - \alpha + \delta) \times Surcharge \times h_{eff}$ = **13.5** kN/m

Moist backfill above water table — $F_{m\_a} = 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water})^2$ = **3.1** kN/m

Moist backfill below water table — $F_{m\_b} = K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **17.9** kN/m

Saturated backfill — $F_s = 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **15.9** kN/m

Water — $F_{water} = 0.5 \times h_{water}^2 \times \gamma_{water}$ = **39.8** kN/m

Total horizontal load — $F_{total} = F_{sur} + F_{m\_a} + F_{m\_b} + F_s + F_{water}$ = **90.3** kN/m

Calculate total propping force

Passive resistance of soil in front of wall — $F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **4.4** kN/m

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

F_{prop} = **56.4** kN/m

Overturning moments

Surcharge — $M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **25.9** kNm/m

Moist backfill above water table — $M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **10** kNm/m

Moist backfill below water table — $M_{m\_b} = F_{m\_b} \times (h_{water} - 2 \times d_{ds}) / 2$ = **25.6** kNm/m

Saturated backfill — $M_s = F_s \times (h_{water} - 3 \times d_{ds}) / 3$ = **15.1** kNm/m

Water — $M_{water} = F_{water} \times (h_{water} - 3 \times d_{ds}) / 3$ = **37.8** kNm/m

Total overturning moment — $M_{ot} = M_{sur} + M_{m\_a} + M_{m\_b} + M_s + M_{water}$ = **114.5** kNm/m

Restoring moments

Wall stem — $M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2)$ = **34** kNm/m

Wall base — $M_{base} = w_{base} \times l_{base} / 2$ = **7.5** kNm/m

Design vertical dead load — $M_{dead} = W_{dead} \times l_{load}$ = **55.9** kNm/m

Total restoring moment — $M_{rest} = M_{wall} + M_{base} + M_{dead}$ = **97.4** kNm/m

Check bearing pressure

Total vertical reaction — $R = W_{total}$ = **91.9** kN/m

Distance to reaction — $x_{bar} = l_{base} / 2$ = **675** mm

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

Reaction acts within middle third of base

Bearing pressure at toe — $p_{toe} = (R / l_{base}) - (6 \times R \times e / l_{base}^2)$ = **68.1** kN/m²

Bearing pressure at heel — $p_{heel} = (R / l_{base}) + (6 \times R \times e / l_{base}^2)$ = **68.1** 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

$F_{prop\_top} = (M_{ot} - M_{rest} + R \times l_{base} / 2 - F_{prop} \times t_{base} / 2) / (h_{stem} + t_{base} / 2)$ = **18.829** kN/m

Propping force to base of wall — $F_{prop\_base} = F_{prop} - F_{prop\_top}$ = **37.600** 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 $w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **40.5** kN/m

Wall base $w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **15.6** kN/m

Applied vertical load $W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live}$ = **73.4** kN/m

Total vertical load $W_{total\_f} = w_{wall\_f} + w_{base\_f} + W_{v\_f}$ = **129.5** kN/m

Factored horizontal at-rest forces on wall

Surcharge $F_{sur\_f} = \gamma_{f\_l} \times K_0 \times Surcharge \times h_{eff}$ = **36.3** kN/m

Moist backfill above water table $F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2$ = **7.4** kN/m

Moist backfill below water table $F_{m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **42.4** kN/m

Saturated backfill $F_{s\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **37.5** kN/m

Water $F_{water\_f} = \gamma_{f\_e} \times 0.5 \times h_{water}^2 \times \gamma_{water}$ = **55.8** kN/m

Total horizontal load $F_{total\_f} = F_{sur\_f} + F_{m\_a\_f} + F_{m\_b\_f} + F_{s\_f} + F_{water\_f}$ = **179.5** kN/m

Calculate total propping force

Passive resistance of soil in front of wall $F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **6.1** 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} = **132.1** kN/m

Factored overturning moments

Surcharge $M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **70** kNm/m

Moist backfill above water table $M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **23.7** kNm/m

Moist backfill below water table $M_{m\_b\_f} = F_{m\_b\_f} \times (h_{water} - 2 \times d_{ds}) / 2$ = **60.4** kNm/m

Saturated backfill $M_{s\_f} = F_{s\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **35.7** kNm/m

Water $M_{water\_f} = F_{water\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **53** kNm/m

Total overturning moment $M_{ot\_f} = M_{sur\_f} + M_{m\_a\_f} + M_{m\_b\_f} + M_{s\_f} + M_{water\_f}$ = **242.7** kNm/m

Restoring moments

Wall stem $M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **47.6** kNm/m

Wall base $M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **10.5** kNm/m

Design vertical load $M_{v\_f} = W_{v\_f} \times l_{load}$ = **86.2** kNm/m

Total restoring moment $M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{v\_f}$ = **144.3** kNm/m

Factored bearing pressure

Total vertical reaction $R_f = W_{total\_f}$ = **129.5** kN/m

Distance to reaction $x_{bar\_f} = l_{base} / 2$ = **675** mm

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

Reaction acts within middle third of base

Bearing pressure at toe $p_{toe\_f} = (R_f / l_{base}) - (6 \times R_f \times e_f / l_{base}^2)$ = **95.9** kN/m^2

Bearing pressure at heel $p_{heel\_f} = (R_f / l_{base}) + (6 \times R_f \times e_f / l_{base}^2)$ = **95.9** kN/m^2

Rate of change of base reaction $rate = (p_{toe\_f} - p_{heel\_f}) / l_{base}$ = **0.00** kN/m^2/m

Bearing pressure at stem / toe $p_{stem\_toe\_f} = \max(p_{toe\_f} - (rate \times l_{toe}), 0 \text{ kN/m}^2)$ = **95.9** kN/m^2

Bearing pressure at mid stem $p_{stem\_mid\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall} / 2)), 0\ kN/m^2) = \mathbf{95.9}\ kN/m^2$

Bearing pressure at stem / heel $p_{stem\_heel\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall})), 0\ kN/m^2) = \mathbf{95.9}\ kN/m^2$

Calculate propping forces to top and base of wall

Propping force to top of wall

$F_{prop\_top\_f} = (M_{ot\_f} - M_{rest\_f} + R_f \times l_{base} / 2 - F_{prop\_f} \times t_{base} / 2) / (h_{stem} + t_{base} / 2) = \mathbf{44.256}\ kN/m$

Propping force to base of wall $F_{prop\_base\_f} = F_{prop\_f} - F_{prop\_top\_f} = \mathbf{87.801}\ kN/m$

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

Material properties

Characteristic strength of concrete $f_{cu} = \mathbf{40}\ N/mm^2$

Characteristic strength of reinforcement $f_y = \mathbf{500}\ N/mm^2$

Base details

Minimum area of reinforcement $k = \mathbf{0.13}\ \%$

Cover to reinforcement in toe $c_{toe} = \mathbf{50}\ mm$

Calculate shear for toe design

Shear from bearing pressure $V_{toe\_bear} = (p_{toe\_f} + p_{stem\_toe\_f}) \times l_{toe} / 2 = \mathbf{95.9}\ kN/m$

Shear from weight of base $V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base} = \mathbf{11.6}\ kN/m$

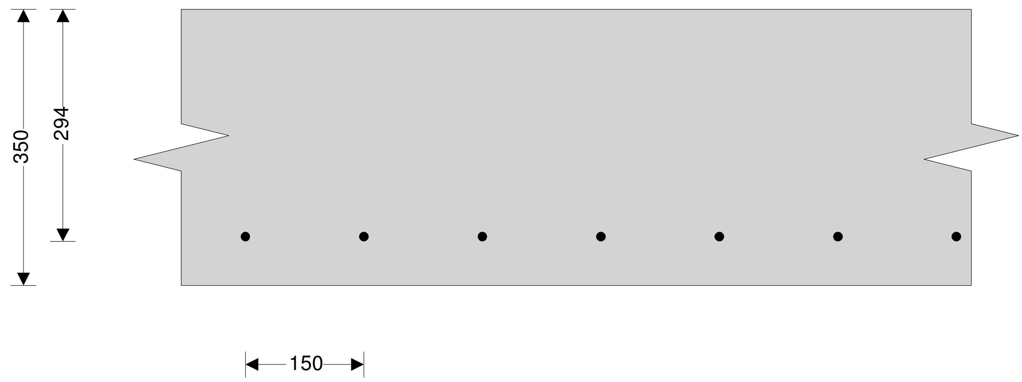
Total shear for toe design $V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base} = \mathbf{84.3}\ kN/m$

Calculate moment for toe design

Moment from bearing pressure $M_{toe\_bear} = (2 \times p_{toe\_f} + p_{stem\_mid\_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6 = \mathbf{66.2}\ kNm/m$

Moment from weight of base $M_{toe\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2) = \mathbf{8}\ kNm/m$

Total moment for toe design $M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base} = \mathbf{58.2}\ kNm/m$



Check toe in bending

Width of toe $b = \mathbf{1000}\ mm/m$

Depth of reinforcement $d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) = \mathbf{294.0}\ mm$

Constant $K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu}) = \mathbf{0.017}$

Compression reinforcement is not required

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

$z_{toe} = \mathbf{279}\ mm$

Area of tension reinforcement required $A_{s\_toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe}) = \mathbf{479}\ mm^2/m$

Minimum area of tension reinforcement $A_{s\_toe\_min} = k \times b \times t_{base} = \mathbf{455}\ mm^2/m$

Area of tension reinforcement required $A_{s\_toe\_req} = \max(A_{s\_toe\_des}, A_{s\_toe\_min}) = \mathbf{479}\ mm^2/m$

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

Area of reinforcement provided $A_{s\_toe\_prov} = \mathbf{754}\ mm^2/m$

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress $v_{toe} = V_{toe} / (b \times d_{toe})$ = **0.287** 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** 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} = **0.507** N/mm^2

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

<u>Design of reinforced concrete retaining wall stem (BS 8002:1994)</u>

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} = **50** mm

Cover to reinforcement in wall c_{wall} = **50** mm

Factored horizontal at-rest forces on stem

Surcharge $F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds})$ = **33** kN/m

Moist backfill above water table $F_{s\_m\_a\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2$ = **7.4** kN/m

Moist backfill below water table $F_{s\_m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat}) \times h_{sat}$ = **37.2** kN/m

Saturated backfill $F_{s\_s\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{sat}^2$ = **28.9** kN/m

Water $F_{s\_water\_f} = 0.5 \times \gamma_{f\_e} \times \gamma_{water} \times h_{sat}^2$ = **42.9** kN/m

Calculate shear for stem design

Surcharge $V_{s\_sur\_f} = 5 \times F_{s\_sur\_f} / 8$ = **20.7** kN/m

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

Moist backfill below water table $V_{s\_m\_b\_f} = F_{s\_m\_b\_f} \times (8 - (n^2 \times (4 - n))) / 8$ = **29.1** kN/m

Saturated backfill $V_{s\_s\_f} = F_{s\_s\_f} \times (1 - (a_l^2 \times ((5 \times L) - a_l) / (20 \times L^3)))$ = **25.6** kN/m

Water $V_{s\_water\_f} = F_{s\_water\_f} \times (1 - (a_l^2 \times ((5 \times L) - a_l) / (20 \times L^3)))$ = **38.1** kN/m

Total shear for stem design $V_{stem} = V_{s\_sur\_f} + V_{s\_m\_a\_f} + V_{s\_m\_b\_f} + V_{s\_s\_f} + V_{s\_water\_f}$ = **115.4** kN/m

Calculate moment for stem design

Surcharge $M_{s\_sur} = F_{s\_sur\_f} \times L / 8$ = **15.2** kNm/m

Moist backfill above water table $M_{s\_m\_a} = F_{s\_m\_a\_f} \times b_l \times ((5 \times L^2) - (3 \times b_l^2)) / (15 \times L^2)$ = **2.4** kNm/m

Moist backfill below water table $M_{s\_m\_b} = F_{s\_m\_b\_f} \times a_l \times (2 - n)^2 / 8$ = **20.1** kNm/m

Saturated backfill $M_{s\_s} = F_{s\_s\_f} \times a_l \times ((3 \times a_l^2) - (15 \times a_l \times L) + (20 \times L^2)) / (60 \times L^2)$ = **13.7** kNm/m

Water $M_{s\_water} = F_{s\_water\_f} \times a_l \times ((3 \times a_l^2) - (15 \times a_l \times L) + (20 \times L^2)) / (60 \times L^2)$ = **20.4**
kNm/m

Total moment for stem design $M_{stem} = M_{s\_sur} + M_{s\_m\_a} + M_{s\_m\_b} + M_{s\_s} + M_{s\_water}$ = **71.8** kNm/m

Calculate moment for wall design

Surcharge $M_{w\_sur} = 9 \times F_{s\_sur\_f} \times L / 128$ = **8.5** kNm/m

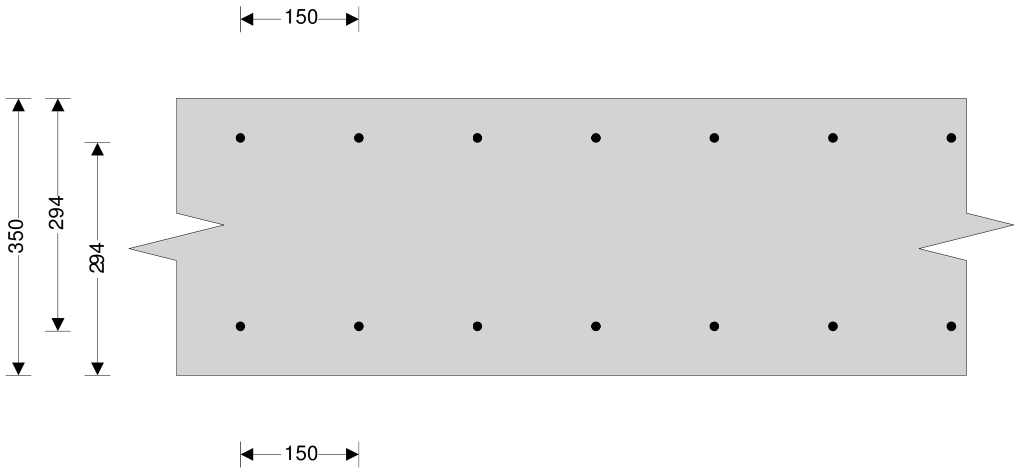
Moist backfill above water table $M_{w\_m\_a} = F_{s\_m\_a\_f} \times 0.577 \times b_l \times [(b_l^3 + 5 \times a_l \times L^2)/(5 \times L^3) - 0.577^2/3]$ = **2.7**
kNm/m

Moist backfill below water table $M_{w\_m\_b} = F_{s\_m\_b\_f} \times a_l \times [((8 - n^2 \times (4 - n))^2 / 16) - 4 + n \times (4 - n)]/8$ = **10.4** kNm/m

Saturated backfill $M_{w\_s} = F_{s\_s\_f} \times [a_l^2 \times x \times ((5 \times L) - a_l)/(20 \times L^3) - (x - b_l)^3 / (3 \times a_l^2)]$ = **5.2** kNm/m

Water $M_{w\_water} = F_{s\_water\_f} \times [a_l^2 \times x \times ((5 \times L) - a_l)/(20 \times L^3) - (x - b_l)^3 / (3 \times a_l^2)]$ = **7.8**
kNm/m

Total moment for wall design $M_{wall} = M_{w\_sur} + M_{w\_m\_a} + M_{w\_m\_b} + M_{w\_s} + M_{w\_water} = \mathbf{34.6}$ kNm/m



Check wall stem in bending

Width of wall stem $b = \mathbf{1000}$ mm/m

Depth of reinforcement $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2) = \mathbf{294.0}$ mm

Constant $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu}) = \mathbf{0.021}$

Compression reinforcement is not required

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

$z_{stem} = \mathbf{279}$ mm

Area of tension reinforcement required $A_{s\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem}) = \mathbf{591}$ mm²/m

Minimum area of tension reinforcement $A_{s\_stem\_min} = k \times b \times t_{wall} = \mathbf{455}$ mm²/m

Area of tension reinforcement required $A_{s\_stem\_req} = \mathrm{Max}(A_{s\_stem\_des}, A_{s\_stem\_min}) = \mathbf{591}$ mm²/m

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

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

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress $v_{stem} = V_{stem} / (b \times d_{stem}) = \mathbf{0.393}$ N/mm²

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

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress $v_{c\_stem} = \mathbf{0.507}$ N/mm²

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

Check mid height of wall in bending

Depth of reinforcement $d_{wall} = t_{wall} - c_{wall} - (\phi_{wall} / 2) = \mathbf{294.0}$ mm

Constant $K_{wall} = M_{wall} / (b \times d_{wall}^2 \times f_{cu}) = \mathbf{0.010}$

Compression reinforcement is not required

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

$z_{wall} = \mathbf{279}$ mm

Area of tension reinforcement required $A_{s\_wall\_des} = M_{wall} / (0.87 \times f_y \times z_{wall}) = \mathbf{285}$ mm²/m

Minimum area of tension reinforcement $A_{s\_wall\_min} = k \times b \times t_{wall} = \mathbf{455}$ mm²/m

Area of tension reinforcement required $A_{s\_wall\_req} = \mathrm{Max}(A_{s\_wall\_des}, A_{s\_wall\_min}) = \mathbf{455}$ mm²/m

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

Area of reinforcement provided $A_{s\_wall\_prov} = \mathbf{754}$ 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 $f_s = 2 \times f_y \times A_{s\_stem\_req} / (3 \times A_{s\_stem\_prov})$ = **261.4** N/mm²

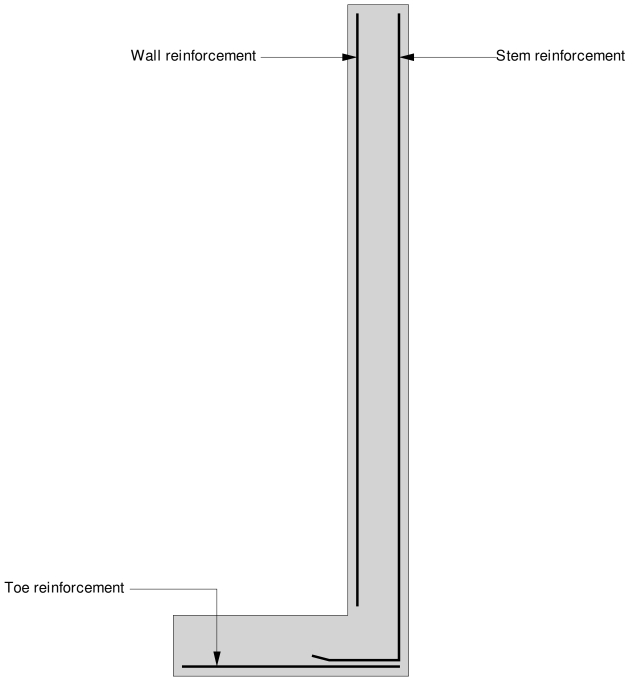
Modification factor $factor_{tens} = \min(0.55 + (477 \text{ N/mm}^2 - f_s)/(120 \times (0.9 \text{ N/mm}^2 + (M_{stem}/(b \times d_{stem}^2)))),2)$ = **1.59**

Maximum span/effective depth ratio $ratio_{max} = ratio_{bas} \times factor_{tens}$ = **31.76**

Actual span/effective depth ratio $ratio_{act} = h_{stem} / d_{stem}$ = **11.90**

PASS - Span to depth ratio is acceptable

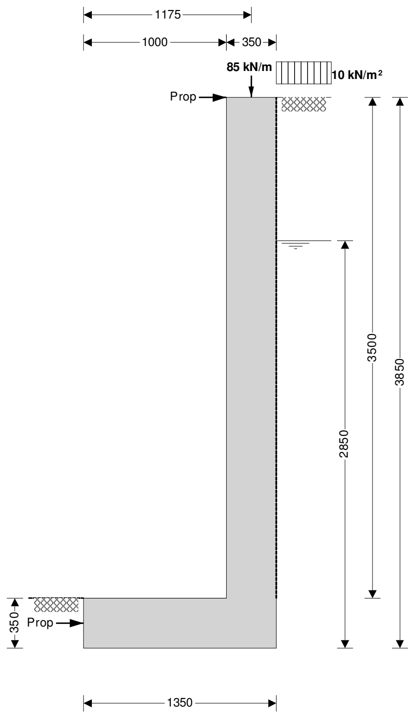
Indicative retaining wall reinforcement diagram



Toe bars - 12 mm dia.@ 150 mm centres - (754 mm^2/m)
Wall bars - 12 mm dia.@ 150 mm centres - (754 mm^2/m)
Stem bars - 12 mm dia.@ 150 mm centres - (754 mm^2/m)

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} = **3500** mm
Thickness of wall stem	t_{wall} = **350** mm
Length of toe	l_{toe} = **1000** mm
Length of heel	l_{heel} = **0** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **1350** mm
Thickness of base	t_{base} = **350** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **900** mm
Thickness of downstand	t_{ds} = **350** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **3850** 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} = **2850** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0 \text{ mm})$ = **2500** 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	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **3850** mm

Retained material details

Mobilisation factor	M = **1.5**
Moist density of retained material	γ_m = **18.0** kN/m^3

Saturated density of retained material γ_s = **21.0** kN/m^3

Design shear strength ϕ' = **24.2** deg

Angle of wall friction δ = **18.6** deg

Base material details

Firm clay

Moist density γ_{mb} = **18.0** kN/m^3

Design shear strength ϕ'_b = **24.2** deg

Design base friction δ_b = **18.6** deg

Allowable bearing pressure $P_{bearing}$ = **125** kN/m^2

Using Coulomb theory

Active pressure coefficient for retained material

$$K_a = \sin(\alpha + \phi')^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta) \times [1 + \sqrt{(\sin(\phi' + \delta) \times \sin(\phi' - \beta) / (\sin(\alpha - \delta) \times \sin(\alpha + \beta)))}]^2) = \mathbf{0.369}$$

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 $K_0 = 1 - \sin(\phi')$ = **0.590**

Loading details

Surcharge load on plan Surcharge = **10.0** kN/m^2

Applied vertical dead load on wall W_{dead} = **79.2** kN/m

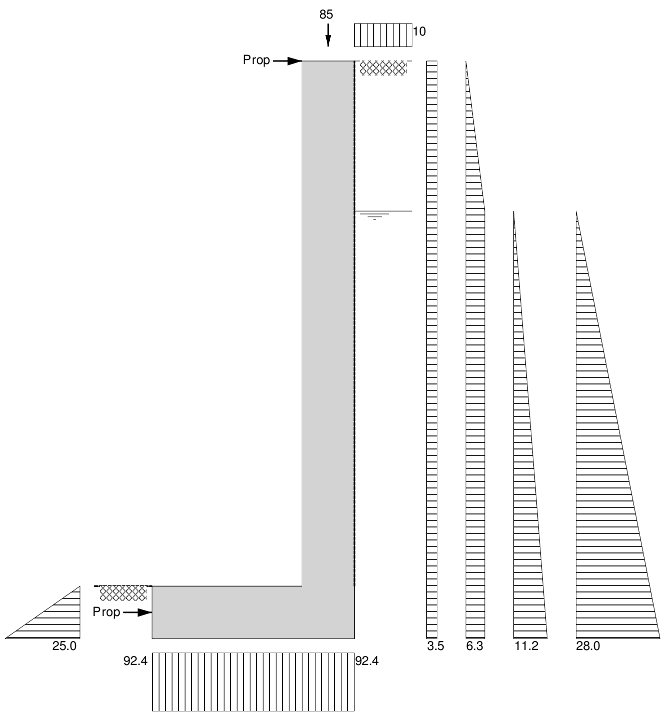
Applied vertical live load on wall W_{live} = **5.4** kN/m

Position of applied vertical load on wall l_{load} = **1175** 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 $w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **28.9** kN/m

Wall base $w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **11.2** kN/m

Applied vertical load $W_v = W_{dead} + W_{live}$ = **84.6** kN/m

Total vertical load $W_{total} = w_{wall} + w_{base} + W_v$ = **124.7** kN/m

Horizontal forces on wall

Surcharge $F_{sur} = K_a \times \cos(90 - \alpha + \delta) \times Surcharge \times h_{eff}$ = **13.5** kN/m

Moist backfill above water table $F_{m\_a} = 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water})^2$ = **3.1** kN/m

Moist backfill below water table $F_{m\_b} = K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **17.9** kN/m

Saturated backfill $F_s = 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **15.9** kN/m

Water $F_{water} = 0.5 \times h_{water}^2 \times \gamma_{water}$ = **39.8** kN/m

Total horizontal load $F_{total} = F_{sur} + F_{m\_a} + F_{m\_b} + F_s + F_{water}$ = **90.3** kN/m

Calculate total propping force

Passive resistance of soil in front of wall $F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **4.4** kN/m

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

F_{prop} = **45.8** kN/m

Overturning moments

Surcharge $M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **25.9** kNm/m

Moist backfill above water table $M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **10** kNm/m

Moist backfill below water table $M_{m\_b} = F_{m\_b} \times (h_{water} - 2 \times d_{ds}) / 2$ = **25.6** kNm/m

Saturated backfill $M_s = F_s \times (h_{water} - 3 \times d_{ds}) / 3$ = **15.1** kNm/m

Water $M_{water} = F_{water} \times (h_{water} - 3 \times d_{ds}) / 3$ = **37.8** kNm/m

Total overturning moment $M_{ot} = M_{sur} + M_{m\_a} + M_{m\_b} + M_s + M_{water}$ = **114.5** kNm/m

Restoring moments

Wall stem $M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2)$ = **34** kNm/m

Wall base $M_{base} = w_{base} \times l_{base} / 2$ = **7.5** kNm/m

Design vertical dead load $M_{dead} = W_{dead} \times l_{load}$ = **93.1** kNm/m

Total restoring moment $M_{rest} = M_{wall} + M_{base} + M_{dead}$ = **134.6** kNm/m

Check bearing pressure

Total vertical reaction $R = W_{total}$ = **124.7** kN/m

Distance to reaction $x_{bar} = l_{base} / 2$ = **675** mm

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

Reaction acts within middle third of base

Bearing pressure at toe $p_{toe} = (R / l_{base}) - (6 \times R \times e / l_{base}^2)$ = **92.4** kN/m²

Bearing pressure at heel $p_{heel} = (R / l_{base}) + (6 \times R \times e / l_{base}^2)$ = **92.4** 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

$F_{prop\_top} = (M_{ot} - M_{rest} + R \times l_{base} / 2 - F_{prop} \times t_{base} / 2) / (h_{stem} + t_{base} / 2)$ = **15.260** kN/m

Propping force to base of wall $F_{prop\_base} = F_{prop} - F_{prop\_top}$ = **30.534** 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 $w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **40.5** kN/m

Wall base $w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **15.6** kN/m

Applied vertical load $W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live}$ = **119.6** kN/m

Total vertical load $W_{total\_f} = w_{wall\_f} + w_{base\_f} + W_{v\_f}$ = **175.7** kN/m

Factored horizontal at-rest forces on wall

Surcharge $F_{sur\_f} = \gamma_{f\_l} \times K_0 \times Surcharge \times h_{eff}$ = **36.3** kN/m

Moist backfill above water table $F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2$ = **7.4** kN/m

Moist backfill below water table $F_{m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **42.4** kN/m

Saturated backfill $F_{s\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **37.5** kN/m

Water $F_{water\_f} = \gamma_{f\_e} \times 0.5 \times h_{water}^2 \times \gamma_{water}$ = **55.8** kN/m

Total horizontal load $F_{total\_f} = F_{sur\_f} + F_{m\_a\_f} + F_{m\_b\_f} + F_{s\_f} + F_{water\_f}$ = **179.5** kN/m

Calculate total propping force

Passive resistance of soil in front of wall $F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **6.1** 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} = **117.2** kN/m

Factored overturning moments

Surcharge $M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **70** kNm/m

Moist backfill above water table $M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **23.7** kNm/m

Moist backfill below water table $M_{m\_b\_f} = F_{m\_b\_f} \times (h_{water} - 2 \times d_{ds}) / 2$ = **60.4** kNm/m

Saturated backfill $M_{s\_f} = F_{s\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **35.7** kNm/m

Water $M_{water\_f} = F_{water\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **53** kNm/m

Total overturning moment $M_{ot\_f} = M_{sur\_f} + M_{m\_a\_f} + M_{m\_b\_f} + M_{s\_f} + M_{water\_f}$ = **242.7** kNm/m

Restoring moments

Wall stem $M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **47.6** kNm/m

Wall base $M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **10.5** kNm/m

Design vertical load $M_{v\_f} = W_{v\_f} \times l_{load}$ = **140.5** kNm/m

Total restoring moment $M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{v\_f}$ = **198.6** kNm/m

Factored bearing pressure

Total vertical reaction $R_f = W_{total\_f}$ = **175.7** kN/m

Distance to reaction $x_{bar\_f} = l_{base} / 2$ = **675** mm

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

Reaction acts within middle third of base

Bearing pressure at toe $p_{toe\_f} = (R_f / l_{base}) - (6 \times R_f \times e_f / l_{base}^2)$ = **130.1** kN/m^2

Bearing pressure at heel $p_{heel\_f} = (R_f / l_{base}) + (6 \times R_f \times e_f / l_{base}^2)$ = **130.1** kN/m^2

Rate of change of base reaction $rate = (p_{toe\_f} - p_{heel\_f}) / l_{base}$ = **0.00** kN/m^2/m

Bearing pressure at stem / toe $p_{stem\_toe\_f} = \max(p_{toe\_f} - (rate \times l_{toe}), 0 \text{ kN/m}^2)$ = **130.1** kN/m^2

Bearing pressure at mid stem $p_{stem\_mid\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall} / 2)), 0\ kN/m^2) =$ **130.1** kN/m²

Bearing pressure at stem / heel $p_{stem\_heel\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall})), 0\ kN/m^2) =$ **130.1** kN/m²

Calculate propping forces to top and base of wall

Propping force to top of wall

$F_{prop\_top\_f} = (M_{ot\_f} - M_{rest\_f} + R_f \times l_{base} / 2 - F_{prop\_f} \times t_{base} / 2) / (h_{stem} + t_{base} / 2) =$ **38.680** kN/m

Propping force to base of wall $F_{prop\_base\_f} = F_{prop\_f} - F_{prop\_top\_f} =$ **78.488** 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 $c_{toe} =$ **50** mm

Calculate shear for toe design

Shear from bearing pressure $V_{toe\_bear} = (p_{toe\_f} + p_{stem\_toe\_f}) \times l_{toe} / 2 =$ **130.1** kN/m

Shear from weight of base $V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base} =$ **11.6** kN/m

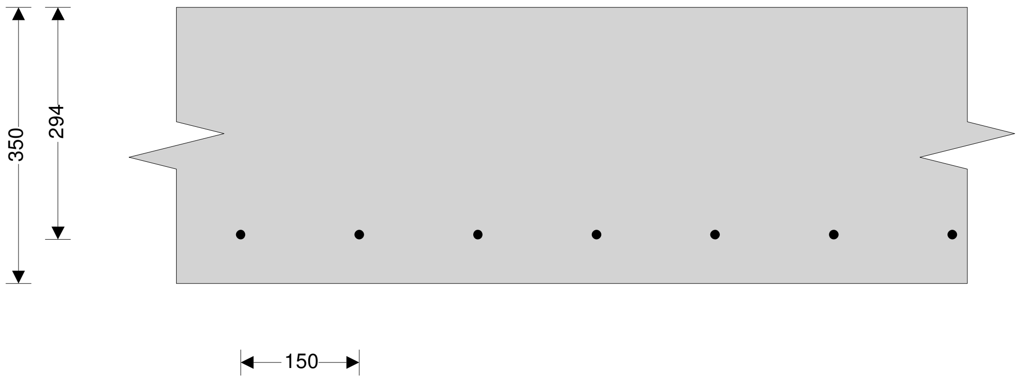
Total shear for toe design $V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base} =$ **118.6** kN/m

Calculate moment for toe design

Moment from bearing pressure $M_{toe\_bear} = (2 \times p_{toe\_f} + p_{stem\_mid\_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6 =$ **89.8** kNm/m

Moment from weight of base $M_{toe\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2) =$ **8** kNm/m

Total moment for toe design $M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base} =$ **81.8** kNm/m



Check toe in bending

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

Depth of reinforcement $d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) =$ **294.0** mm

Constant $K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu}) =$ **0.024**

Compression reinforcement is not required

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

$z_{toe} =$ **279** mm

Area of tension reinforcement required $A_{s\_toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe}) =$ **674** 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 $A_{s\_toe\_req} = \max(A_{s\_toe\_des}, A_{s\_toe\_min}) =$ **674** mm²/m

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

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

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress $v_{toe} = V_{toe} / (b \times d_{toe})$ = **0.403** 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_toe} = **0.507** N/mm²

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

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

Material properties

Characteristic strength of concrete f_{cu} = **40** N/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} = **50** mm

Cover to reinforcement in wall c_{wall} = **50** mm

Factored horizontal at-rest forces on stem

Surcharge $F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds})$ = **33** kN/m

Moist backfill above water table $F_{s\_m\_a\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2$ = **7.4** kN/m

Moist backfill below water table $F_{s\_m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat}) \times h_{sat}$ = **37.2** kN/m

Saturated backfill $F_{s\_s\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{sat}^2$ = **28.9** kN/m

Water $F_{s\_water\_f} = 0.5 \times \gamma_{f\_e} \times \gamma_{water} \times h_{sat}^2$ = **42.9** kN/m

Calculate shear for stem design

Surcharge $V_{s\_sur\_f} = 5 \times F_{s\_sur\_f} / 8$ = **20.7** kN/m

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

Moist backfill below water table $V_{s\_m\_b\_f} = F_{s\_m\_b\_f} \times (8 - (n^2 \times (4 - n))) / 8$ = **29.1** kN/m

Saturated backfill $V_{s\_s\_f} = F_{s\_s\_f} \times (1 - (a_l^2 \times ((5 \times L) - a_l) / (20 \times L^3)))$ = **25.6** kN/m

Water $V_{s\_water\_f} = F_{s\_water\_f} \times (1 - (a_l^2 \times ((5 \times L) - a_l) / (20 \times L^3)))$ = **38.1** kN/m

Total shear for stem design $V_{stem} = V_{s\_sur\_f} + V_{s\_m\_a\_f} + V_{s\_m\_b\_f} + V_{s\_s\_f} + V_{s\_water\_f}$ = **115.4** kN/m

Calculate moment for stem design

Surcharge $M_{s\_sur} = F_{s\_sur\_f} \times L / 8$ = **15.2** kNm/m

Moist backfill above water table $M_{s\_m\_a} = F_{s\_m\_a\_f} \times b_l \times ((5 \times L^2) - (3 \times b_l^2)) / (15 \times L^2)$ = **2.4** kNm/m

Moist backfill below water table $M_{s\_m\_b} = F_{s\_m\_b\_f} \times a_l \times (2 - n)^2 / 8$ = **20.1** kNm/m

Saturated backfill $M_{s\_s} = F_{s\_s\_f} \times a_l \times ((3 \times a_l^2) - (15 \times a_l \times L) + (20 \times L^2)) / (60 \times L^2)$ = **13.7** kNm/m

Water $M_{s\_water} = F_{s\_water\_f} \times a_l \times ((3 \times a_l^2) - (15 \times a_l \times L) + (20 \times L^2)) / (60 \times L^2)$ = **20.4**
kNm/m

Total moment for stem design $M_{stem} = M_{s\_sur} + M_{s\_m\_a} + M_{s\_m\_b} + M_{s\_s} + M_{s\_water}$ = **71.8** kNm/m

Calculate moment for wall design

Surcharge $M_{w\_sur} = 9 \times F_{s\_sur\_f} \times L / 128$ = **8.5** kNm/m

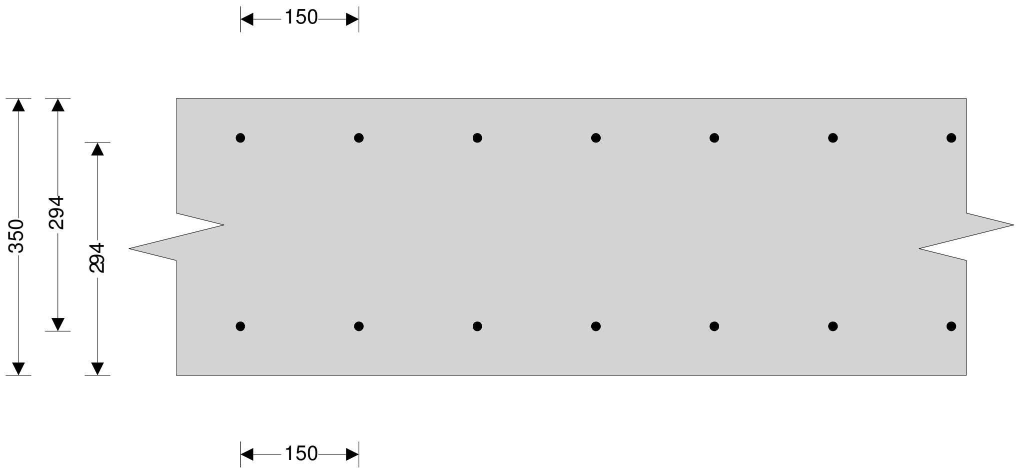
Moist backfill above water table $M_{w\_m\_a} = F_{s\_m\_a\_f} \times 0.577 \times b_l \times [(b_l^3 + 5 \times a_l \times L^2)/(5 \times L^3) - 0.577^2/3]$ = **2.7**
kNm/m

Moist backfill below water table $M_{w\_m\_b} = F_{s\_m\_b\_f} \times a_l \times [((8 - n^2 \times (4-n))^2 / 16) - 4 + n \times (4-n)]/8$ = **10.4** kNm/m

Saturated backfill $M_{w\_s} = F_{s\_s\_f} \times [a_l^2 \times x \times ((5 \times L) - a_l)/(20 \times L^3) - (x - b_l)^3 / (3 \times a_l^2)]$ = **5.2** kNm/m

Water $M_{w\_water} = F_{s\_water\_f} \times [a_l^2 \times x \times ((5 \times L) - a_l)/(20 \times L^3) - (x - b_l)^3 / (3 \times a_l^2)]$ = **7.8**
kNm/m

Total moment for wall design $M_{wall} = M_{w\_sur} + M_{w\_m\_a} + M_{w\_m\_b} + M_{w\_s} + M_{w\_water} = \mathbf{34.6}$ kNm/m



Check wall stem in bending

Width of wall stem $b = \mathbf{1000}$ mm/m

Depth of reinforcement $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2) = \mathbf{294.0}$ mm

Constant $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu}) = \mathbf{0.021}$

Compression reinforcement is not required

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

$z_{stem} = \mathbf{279}$ mm

Area of tension reinforcement required $A_{s\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem}) = \mathbf{591}$ mm²/m

Minimum area of tension reinforcement $A_{s\_stem\_min} = k \times b \times t_{wall} = \mathbf{455}$ mm²/m

Area of tension reinforcement required $A_{s\_stem\_req} = \mathrm{Max}(A_{s\_stem\_des}, A_{s\_stem\_min}) = \mathbf{591}$ mm²/m

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

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

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress $v_{stem} = V_{stem} / (b \times d_{stem}) = \mathbf{0.393}$ N/mm²

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

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress $v_{c\_stem} = \mathbf{0.507}$ N/mm²

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

Check mid height of wall in bending

Depth of reinforcement $d_{wall} = t_{wall} - c_{wall} - (\phi_{wall} / 2) = \mathbf{294.0}$ mm

Constant $K_{wall} = M_{wall} / (b \times d_{wall}^2 \times f_{cu}) = \mathbf{0.010}$

Compression reinforcement is not required

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

$z_{wall} = \mathbf{279}$ mm

Area of tension reinforcement required $A_{s\_wall\_des} = M_{wall} / (0.87 \times f_y \times z_{wall}) = \mathbf{285}$ mm²/m

Minimum area of tension reinforcement $A_{s\_wall\_min} = k \times b \times t_{wall} = \mathbf{455}$ mm²/m

Area of tension reinforcement required $A_{s\_wall\_req} = \mathrm{Max}(A_{s\_wall\_des}, A_{s\_wall\_min}) = \mathbf{455}$ mm²/m

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

Area of reinforcement provided $A_{s\_wall\_prov} = \mathbf{754}$ 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 $f_s = 2 \times f_y \times A_{s\_stem\_req} / (3 \times A_{s\_stem\_prov})$ = **261.4** N/mm²

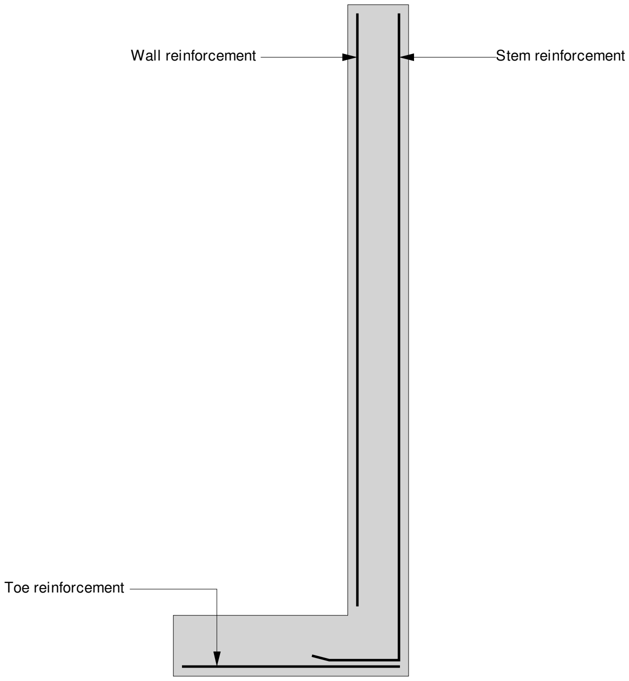
Modification factor $factor_{tens} = \min(0.55 + (477 \text{ N/mm}^2 - f_s)/(120 \times (0.9 \text{ N/mm}^2 + (M_{stem}/(b \times d_{stem}^2)))),2)$ = **1.59**

Maximum span/effective depth ratio $ratio_{max} = ratio_{bas} \times factor_{tens}$ = **31.76**

Actual span/effective depth ratio $ratio_{act} = h_{stem} / d_{stem}$ = **11.90**

PASS - Span to depth ratio is acceptable

Indicative retaining wall reinforcement diagram

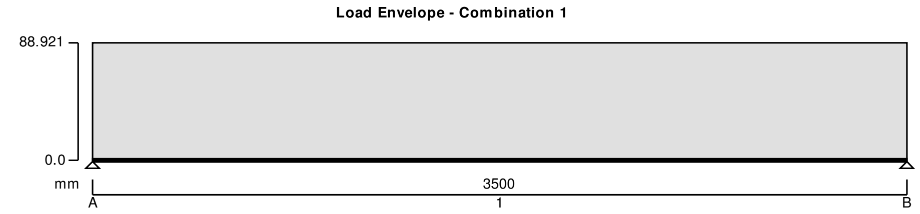


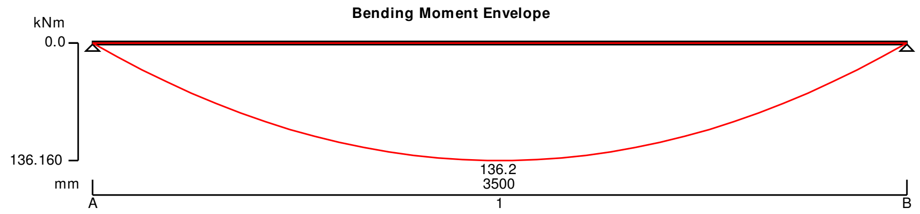
Toe bars - 12 mm dia.@ 150 mm centres - (754 mm^2/m)
Wall bars - 12 mm dia.@ 150 mm centres - (754 mm^2/m)
Stem bars - 12 mm dia.@ 150 mm centres - (754 mm^2/m)

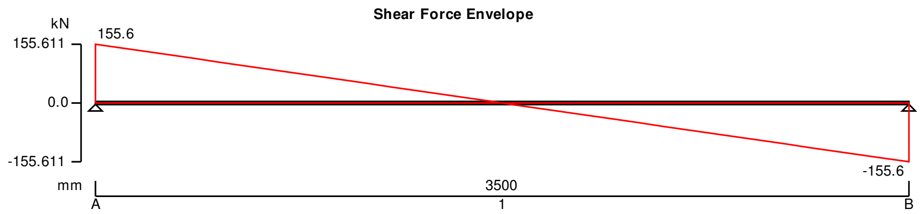
Conisbee 1-5 Offord Street London N1 1DH	Project 1 St Marks Crescent				Job no. 180507	
	Calcs for R.C capping beam lightwell				Start page no./Revision 1	
	Calcs by HH	Calcs date 13/06/2018	Checked by	Checked date	Approved by	Approved date

RC BEAM ANALYSIS & DESIGN BS8110

TEDDS calculation version 2.1.12







Support conditions

Support A	Vertically restrained
	Rotationally free
Support B	Vertically restrained
	Rotationally free

Applied loading

Dead self weight of beam × 1

Imposed full UDL 53 kN/m

Load combinations

Load combination 1	Support A	Dead × 1.40
		Imposed × 1.60
	Span 1	Dead × 1.40
		Imposed × 1.60
	Support B	Dead × 1.40
		Imposed × 1.60

Analysis results

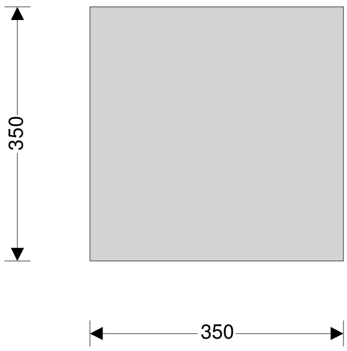
Maximum moment support A	M_{A_max} = **0** kNm	M_{A_red} = **0** kNm
Maximum moment span 1 at 1750 mm	M_{s1_max} = **136** kNm	M_{s1_red} = **136** kNm

Maximum moment support B	M_{B_max} = **0** kNm	M_{B_red} = **0** kNm
Maximum shear support A	V_{A_max} = **156** kN	V_{A_red} = **156** kN
Maximum shear support A span 1 at 300 mm	$V_{A\_s1\_max}$ = **129** kN	$V_{A\_s1\_red}$ = **129** kN
Maximum shear support B	V_{B_max} = **-156** kN	V_{B_red} = **-156** kN
Maximum shear support B span 1 at 3200 mm	$V_{B\_s1\_max}$ = **-129** kN	$V_{B\_s1\_red}$ = **-129** kN
Maximum reaction at support A	R_A = **156** kN	
Unfactored dead load reaction at support A	R_{A_Dead} = **5** kN	
Unfactored imposed load reaction at support A	$R_{A\_Imposed}$ = **93** kN	
Maximum reaction at support B	R_B = **156** kN	
Unfactored dead load reaction at support B	R_{B_Dead} = **5** kN	
Unfactored imposed load reaction at support B	$R_{B\_Imposed}$ = **93** kN	

Rectangular section details

Section width b = **350** mm

Section depth h = **350** mm



Concrete details

Concrete strength class **C40/50**

Characteristic compressive cube strength f_{cu} = **50** N/mm^2

Modulus of elasticity of concrete $E_c = 20kN/mm^2 + 200 \times f_{cu}$ = **30000** N/mm^2

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

Reinforcement details

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

Characteristic yield strength of shear reinforcement f_{yv} = **500** N/mm^2

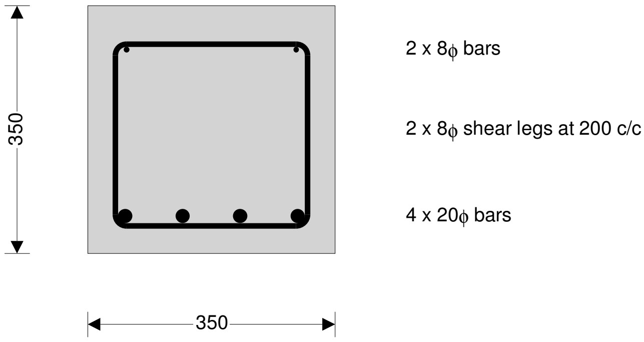
Nominal cover to reinforcement

Nominal cover to top reinforcement c_{nom_t} = **50** mm

Nominal cover to bottom reinforcement c_{nom_b} = **35** mm

Nominal cover to side reinforcement c_{nom_s} = **35** mm

Mid span 1



Design moment resistance of rectangular section (cl. 3.4.4) - Positive moment

Design bending moment | $M = abs(M_{s1\_red})$ = **136** kNm

Depth to tension reinforcement | $d = h - c_{nom\_b} - \phi_v - \phi_{bot} / 2$ = **297** mm

Redistribution ratio | $\beta_b = min(1 - m_{rs1}, 1)$ = **1.000**

$K = M / (b \times d^2 \times f_{cu})$ = **0.088**

$K' = 0.156$

K' > K - No compression reinforcement is required

Lever arm | $z = min(d \times (0.5 + (0.25 - K / 0.9)^{0.5}), 0.95 \times d)$ = **264** mm

Depth of neutral axis | $x = (d - z) / 0.45$ = **73** mm

Area of tension reinforcement required | $A_{s,req} = M / (0.87 \times f_y \times z)$ = **1184** mm^2

Tension reinforcement provided | $4 \times 20\phi$ bars

Area of tension reinforcement provided | $A_{s,prov}$ = **1257** mm^2

Minimum area of reinforcement | $A_{s,min} = 0.0013 \times b \times h$ = **159** mm^2

Maximum area of reinforcement | $A_{s,max} = 0.04 \times b \times h$ = **4900** mm^2

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

Rectangular section in shear

Shear reinforcement provided | $2 \times 8\phi$ legs at 200 c/c

Area of shear reinforcement provided | $A_{sv,prov}$ = **503** mm^2/m

Minimum area of shear reinforcement (Table 3.7) | $A_{sv,min} = 0.4N/mm^2 \times b / (0.87 \times f_{yv})$ = **322** mm^2/m

PASS - Area of shear reinforcement provided exceeds minimum required

Maximum longitudinal spacing (cl. 3.4.5.5) | $s_{vl,max} = 0.75 \times d$ = **223** mm

PASS - Longitudinal spacing of shear reinforcement provided is less than maximum

Design concrete shear stress | $v_c = 0.79N/mm^2 \times min(3,[100 \times A_{s,prov} / (b \times d)]^{1/3}) \times max(1, (400mm / d)^{1/4}) \times (min(f_{cu}, 40N/mm^2) / 25N/mm^2)^{1/3} / \gamma_m$ = **0.848** N/mm^2

Design shear resistance provided | $v_{s,prov} = A_{sv,prov} \times 0.87 \times f_{yv} / b$ = **0.625** N/mm^2

Design shear stress provided | $v_{prov} = v_{s,prov} + v_c$ = **1.473** N/mm^2

Design shear resistance | $V_{prov} = v_{prov} \times (b \times d)$ = **153.1** kN

Shear links provided valid between 100 mm and 3400 mm with tension reinforcement of 1257 mm²

Spacing of reinforcement (cl 3.12.11)

Actual distance between bars in tension | $s = (b - 2 \times (c_{nom\_s} + \phi_v + \phi_{bot}/2)) /(N_{bot} - 1) - \phi_{bot}$ = **61** mm

Minimum distance between bars in tension (cl 3.12.11.1)

Minimum distance between bars in tension | $s_{min} = h_{agg} + 5$ mm = **25** mm

PASS - Satisfies the minimum spacing criteria

Maximum distance between bars in tension (cl 3.12.11.2)

Design service stress $f_s = (2 \times f_y \times A_{s,req}) / (3 \times A_{s,prov} \times \beta_b) = \mathbf{314.2}$ N/mm^2

Maximum distance between bars in tension $s_{max} = \min(47000 \text{ N/mm} / f_s, 300 \text{ mm}) = \mathbf{150}$ mm

PASS - Satisfies the maximum spacing criteria

Span to depth ratio (cl. 3.4.6)

Basic span to depth ratio (Table 3.9) $span\_to\_depth_{basic} = \mathbf{20.0}$

Design service stress in tension reinforcement $f_s = (2 \times f_y \times A_{s,req})/ (3 \times A_{s,prov} \times \beta_b) = \mathbf{314.2}$ N/mm^2

Modification for tension reinforcement

$$f_{tens} = \min(2.0, 0.55 + (477\text{N/mm}^2 - f_s) / (120 \times (0.9\text{N/mm}^2 + (M / (b \times d^2))))) = \mathbf{0.806}$$

Modification for compression reinforcement

$$f_{comp} = \min(1.5, 1 + (100 \times A_{s2,prov} / (b \times d)) / (3 + (100 \times A_{s2,prov} / (b \times d)))) = \mathbf{1.031}$$

Modification for span length $f_{long} = 1.000$

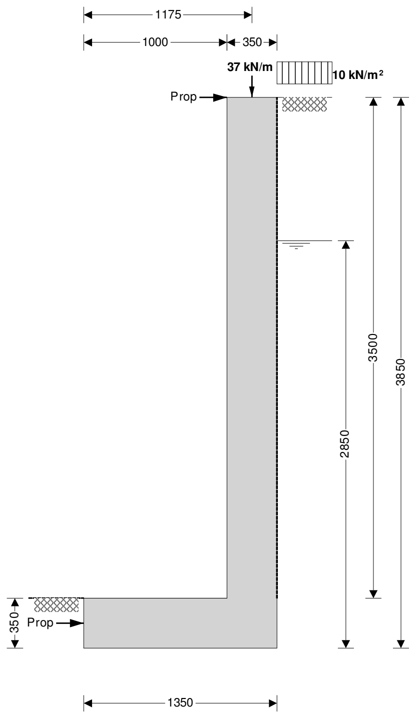
Allowable span to depth ratio $span\_to\_depth_{allow} = span\_to\_depth_{basic} \times f_{tens} \times f_{comp} = \mathbf{16.6}$

Actual span to depth ratio $span\_to\_depth_{actual} = L_{s1} / d = \mathbf{11.8}$

PASS - Actual span to depth ratio is within the allowable limit

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} = **3500** mm
Thickness of wall stem	t_{wall} = **350** mm
Length of toe	l_{toe} = **1000** mm
Length of heel	l_{heel} = **0** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **1350** mm
Thickness of base	t_{base} = **350** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **900** mm
Thickness of downstand	t_{ds} = **350** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **3850** 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} = **2850** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0\ mm)$ = **2500** 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	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **3850** mm

Retained material details

Mobilisation factor	M = **1.5**
Moist density of retained material	γ_m = **18.0** kN/m^3

Conisbee 1-5 Offord Street London N1 1DH	Project 1 St Marks Crescent				Job no. 180507	
	Calcs for Retaining wall No. 1/31 Rear				Start page no./Revision 2	
	Calcs by HH	Calcs date 13/06/2018	Checked by	Checked date	Approved by	Approved date

Saturated density of retained material γ_s = **21.0** kN/m^3

Design shear strength ϕ' = **24.2** deg

Angle of wall friction δ = **18.6** deg

Base material details

Firm clay

Moist density γ_{mb} = **18.0** kN/m^3

Design shear strength ϕ'_b = **24.2** deg

Design base friction δ_b = **18.6** deg

Allowable bearing pressure $P_{bearing}$ = **125** kN/m^2

Using Coulomb theory

Active pressure coefficient for retained material

$$K_a = \sin(\alpha + \phi')^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta) \times [1 + \sqrt{(\sin(\phi' + \delta) \times \sin(\phi' - \beta) / (\sin(\alpha - \delta) \times \sin(\alpha + \beta)))}]^2) = \mathbf{0.369}$$

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 = **10.0** kN/m^2

Applied vertical dead load on wall W_{dead} = **33.0** kN/m

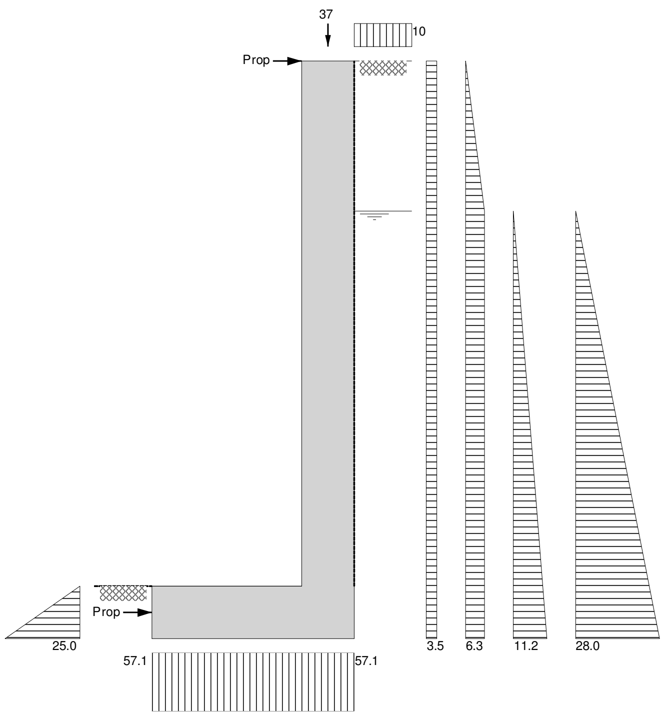
Applied vertical live load on wall W_{live} = **4.0** kN/m

Position of applied vertical load on wall l_{load} = **1175** 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 — $w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall} = \mathbf{28.9}$ kN/m

Wall base — $w_{base} = l_{base} \times t_{base} \times \gamma_{base} = \mathbf{11.2}$ kN/m

Applied vertical load — $W_v = W_{dead} + W_{live} = \mathbf{37}$ kN/m

Total vertical load — $W_{total} = w_{wall} + w_{base} + W_v = \mathbf{77.1}$ kN/m

Horizontal forces on wall

Surcharge — $F_{sur} = K_a \times \cos(90 - \alpha + \delta) \times \text{Surcharge} \times h_{eff} = \mathbf{13.5}$ kN/m

Moist backfill above water table — $F_{m\_a} = 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water})^2 = \mathbf{3.1}$ kN/m

Moist backfill below water table — $F_{m\_b} = K_a \times \cos(90 - \alpha + \delta) \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water} = \mathbf{17.9}$ kN/m

Saturated backfill — $F_s = 0.5 \times K_a \times \cos(90 - \alpha + \delta) \times (\gamma_s - \gamma_{water}) \times h_{water}^2 = \mathbf{15.9}$ kN/m

Water — $F_{water} = 0.5 \times h_{water}^2 \times \gamma_{water} = \mathbf{39.8}$ kN/m

Total horizontal load — $F_{total} = F_{sur} + F_{m\_a} + F_{m\_b} + F_s + F_{water} = \mathbf{90.3}$ kN/m

Calculate total propping force

Passive resistance of soil in front of wall — $F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb} = \mathbf{4.4}$ kN/m

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

$F_{prop} = \mathbf{61.3}$ kN/m

Overturning moments

Surcharge — $M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2 = \mathbf{25.9}$ kNm/m

Moist backfill above water table — $M_{m\_a} = F_{m\_a} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3 = \mathbf{10}$ kNm/m

Moist backfill below water table — $M_{m\_b} = F_{m\_b} \times (h_{water} - 2 \times d_{ds}) / 2 = \mathbf{25.6}$ kNm/m

Saturated backfill — $M_s = F_s \times (h_{water} - 3 \times d_{ds}) / 3 = \mathbf{15.1}$ kNm/m

Water — $M_{water} = F_{water} \times (h_{water} - 3 \times d_{ds}) / 3 = \mathbf{37.8}$ kNm/m

Total overturning moment — $M_{ot} = M_{sur} + M_{m\_a} + M_{m\_b} + M_s + M_{water} = \mathbf{114.5}$ kNm/m

Restoring moments

Wall stem — $M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2) = \mathbf{34}$ kNm/m

Wall base — $M_{base} = w_{base} \times l_{base} / 2 = \mathbf{7.5}$ kNm/m

Design vertical dead load — $M_{dead} = W_{dead} \times l_{load} = \mathbf{38.8}$ kNm/m

Total restoring moment — $M_{rest} = M_{wall} + M_{base} + M_{dead} = \mathbf{80.3}$ kNm/m

Check bearing pressure

Total vertical reaction — $R = W_{total} = \mathbf{77.1}$ kN/m

Distance to reaction — $x_{bar} = l_{base} / 2 = \mathbf{675}$ mm

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

Reaction acts within middle third of base

Bearing pressure at toe — $p_{toe} = (R / l_{base}) - (6 \times R \times e / l_{base}^2) = \mathbf{57.1}$ kN/m^2

Bearing pressure at heel — $p_{heel} = (R / l_{base}) + (6 \times R \times e / l_{base}^2) = \mathbf{57.1}$ kN/m^2

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

$F_{prop\_top} = (M_{ot} - M_{rest} + R \times l_{base} / 2 - F_{prop} \times t_{base} / 2) / (h_{stem} + t_{base} / 2) = \mathbf{20.541}$ kN/m

Propping force to base of wall — $F_{prop\_base} = F_{prop} - F_{prop\_top} = \mathbf{40.801}$ 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 $w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **40.5** kN/m

Wall base $w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **15.6** kN/m

Applied vertical load $W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live}$ = **52.6** kN/m

Total vertical load $W_{total\_f} = w_{wall\_f} + w_{base\_f} + W_{v\_f}$ = **108.7** kN/m

Factored horizontal at-rest forces on wall

Surcharge $F_{sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times h_{eff}$ = **36.3** kN/m

Moist backfill above water table $F_{m\_a\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times \gamma_m \times (h_{eff} - h_{water})^2$ = **7.4** kN/m

Moist backfill below water table $F_{m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - h_{water}) \times h_{water}$ = **42.4** kN/m

Saturated backfill $F_{s\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **37.5** kN/m

Water $F_{water\_f} = \gamma_{f\_e} \times 0.5 \times h_{water}^2 \times \gamma_{water}$ = **55.8** kN/m

Total horizontal load $F_{total\_f} = F_{sur\_f} + F_{m\_a\_f} + F_{m\_b\_f} + F_{s\_f} + F_{water\_f}$ = **179.5** kN/m

Calculate total propping force

Passive resistance of soil in front of wall $F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **6.1** 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} = **138.9** kN/m

Factored overturning moments

Surcharge $M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **70** kNm/m

Moist backfill above water table $M_{m\_a\_f} = F_{m\_a\_f} \times (h_{eff} + 2 \times h_{water} - 3 \times d_{ds}) / 3$ = **23.7** kNm/m

Moist backfill below water table $M_{m\_b\_f} = F_{m\_b\_f} \times (h_{water} - 2 \times d_{ds}) / 2$ = **60.4** kNm/m

Saturated backfill $M_{s\_f} = F_{s\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **35.7** kNm/m

Water $M_{water\_f} = F_{water\_f} \times (h_{water} - 3 \times d_{ds}) / 3$ = **53** kNm/m

Total overturning moment $M_{ot\_f} = M_{sur\_f} + M_{m\_a\_f} + M_{m\_b\_f} + M_{s\_f} + M_{water\_f}$ = **242.7** kNm/m

Restoring moments

Wall stem $M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **47.6** kNm/m

Wall base $M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **10.5** kNm/m

Design vertical load $M_{v\_f} = W_{v\_f} \times l_{load}$ = **61.8** kNm/m

Total restoring moment $M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{v\_f}$ = **119.9** kNm/m

Factored bearing pressure

Total vertical reaction $R_f = W_{total\_f}$ = **108.7** kN/m

Distance to reaction $x_{bar\_f} = l_{base} / 2$ = **675** 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 $p_{toe\_f} = (R_f / l_{base}) - (6 \times R_f \times e_f / l_{base}^2)$ = **80.5** kN/m^2

Bearing pressure at heel $p_{heel\_f} = (R_f / l_{base}) + (6 \times R_f \times e_f / l_{base}^2)$ = **80.5** kN/m^2

Rate of change of base reaction $\text{rate} = (p_{toe\_f} - p_{heel\_f}) / l_{base}$ = **0.00** kN/m^2/m

Bearing pressure at stem / toe $p_{stem\_toe\_f} = \max(p_{toe\_f} - (\text{rate} \times l_{toe}), 0\text{ kN/m}^2)$ = **80.5** kN/m^2

Bearing pressure at mid stem $p_{stem\_mid\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall} / 2)), 0 \text{ kN/m}^2) =$ **80.5** kN/m²

Bearing pressure at stem / heel $p_{stem\_heel\_f} = \max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall})), 0 \text{ kN/m}^2) =$ **80.5** kN/m²

Calculate propping forces to top and base of wall

Propping force to top of wall

$F_{prop\_top\_f} = (M_{ot\_f} - M_{rest\_f} + R_f \times l_{base} / 2 - F_{prop\_f} \times t_{base} / 2) / (h_{stem} + t_{base} / 2) =$ **46.757** kN/m

Propping force to base of wall $F_{prop\_base\_f} = F_{prop\_f} - F_{prop\_top\_f} =$ **92.179** 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 $c_{toe} =$ **50** mm

Calculate shear for toe design

Shear from bearing pressure $V_{toe\_bear} = (p_{toe\_f} + p_{stem\_toe\_f}) \times l_{toe} / 2 =$ **80.5** kN/m

Shear from weight of base $V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base} =$ **11.6** kN/m

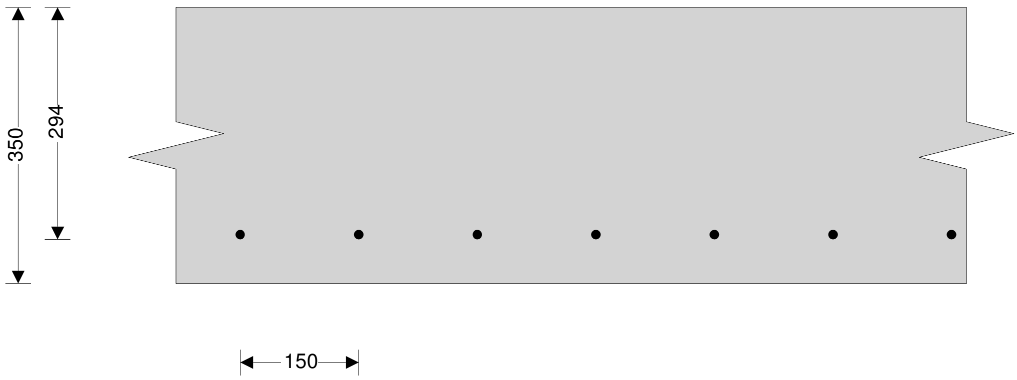
Total shear for toe design $V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base} =$ **68.9** kN/m

Calculate moment for toe design

Moment from bearing pressure $M_{toe\_bear} = (2 \times p_{toe\_f} + p_{stem\_mid\_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6 =$ **55.6** kNm/m

Moment from weight of base $M_{toe\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2) =$ **8** kNm/m

Total moment for toe design $M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base} =$ **47.6** kNm/m



Check toe in bending

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

Depth of reinforcement $d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) =$ **294.0** mm

Constant $K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu}) =$ **0.014**

Compression reinforcement is not required

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

$z_{toe} =$ **279** mm

Area of tension reinforcement required $A_{s\_toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe}) =$ **392** 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 $A_{s\_toe\_req} = \text{Max}(A_{s\_toe\_des}, A_{s\_toe\_min}) =$ **455** mm²/m

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

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

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress $v_{toe} = V_{toe} / (b \times d_{toe}) =$ **0.235** N/mm^2

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/mm^2

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress $v_{c\_toe} =$ **0.507** 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 $c_{stem} =$ **50** mm

Cover to reinforcement in wall $c_{wall} =$ **50** mm

Factored horizontal at-rest forces on stem

Surcharge $F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times Surcharge \times (h_{eff} - t_{base} - d_{ds}) =$ **33** kN/m

Moist backfill above water table $F_{s\_m\_a\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat})^2 =$ **7.4** kN/m

Moist backfill below water table $F_{s\_m\_b\_f} = \gamma_{f\_e} \times K_0 \times \gamma_m \times (h_{eff} - t_{base} - d_{ds} - h_{sat}) \times h_{sat} =$ **37.2** kN/m

Saturated backfill $F_{s\_s\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{sat}^2 =$ **28.9** kN/m

Water $F_{s\_water\_f} = 0.5 \times \gamma_{f\_e} \times \gamma_{water} \times h_{sat}^2 =$ **42.9** kN/m

Calculate shear for stem design

Surcharge $V_{s\_sur\_f} = 5 \times F_{s\_sur\_f} / 8 =$ **20.7** kN/m

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

Moist backfill below water table $V_{s\_m\_b\_f} = F_{s\_m\_b\_f} \times (8 - (n^2 \times (4 - n))) / 8 =$ **29.1** kN/m

Saturated backfill $V_{s\_s\_f} = F_{s\_s\_f} \times (1 - (a_l^2 \times ((5 \times L) - a_l) / (20 \times L^3))) =$ **25.6** kN/m

Water $V_{s\_water\_f} = F_{s\_water\_f} \times (1 - (a_l^2 \times ((5 \times L) - a_l) / (20 \times L^3))) =$ **38.1** kN/m

Total shear for stem design $V_{stem} = V_{s\_sur\_f} + V_{s\_m\_a\_f} + V_{s\_m\_b\_f} + V_{s\_s\_f} + V_{s\_water\_f} =$ **115.4** kN/m

Calculate moment for stem design

Surcharge $M_{s\_sur} = F_{s\_sur\_f} \times L / 8 =$ **15.2** kNm/m

Moist backfill above water table $M_{s\_m\_a} = F_{s\_m\_a\_f} \times b_l \times ((5 \times L^2) - (3 \times b_l^2)) / (15 \times L^2) =$ **2.4** kNm/m

Moist backfill below water table $M_{s\_m\_b} = F_{s\_m\_b\_f} \times a_l \times (2 - n)^2 / 8 =$ **20.1** kNm/m

Saturated backfill $M_{s\_s} = F_{s\_s\_f} \times a_l \times ((3 \times a_l^2) - (15 \times a_l \times L) + (20 \times L^2)) / (60 \times L^2) =$ **13.7** kNm/m

Water $M_{s\_water} = F_{s\_water\_f} \times a_l \times ((3 \times a_l^2) - (15 \times a_l \times L) + (20 \times L^2)) / (60 \times L^2) =$ **20.4**
kNm/m

Total moment for stem design $M_{stem} = M_{s\_sur} + M_{s\_m\_a} + M_{s\_m\_b} + M_{s\_s} + M_{s\_water} =$ **71.8** kNm/m

Calculate moment for wall design

Surcharge $M_{w\_sur} = 9 \times F_{s\_sur\_f} \times L / 128 =$ **8.5** kNm/m

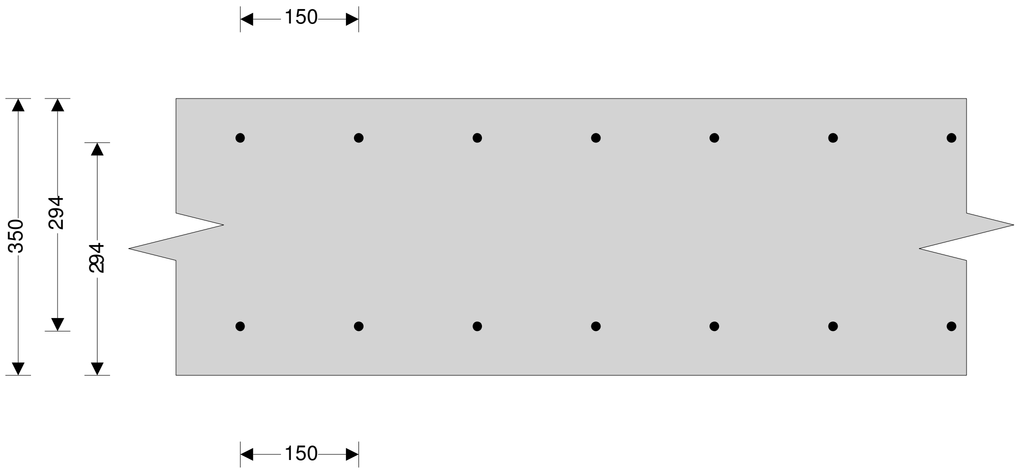
Moist backfill above water table $M_{w\_m\_a} = F_{s\_m\_a\_f} \times 0.577 \times b_l \times [(b_l^3 + 5 \times a_l \times L^2)/(5 \times L^3) - 0.577^2/3] =$ **2.7**
kNm/m

Moist backfill below water table $M_{w\_m\_b} = F_{s\_m\_b\_f} \times a_l \times [((8 - n^2 \times (4-n))^2 / 16) - 4 + n \times (4-n)]/8 =$ **10.4** kNm/m

Saturated backfill $M_{w\_s} = F_{s\_s\_f} \times [a_l^2 \times x \times ((5 \times L) - a_l)/(20 \times L^3) - (x - b_l)^3 / (3 \times a_l^2)] =$ **5.2** kNm/m

Water $M_{w\_water} = F_{s\_water\_f} \times [a_l^2 \times x \times ((5 \times L) - a_l)/(20 \times L^3) - (x - b_l)^3 / (3 \times a_l^2)] =$ **7.8**
kNm/m

Total moment for wall design $M_{wall} = M_{w\_sur} + M_{w\_m\_a} + M_{w\_m\_b} + M_{w\_s} + M_{w\_water} = \mathbf{34.6}$ kNm/m



Check wall stem in bending

Width of wall stem $b = \mathbf{1000}$ mm/m

Depth of reinforcement $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2) = \mathbf{294.0}$ mm

Constant $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu}) = \mathbf{0.021}$

Compression reinforcement is not required

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

$z_{stem} = \mathbf{279}$ mm

Area of tension reinforcement required $A_{s\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem}) = \mathbf{591}$ mm²/m

Minimum area of tension reinforcement $A_{s\_stem\_min} = k \times b \times t_{wall} = \mathbf{455}$ mm²/m

Area of tension reinforcement required $A_{s\_stem\_req} = \mathrm{Max}(A_{s\_stem\_des}, A_{s\_stem\_min}) = \mathbf{591}$ mm²/m

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

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

PASS - Reinforcement provided at the retaining wall stem is adequate

Check shear resistance at wall stem

Design shear stress $v_{stem} = V_{stem} / (b \times d_{stem}) = \mathbf{0.393}$ N/mm²

Allowable shear stress $v_{adm} = \min(0.8 \times \surd(f_{cu} / 1\ \mathrm{N/mm^2}), 5) \times 1\ \mathrm{N/mm^2} = \mathbf{5.000}$ N/mm²

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress $v_{c\_stem} = \mathbf{0.507}$ N/mm²

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

Check mid height of wall in bending

Depth of reinforcement $d_{wall} = t_{wall} - c_{wall} - (\phi_{wall} / 2) = \mathbf{294.0}$ mm

Constant $K_{wall} = M_{wall} / (b \times d_{wall}^2 \times f_{cu}) = \mathbf{0.010}$

Compression reinforcement is not required

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

$z_{wall} = \mathbf{279}$ mm

Area of tension reinforcement required $A_{s\_wall\_des} = M_{wall} / (0.87 \times f_y \times z_{wall}) = \mathbf{285}$ mm²/m

Minimum area of tension reinforcement $A_{s\_wall\_min} = k \times b \times t_{wall} = \mathbf{455}$ mm²/m

Area of tension reinforcement required $A_{s\_wall\_req} = \mathrm{Max}(A_{s\_wall\_des}, A_{s\_wall\_min}) = \mathbf{455}$ mm²/m

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

Area of reinforcement provided $A_{s\_wall\_prov} = \mathbf{754}$ 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 $f_s = 2 \times f_y \times A_{s\_stem\_req} / (3 \times A_{s\_stem\_prov})$ = **261.4** N/mm^2

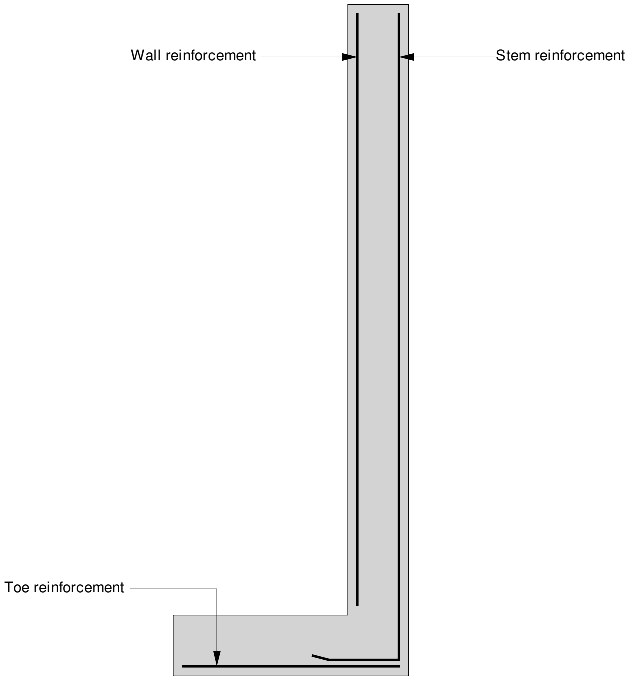
Modification factor $factor_{tens} = \min(0.55 + (477\ N/mm^2 - f_s)/(120 \times (0.9\ N/mm^2 + (M_{stem}/(b \times d_{stem}^2)))),2)$ = **1.59**

Maximum span/effective depth ratio $ratio_{max} = ratio_{bas} \times factor_{tens}$ = **31.76**

Actual span/effective depth ratio $ratio_{act} = h_{stem} / d_{stem}$ = **11.90**

PASS - Span to depth ratio is acceptable

Indicative retaining wall reinforcement diagram



Toe bars - 12 mm dia.@ 150 mm centres - (754 mm^2/m)
Wall bars - 12 mm dia.@ 150 mm centres - (754 mm^2/m)
Stem bars - 12 mm dia.@ 150 mm centres - (754 mm^2/m)

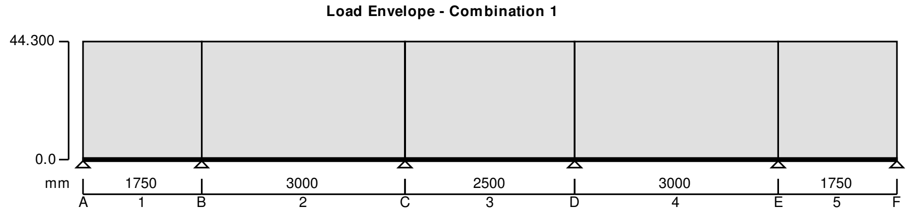
Tedds Conisbee 1-5 Offord Street London N1 1DH	Project 1 St. Marks Crescent NW1-7TS	Job no. 180507
	Calcs for Steel Waling Beam	Start page no./Revision 1

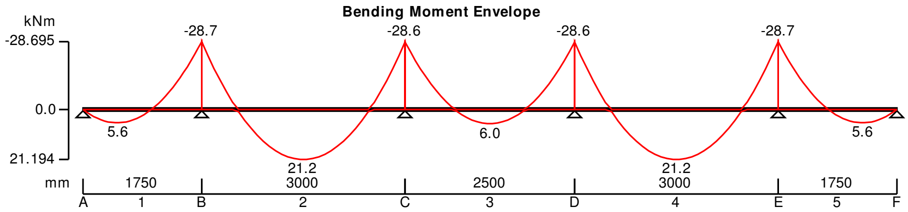
Calcs by	Calcs date	Checked by	Checked date	Approved by	Approved date
DB	25/07/2018				

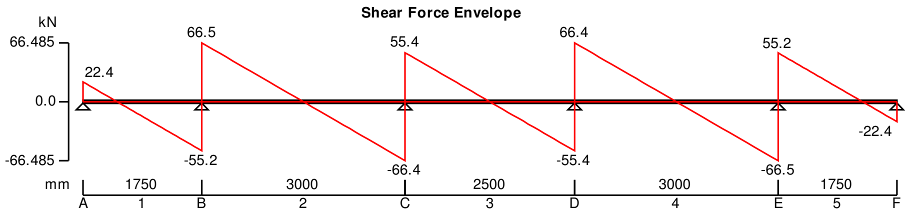
STEEL BEAM ANALYSIS & DESIGN (BS5950)

In accordance with BS5950-1:2000 incorporating Corrigendum No.1

TEDDS calculation version 3.0.05







Support conditions

Support A	Vertically restrained Rotationally free
Support B	Vertically restrained Rotationally free
Support C	Vertically restrained Rotationally free
Support D	Vertically restrained Rotationally free
Support E	Vertically restrained Rotationally free
Support F	Vertically restrained Rotationally free

Applied loading

Beam loads — Other full UDL 44.3 kN/m

Load combinations

Load combination 1	Support A	Dead × 1.40 Imposed × 1.60

		Other × 1.00
	Span 1	Dead × 1.40
		Imposed × 1.60
		Other × 1.00
	Support B	Dead × 1.40
		Imposed × 1.60
		Other × 1.00
	Span 2	Dead × 1.40
		Imposed × 1.60
		Other × 1.00
	Support C	Dead × 1.40
		Imposed × 1.60
		Other × 1.00
	Span 3	Dead × 1.40
		Imposed × 1.60
		Other × 1.00
	Support D	Dead × 1.40
		Imposed × 1.60
		Other × 1.00
	Span 4	Dead × 1.40
		Imposed × 1.60
		Other × 1.00
	Support E	Dead × 1.40
		Imposed × 1.60
		Other × 1.00
	Span 5	Dead × 1.40
		Imposed × 1.60
		Other × 1.00
	Support F	Dead × 1.40
		Imposed × 1.60
		Other × 1.00

Analysis results

Maximum moment	M_{max} = **21.2** kNm	M_{min} = **-28.7** kNm
Maximum moment span 1	M_{s1_max} = **5.6** kNm	M_{s1_min} = **-28.7** kNm
Maximum moment span 2	M_{s2_max} = **21.2** kNm	M_{s2_min} = **-28.7** kNm
Maximum moment span 3	M_{s3_max} = **6** kNm	M_{s3_min} = **-28.6** kNm
Maximum moment span 4	M_{s4_max} = **21.2** kNm	M_{s4_min} = **-28.7** kNm
Maximum moment span 5	M_{s5_max} = **5.6** kNm	M_{s5_min} = **-28.7** kNm
Maximum shear	V_{max} = **66.5** kN	V_{min} = **-66.5** kN
Maximum shear span 1	V_{s1_max} = **22.4** kN	V_{s1_min} = **-55.2** kN
Maximum shear span 2	V_{s2_max} = **66.5** kN	V_{s2_min} = **-66.4** kN
Maximum shear span 3	V_{s3_max} = **55.4** kN	V_{s3_min} = **-55.4** kN
Maximum shear span 4	V_{s4_max} = **66.4** kN	V_{s4_min} = **-66.5** kN
Maximum shear span 5	V_{s5_max} = **55.2** kN	V_{s5_min} = **-22.4** kN
Deflection	δ_{max} = **4** mm	δ_{min} = **0.3** mm

Deflection span 1	δ_{s1_max} = **0.1** mm	δ_{s1_min} = **0.3** mm
Deflection span 2	δ_{s2_max} = **4** mm	δ_{s2_min} = **0** mm
Deflection span 3	δ_{s3_max} = **0.1** mm	δ_{s3_min} = **0.3** mm
Deflection span 4	δ_{s4_max} = **4** mm	δ_{s4_min} = **0** mm
Deflection span 5	δ_{s5_max} = **0.1** mm	δ_{s5_min} = **0.3** mm
Maximum reaction at support A	R_{A_max} = **22.4** kN	R_{A_min} = **22.4** kN
Unfactored other load reaction at support A	R_{A_Other} = **22.4** kN	
Maximum reaction at support B	R_{B_max} = **121.6** kN	R_{B_min} = **121.6** kN
Unfactored other load reaction at support B	R_{B_Other} = **121.6** kN	
Maximum reaction at support C	R_{C_max} = **121.8** kN	R_{C_min} = **121.8** kN
Unfactored other load reaction at support C	R_{C_Other} = **121.8** kN	
Maximum reaction at support D	R_{D_max} = **121.8** kN	R_{D_min} = **121.8** kN
Unfactored other load reaction at support D	R_{D_Other} = **121.8** kN	
Maximum reaction at support E	R_{E_max} = **121.6** kN	R_{E_min} = **121.6** kN
Unfactored other load reaction at support E	R_{E_Other} = **121.6** kN	
Maximum reaction at support F	R_{F_max} = **22.4** kN	R_{F_min} = **22.4** kN
Unfactored other load reaction at support F	R_{F_Other} = **22.4** kN	

Section details

Section type **UC 152x152x30 (BS4-1)**

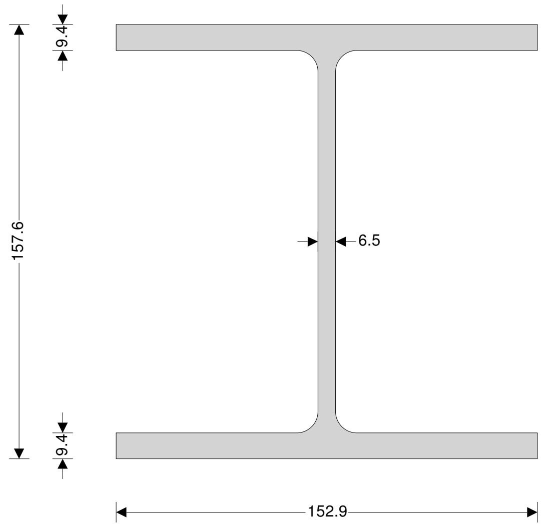
Steel grade **S275**

From table 9: Design strength p_y

Thickness of element max(T, t) = **9.4** mm

Design strength p_y = **275** N/mm²

Modulus of elasticity E = **205000** N/mm²



Lateral restraint

Span 1 has lateral restraint at supports only

Span 2 has full lateral restraint

Span 3 has full lateral restraint

Span 4 has full lateral restraint

Span 5 has full lateral restraint

Effective length factors

Effective length factor in major axis K_x = **1.00**

Effective length factor in minor axis K_y = **1.00**

Effective length factor for lateral-torsional buckling $K_{LT.A}$ = **1.00**

$K_{LT.B}$ = **1.00**

$K_{LT.C}$ = **1.00**

$K_{LT.D}$ = **1.00**

$K_{LT.E}$ = **1.00**

$K_{LT.F}$ = **1.00**

Classification of cross sections - Section 3.5

$\varepsilon = \sqrt{[275\ N/mm^2 / p_y]}$ = **1.00**

Internal compression parts - Table 11

Depth of section d = **123.6** mm

$d / t = 19.0 \times \varepsilon <= 80 \times \varepsilon$ Class 1 plastic

Outstand flanges - Table 11

Width of section $b = B / 2$ = **76.5** mm

$b / T = 8.1 \times \varepsilon <= 9 \times \varepsilon$ Class 1 plastic

Section is class 1 plastic

Shear capacity - Section 4.2.3

Design shear force $F_v = \max(abs(V_{max}), abs(V_{min}))$ = **66.5** kN

$d / t < 70 \times \varepsilon$

Web does not need to be checked for shear buckling

Shear area $A_v = t \times D$ = **1024** mm^2

Design shear resistance $P_v = 0.6 \times p_y \times A_v$ = **169** kN

PASS - Design shear resistance exceeds design shear force

Moment capacity at span 1 - Section 4.2.5

Design bending moment $M = \max(abs(M_{s1\_max}), abs(M_{s1\_min}))$ = **28.7** kNm

Moment capacity low shear - cl.4.2.5.2 $M_c = \min(p_y \times S_{xx}, 1.5 \times p_y \times Z_{xx})$ = **68.1** kNm

Effective length for lateral-torsional buckling - Section 4.3.5

Effective length for lateral torsional buckling $L_E = 1.0 \times L_{s1}$ = **1750** mm

Slenderness ratio $\lambda = L_E / r_{yy}$ = **45.725**

Equivalent slenderness - Section 4.3.6.7

Buckling parameter u = **0.849**

Torsional index x = **15.999**

Slenderness factor $v = 1 / [1 + 0.05 \times (\lambda / x)^2]^{0.25}$ = **0.918**

Ratio - cl.4.3.6.9 β_W = **1.000**

Equivalent slenderness - cl.4.3.6.7 $\lambda_{LT} = u \times v \times \lambda \times \sqrt{[\beta_W]}$ = **35.615**

Limiting slenderness - Annex B.2.2 $\lambda_{L0} = 0.4 \times (\pi^2 \times E / p_y)^{0.5}$ = **34.310**

$\lambda_{LT} > \lambda_{L0}$ - Allowance should be made for lateral-torsional buckling

Bending strength - Section 4.3.6.5

Robertson constant α_{LT} = **7.0**

Perry factor $\eta_{LT} = \max(\alpha_{LT} \times (\lambda_{LT} - \lambda_{L0}) / 1000, 0)$ = **0.009**

Euler stress $p_E = \pi^2 \times E / \lambda_{LT}^2$ = **1595.1** N/mm^2

$\phi_{LT} = (p_y + (\eta_{LT} + 1) \times p_E) / 2$ = **942.3** N/mm^2

Bending strength - Annex B.2.1 $p_b = p_E \times p_y / (\phi_{LT} + (\phi_{LT}^2 - p_E \times p_y)^{0.5})$ = **272** N/mm^2

Equivalent uniform moment factor - Section 4.3.6.6

Moment at quarter point of segment M_2 = **5.5** kNm

Moment at centre-line of segment M_3 = **2.6** kNm

Moment at three quarter point of segment M_4 = **8.8** kNm

Maximum moment in segment M_{abs} = **28.7** kNm

Maximum moment governing buckling resistance $M_{LT} = M_{abs}$ = **28.7** kNm

Equivalent uniform moment factor for lateral-torsional buckling

$m_{LT} = \max(0.2 + (0.15 \times M_2 + 0.5 \times M_3 + 0.15 \times M_4) / M_{abs}, 0.44)$ = **0.440**

Buckling resistance moment - Section 4.3.6.4

Buckling resistance moment $M_b = p_b \times S_{xx}$ = **67.4** kNm

M_b / m_{LT} = **153.1** kNm

PASS - Moment capacity exceeds design bending moment

Check vertical deflection - Section 2.5.2

Consider deflection due to other loads

Limiting deflection $\delta_{lim} = L_{s4} / 360$ = **8.333** mm

Maximum deflection span 4 $\delta = \max(\text{abs}(\delta_{max}), \text{abs}(\delta_{min}))$ = **4.046** mm

PASS - Maximum deflection does not exceed deflection limit

STEEL MEMBER DESIGN (BS5950)

In accordance with BS5950-1:2000 incorporating Corrigendum No.1

TEDDS calculation version 3.0.05

Section details

Section type **UC 152x152x30 (BS4-1)**

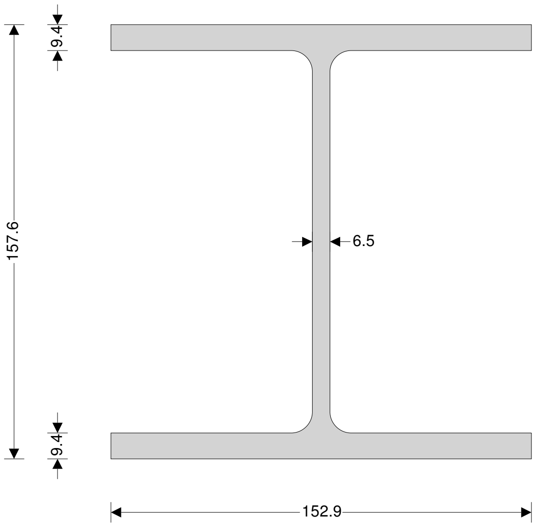
Steel grade **S275**

From table 9: Design strength p_y

Thickness of element max(T, t) = **9.4** mm

Design strength p_y = **275** N/mm^2

Modulus of elasticity E = **205000** N/mm^2



Lateral restraint

Distance between major axis restraints L_x = **5000** mm

Distance between minor axis restraints L_y = **5000** mm

Effective length factors

Effective length factor in major axis K_x = **1.00**

Effective length factor in minor axis K_y = **1.00**

Effective length factor for lateral-torsional buckling K_{LT} = **1.00**

Classification of cross sections - Section 3.5

$\varepsilon = \sqrt{[275 \text{ N/mm}^2 / p_y]}$ = **1.00**

Internal compression parts - Table 11

Depth of section d = **123.6** mm

Stress ratios $r1 = \min(F_c / (d \times t \times p_{yw}), 1)$ = **1**

$r2 = F_c / (A \times p_{yw})$ = **0.232**

$d / t = 19.0 \times \varepsilon <= \max(80 \times \varepsilon / (1 + r1), 40 \times \varepsilon)$ Class 1 plastic

Outstand flanges - Table 11

Width of section b = B / 2 = **76.5** mm

$b / T = 8.1 \times \varepsilon <= 9 \times \varepsilon$ Class 1 plastic

Section is class 1 plastic

Moment capacity - Section 4.2.5

Design bending moment $M = \mathbf{1}$ kNm

Moment capacity low shear - cl.4.2.5.2 $M_c = \min(p_y \times S_{xx}, 1.2 \times p_y \times Z_{xx}) = \mathbf{68.1}$ kNm

Effective length for lateral-torsional buckling - Section 4.3.5

Effective length for lateral torsional buckling $L_E = 1.0 \times L_y = \mathbf{5000}$ mm

Slenderness ratio $\lambda = L_E / r_{yy} = \mathbf{130.643}$

Equivalent slenderness - Section 4.3.6.7

Buckling parameter $u = \mathbf{0.849}$

Torsional index $x = \mathbf{15.999}$

Slenderness factor $v = 1 / [1 + 0.05 \times (\lambda / x)^2]^{0.25} = \mathbf{0.693}$

Ratio - cl.4.3.6.9 $\beta_W = \mathbf{1.000}$

Equivalent slenderness - cl.4.3.6.7 $\lambda_{LT} = u \times v \times \lambda \times \sqrt{[\beta_W]} = \mathbf{76.829}$

Limiting slenderness - Annex B.2.2 $\lambda_{L0} = 0.4 \times (\pi^2 \times E / p_y)^{0.5} = \mathbf{34.310}$

$\lambda_{LT} > \lambda_{L0}$ - Allowance should be made for lateral-torsional buckling

Bending strength - Section 4.3.6.5

Robertson constant $\alpha_{LT} = \mathbf{7.0}$

Perry factor $\eta_{LT} = \max(\alpha_{LT} \times (\lambda_{LT} - \lambda_{L0}) / 1000, 0) = \mathbf{0.298}$

Euler stress $p_E = \pi^2 \times E / \lambda_{LT}^2 = \mathbf{342.8}$ N/mm²

$\phi_{LT} = (p_y + (\eta_{LT} + 1) \times p_E) / 2 = \mathbf{359.9}$ N/mm²

Bending strength - Annex B.2.1 $p_b = p_E \times p_y / (\phi_{LT} + (\phi_{LT}^2 - p_E \times p_y)^{0.5}) = \mathbf{172.1}$ N/mm²

Equivalent uniform moment factor - Section 4.3.6.6

Equivalent uniform moment factor for LTB $m_{LT} = \mathbf{1.000}$

Buckling resistance moment - Section 4.3.6.4

Buckling resistance moment $M_b = p_b \times S_{xx} = \mathbf{42.6}$ kNm

$M_b / m_{LT} = \mathbf{42.6}$ kNm

PASS - Buckling resistance moment exceeds design bending moment

Compression members - Section 4.7

Design compression force $F_c = \mathbf{243.6}$ kN

Effective length for major (x-x) axis buckling - Section 4.7.3

Effective length for buckling $L_{Ex} = L_x \times K_x = \mathbf{5000}$ mm

Slenderness ratio - cl.4.7.2 $\lambda_x = L_{Ex} / r_{xx} = \mathbf{73.975}$

Compressive strength - Section 4.7.5

Limiting slenderness $\lambda_0 = 0.2 \times (\pi^2 \times E / p_y)^{0.5} = \mathbf{17.155}$

Strut curve - Table 23 b

Robertson constant $\alpha_x = \mathbf{3.5}$

Perry factor $\eta_x = \alpha_x \times (\lambda_x - \lambda_0) / 1000 = \mathbf{0.199}$

Euler stress $p_{Ex} = \pi^2 \times E / \lambda_x^2 = \mathbf{369.7}$ N/mm²

$\phi_x = (p_y + (\eta_x + 1) \times p_{Ex}) / 2 = \mathbf{359.1}$ N/mm²

Compressive strength - Annex C.1 $p_{cx} = p_{Ex} \times p_y / (\phi_x + (\phi_x^2 - p_{Ex} \times p_y)^{0.5}) = \mathbf{193.9}$ N/mm²

Compression resistance - Section 4.7.4

Compression resistance - cl.4.7.4 $P_{cx} = A \times p_{cx} = \mathbf{742}$ kN

PASS - Compression resistance exceeds design compression force

Effective length for minor (y-y) axis buckling - Section 4.7.3

Effective length for buckling $L_{Ey} = L_y \times K_y =$ **5000** mm

Slenderness ratio - cl.4.7.2 $\lambda_y = L_{Ey} / r_{yy} =$ **130.643**

Compressive strength - Section 4.7.5

Limiting slenderness $\lambda_0 = 0.2 \times (\pi^2 \times E / p_y)^{0.5} =$ **17.155**

Strut curve - Table 23 c

Robertson constant $\alpha_y =$ **5.5**

Perry factor $\eta_y = \alpha_y \times (\lambda_y - \lambda_0) / 1000 =$ **0.624**

Euler stress $p_{Ey} = \pi^2 \times E / \lambda_y^2 =$ **118.5** N/mm²

$\phi_y = (p_y + (\eta_y + 1) \times p_{Ey}) / 2 =$ **233.8** N/mm²

Compressive strength - Annex C.1 $p_{cy} = p_{Ey} \times p_y / (\phi_y + (\phi_y^2 - p_{Ey} \times p_y)^{0.5}) =$ **85.3** N/mm²

Compression resistance - Section 4.7.4

Compression resistance - cl.4.7.4 $P_{cy} = A \times p_{cy} =$ **326.3** kN

PASS - Compression resistance exceeds design compression force

Compression members with moments - Section 4.8.3

Comb.compression & bending check - cl.4.8.3.2 $F_c / (A \times p_y) + M / M_c =$ **0.246**

PASS - Combined bending and compression check is satisfied

Member buckling resistance - Section 4.8.3.3

Max major axis moment governing M_b $M_{LT} = M_x =$ **1.00** kNm

Equivalent uniform moment factor for major axis flexural buckling

$m_x =$ **1.000**

$m_y =$ **1.000**

Buckling resistance checks - cl.4.8.3.3.2 $F_c / P_{cx} + m_x \times M / M_c \times (1 + 0.5 \times F_c / P_{cx}) =$ **0.345**

$F_c / P_{cy} + m_{LT} \times M_{LT} / M_b =$ **0.770**

PASS - Member buckling resistance checks are satisfied