BS EN 1991-1

NA to BS EN 1991-1

Design Loading

1 Pitched Roof (kN/m^2)

			DL	IL
			kN/m^2	kN/m^2
Pitch =	34 degrees			
Roof tiles			0.50	
Battens+membrane			0.05	
Insulation			0.05	
Timber rafters + Plywood			0.40	
Ceiling and Services			0.25	
Imposed			-	0.60
Sub-total	On slope		1.25	
Sub-total	On plan	Slope load/Cos pitch	1.51	
		Total =	**1.51**	**0.60**

2 First Floor (Timber)

		DL	IL
		kN/m^2	kN/m^2
Finishes		0.20	
Floor Joists+plydeck		0.40	
Ceiling		0.15	
Insulation		0.05	
Services		0.10	
Partitions		0.50	
Imposed		-	1.50
	Total =	**1.40**	**1.50**

3 External Existing Wall

		kN/m^2
Plaster Board+Skim		0.35
215mm Brick		4.00
Insulation		0.10
	Total =	**4.45**

4 Ground Floor (Concrete Slab)

		DL	IL
		kN/m^2	kN/m^2
Finishes		0.20	
250mm RC Slab		6.25	
Ceiling		0.15	
Insulation		0.05	
Services		0.10	
Partitions		0.50	
Imposed		-	1.50
	Total =	**7.25**	**1.50**

5 Basement Floor (Concrete Slab)

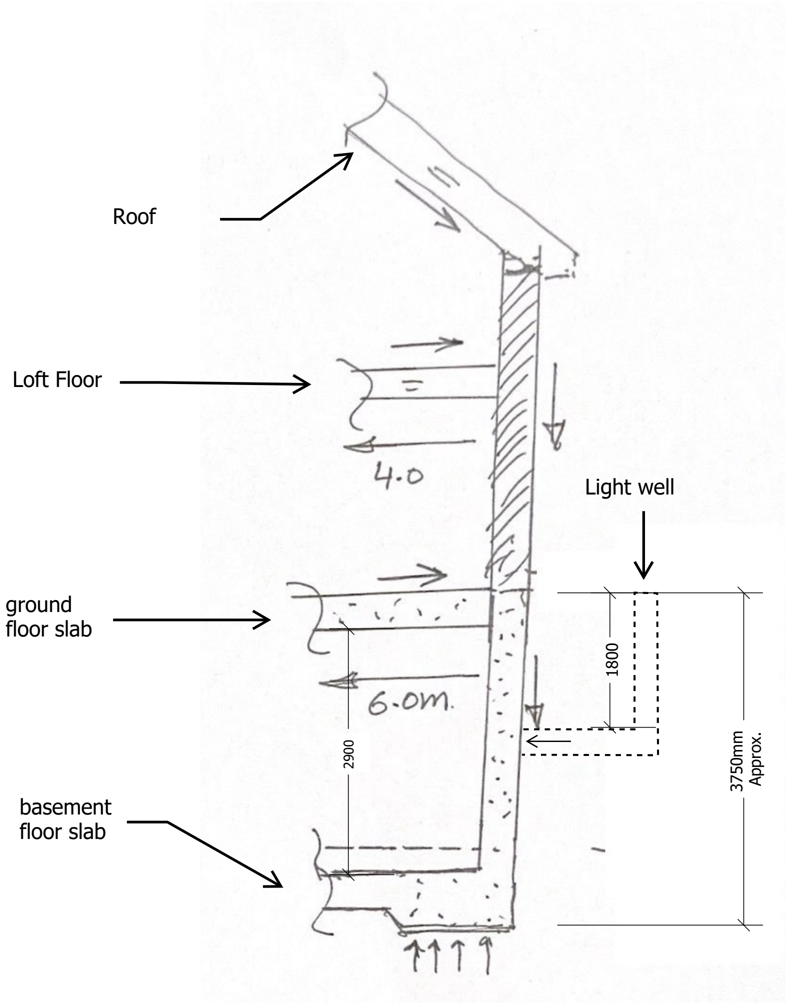
		DL	IL
		kN/m^2	kN/m^2
Finishes		0.20	
300mm RC Slab		7.00	
Insulation		0.05	
Screed		1.65	
Partitions		0.50	
Imposed		-	1.50
	Total =	**9.40**	**1.50**

6 External Basement Wall

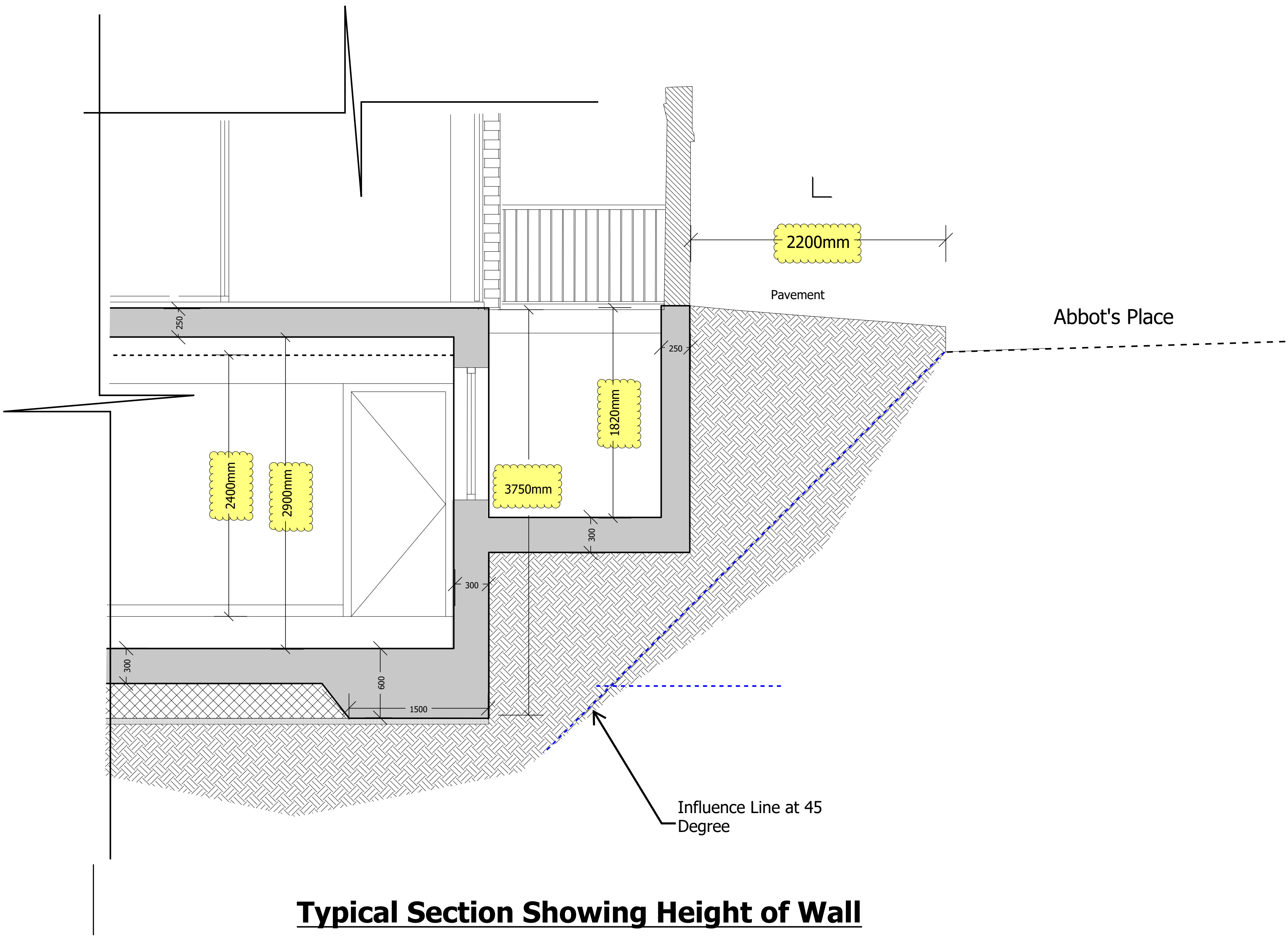
		kN/m^2
Plaster Board+Skim		0.35
300mm RC		7.00
Insulation		0.10
	Total =	**7.45**

5 Wind Pressure

		kN/m^2
WL	Total	**0.75**



Typical Section Showing full height of building



Typical Section Showing Height of Wall

Light Well Retaining Wall Design

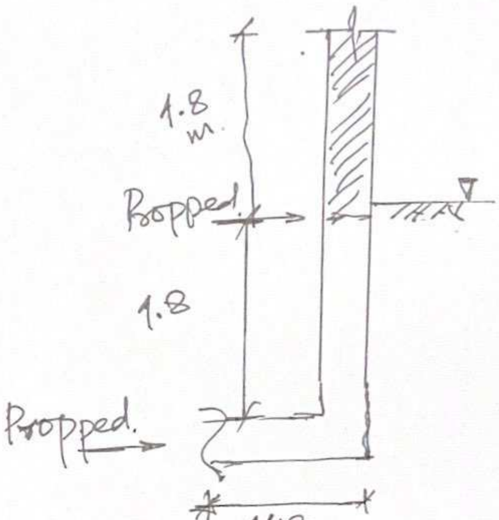
Design Loading Calculations:-

Boundary Wall

Dead Load.

⇒ DL = 4.45 × 1.8
= 8.01

Highway Surcharge Load
= 10 KN/m².



Wind Load

IL = 0.75 × 1.8
= 1.35 KN/m

With regard to proposed foundation designs, the in-situ testing indicates the following Allowable Bearing Capacities (based on a Factor of Safety = 3) within the Natural Strata at depths below current ground/floor level at each location:

Borehole No.	Depth (m)	Allowable Bearing Capacity (kN/m^2)	Strata
1	1.0m	140 (Clay)	London Clay
	2.0m	200 (Clay)	London Clay
	3.0m	240 (Clay)	London Clay
2	1.0m	140 (Clay)	London Clay
	2.5m	220 (Clay)	London Clay
	3.0m	260 (Clay)	London Clay

Table 1, Allowable Bearing Capacity with Depth (FoS = 3)

RETAINING WALL ANALYSIS **Light Well Retaining Wall**

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

Tedds calculation version 2.9.17

Analysis summary

Design summary

Overall design utilisation 0.65

Overall design status Pass

Description	Unit	Capacity	Applied	F o S	Result
Bearing pressure	kN/m^2	150	28.3	5.296	PASS

Design summary

Description	Unit	Provided	Required	Utilisation	Result
Shear resistance	kN/m	23.1	114.8	0.202	PASS
Stem p0 - Shear resistance	kN/m	105.2	52.6	0.500	PASS
Stem p1 rear face - Flexural reinforcement	mm^2/m	565.5	292.2	0.517	PASS
Stem p1 - Shear resistance	kN/m	105.2	20.6	0.196	PASS
Base top face - Flexural reinforcement	mm^2/m	565.5	367.5	0.650	PASS
Base bottom face - Flexural reinforcement	mm^2/m	565.5	329.8	0.583	PASS
Base - Shear resistance	kN/m	114.8	23.1	0.202	PASS

Retaining wall details

Stem type Propped cantilever

Stem height h_{stem} = **2000** mm

Prop height h_{prop} = **1800** mm

Stem thickness t_{stem} = **250** mm

Angle to rear face of stem α = **90** deg

Stem density γ_{stem} = **25** kN/m^3

Toe length l_{toe} = **1480** mm

Base thickness t_{base} = **300** mm

Base density γ_{base} = **25** kN/m^3

Height of retained soil h_{ret} = **1800** mm

Angle of soil surface β = **0** deg

Depth of cover d_{cover} = **100** mm

Depth of excavation d_{exc} = **100** mm

Retained soil properties

Soil type Stiff clay

Moist density γ_{mr} = **19** kN/m^3

Saturated density γ_{sr} = **19** kN/m^3

Base soil properties

Soil type Stiff clay

Soil density γ_b = **19** kN/m^3

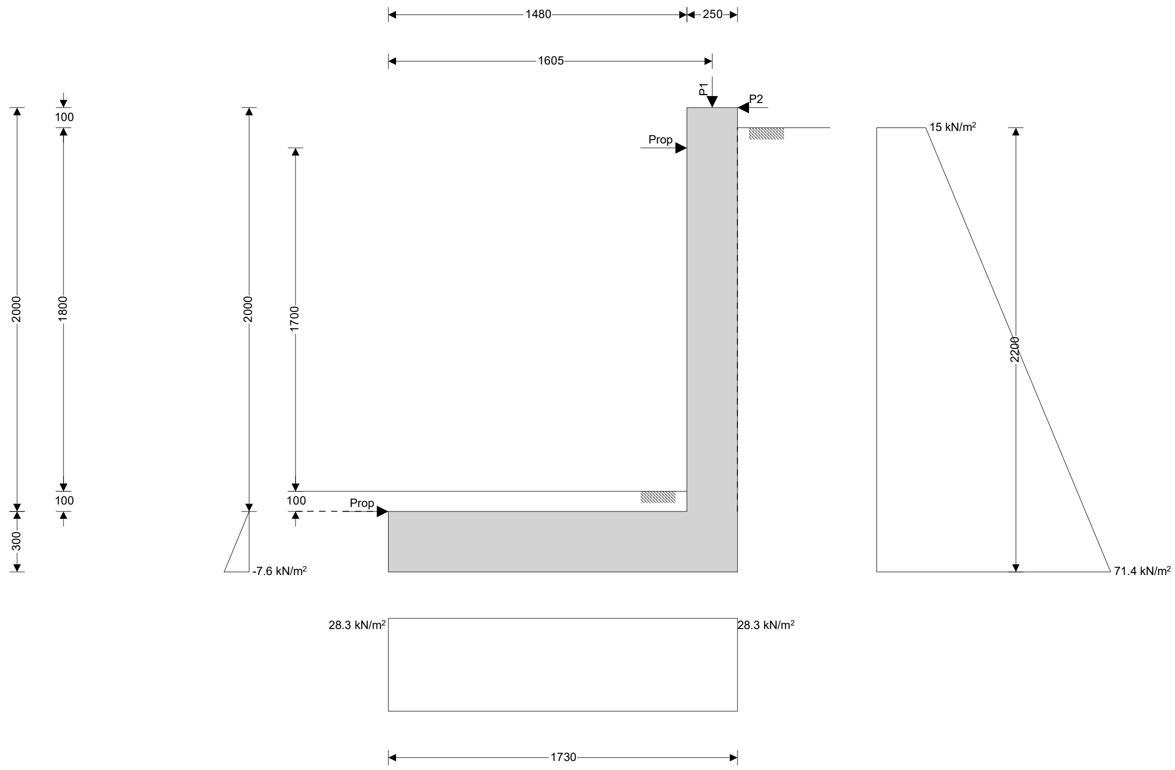
Loading details

Variable surcharge load $Surcharge_Q$ = **10** kN/m^2

Vertical line load at 1605 mm P_{G1} = **8** kN/m

Horizontal line load at 2000 mm P_{Q2} = **1.4** kN/m

QAIM STRUCTURES



General arrangement - sketch pressures relate to bearing check

Calculate retaining wall geometry

Base length	$l_{base} = l_{toe} + t_{stem} = \mathbf{1730}$ mm
Moist soil height	$h_{moist} = h_{soil} = \mathbf{1900}$ mm
Length of surcharge load	$l_{sur} = l_{heel} = \mathbf{0}$ mm
- Distance to vertical component	$x_{sur\_v} = l_{base} - l_{heel} / 2 = \mathbf{1730}$ mm
Effective height of wall	$h_{eff} = h_{base} + d_{cover} + h_{ret} = \mathbf{2200}$ mm
- Distance to horizontal component	$x_{sur\_h} = h_{eff} / 2 = \mathbf{1100}$ mm
Area of wall stem	$A_{stem} = h_{stem} \times t_{stem} = \mathbf{0.5}$ m^2
- Distance to vertical component	$x_{stem} = l_{toe} + t_{stem} / 2 = \mathbf{1605}$ mm
Area of wall base	$A_{base} = l_{base} \times t_{base} = \mathbf{0.519}$ m^2
- Distance to vertical component	$x_{base} = l_{base} / 2 = \mathbf{865}$ mm
Area of base soil	$A_{pass} = d_{cover} \times l_{toe} = \mathbf{0.148}$ m^2
- Distance to vertical component	$x_{pass\_v} = l_{base} - (d_{cover} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{pass} = \mathbf{740}$ mm
- Distance to horizontal component	$x_{pass\_h} = (d_{cover} + h_{base}) / 3 = \mathbf{133}$ mm

Design approach 1

Partial factors on actions - Combination 1

Partial factor set	User defined
Permanent unfavourable action	$\gamma_G = \mathbf{1.350}$
Permanent favourable action	$\gamma_{Gf} = \mathbf{1.000}$
Variable unfavourable action	$\gamma_Q = \mathbf{1.500}$
Variable favourable action	$\gamma_{Qf} = \mathbf{0.000}$

Partial factors for soil parameters – Combination 1

Soil parameter set	User defined
Angle of shearing resistance	$\gamma_{\phi'}$ = **1.00**
Undrained shear strength	γ_{cu} = **1.00**
Weight density	γ_{γ} = **1.00**

Retained soil properties

Design moist density	$\gamma_{mr}' = \gamma_{mr} / \gamma_{\gamma}$ = **19** kN/m^3
Design saturated density	$\gamma_{sr}' = \gamma_{sr} / \gamma_{\gamma}$ = **19** kN/m^3

Base soil properties

Design soil density	$\gamma_{b}' = \gamma_{b} / \gamma_{\gamma}$ = **19** kN/m^3

Soil coefficients

Coefficient of friction to back of wall	K_{fr} = **0.325**
Coefficient of friction to front of wall	K_{fb} = **0.325**
Coefficient of friction beneath base	K_{fbb} = **0.325**
At rest pressure coefficient	K_0 = **1.000**
Passive pressure coefficient	K_P = **1.000**

Bearing pressure check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem}$ = **16.9** kN/m
Wall base	$F_{base} = \gamma_G \times A_{base} \times \gamma_{base}$ = **17.5** kN/m
Line loads	$F_{P\_v} = \gamma_G \times P_{G1}$ = **10.8** kN/m
Base soil	$F_{pass\_v} = \gamma_G \times A_{pass} \times \gamma_b'$ = **3.8** kN/m
Total	$F_{total\_v} = F_{stem} + F_{base} + F_{P\_v} + F_{pass\_v}$ = **49** kN/m

Horizontal forces on wall

Surcharge load	$F_{sur\_h} = K_0 \times \gamma_Q \times Surcharge_Q \times h_{eff}$ = **33** kN/m
Line loads	$F_{P\_h} = \gamma_Q \times P_{Q2}$ = **2** kN/m
Moist retained soil	$F_{moist\_h} = \gamma_G \times K_0 \times \gamma_{mr}' \times h_{eff}^2 / 2$ = **62.1** kN/m
Base soil	$F_{pass\_h} = -\gamma_{Gf} \times K_P \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2$ = **-1.5** kN/m
Total	$F_{total\_h} = F_{sur\_h} + F_{P\_h} + F_{moist\_h} + F_{pass\_h}$ = **95.6** kN/m

Moments on wall

Wall stem	$M_{stem} = F_{stem} \times x_{stem}$ = **27.1** kNm/m
Wall base	$M_{base} = F_{base} \times x_{base}$ = **15.2** kNm/m
Surcharge load	$M_{sur} = -F_{sur\_h} \times x_{sur\_h}$ = **-36.3** kNm/m
Line loads	$M_P = \gamma_G \times P_{G1} \times p_1 - (\gamma_Q \times P_{Q2} \times (p_2 + t_{base}))$ = **12.7** kNm/m
Moist retained soil	$M_{moist} = -F_{moist\_h} \times x_{moist\_h}$ = **-45.5** kNm/m
Base soil	$M_{pass} = F_{pass\_v} \times x_{pass\_v}$ = **2.8** kNm/m
Total	$M_{total} = M_{stem} + M_{base} + M_{sur} + M_P + M_{moist} + M_{pass}$ = **-24.1** kNm/m

Check bearing pressure

Propping force to stem	$F_{prop\_stem} = (F_{total\_v} \times l_{base} / 2 - M_{total}) / (h_{prop} + t_{base})$ = **31.6** kN/m
Propping force to base	$F_{prop\_base} = F_{total\_h} - F_{prop\_stem}$ = **63.9** kN/m
Moment from propping force	$M_{prop} = F_{prop\_stem} \times (h_{prop} + t_{base})$ = **66.5** kNm/m
Distance to reaction	$\bar{x} = (M_{total} + M_{prop}) / F_{total\_v}$ = **865** mm
Eccentricity of reaction	$e = \bar{x} - l_{base} / 2$ = **0** mm

Loaded length of base	$l_{load} = l_{base}$ = **1730** mm
Bearing pressure at toe	$q_{toe} = F_{total\_v} / l_{base}$ = **28.3** kN/m^2
Bearing pressure at heel	$q_{heel} = F_{total\_v} / l_{base}$ = **28.3** kN/m^2
Factor of safety	$FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel})$ = **5.296**

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

Design approach 1

Partial factors on actions - Combination 2

Partial factor set	User defined
Permanent unfavourable action	γ_G = **1.000**
Permanent favourable action	γ_{Gf} = **1.000**
Variable unfavourable action	γ_Q = **1.300**
Variable favourable action	γ_{Qf} = **0.000**

Partial factors for soil parameters – Combination 2

Soil parameter set	User defined
Angle of shearing resistance	$\gamma_{\phi'}$ = **1.25**
Undrained shear strength	γ_{cu} = **1.40**
Weight density	γ_γ = **1.00**

Retained soil properties

Design moist density	$\gamma_{mr}' = \gamma_{mr} / \gamma_\gamma$ = **19** kN/m^3
Design saturated density	$\gamma_{sr}' = \gamma_{sr} / \gamma_\gamma$ = **19** kN/m^3

Base soil properties

Design soil density	$\gamma_b' = \gamma_b / \gamma_\gamma$ = **19** kN/m^3

Soil coefficients

Coefficient of friction to back of wall	K_{fr} = **0.325**
Coefficient of friction to front of wall	K_{fb} = **0.325**
Coefficient of friction beneath base	K_{fbb} = **0.325**
At rest pressure coefficient	K_0 = **1.000**
Passive pressure coefficient	K_P = **1.000**

Bearing pressure check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem}$ = **12.5** kN/m
Wall base	$F_{base} = \gamma_G \times A_{base} \times \gamma_{base}$ = **13** kN/m
Line loads	$F_{P\_v} = \gamma_G \times P_{G1}$ = **8** kN/m
Base soil	$F_{pass\_v} = \gamma_G \times A_{pass} \times \gamma_b'$ = **2.8** kN/m
Total	$F_{total\_v} = F_{stem} + F_{base} + F_{P\_v} + F_{pass\_v}$ = **36.3** kN/m

Horizontal forces on wall

Surcharge load	$F_{sur\_h} = K_0 \times \gamma_Q \times Surcharge_Q \times h_{eff}$ = **28.6** kN/m
Line loads	$F_{P\_h} = \gamma_Q \times P_{Q2}$ = **1.8** kN/m
Moist retained soil	$F_{moist\_h} = \gamma_G \times K_0 \times \gamma_{mr}' \times h_{eff}^2 / 2$ = **46** kN/m
Base soil	$F_{pass\_h} = -\gamma_{Gf} \times K_P \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2$ = **-1.5** kN/m
Total	$F_{total\_h} = F_{sur\_h} + F_{P\_h} + F_{moist\_h} + F_{pass\_h}$ = **74.8** kN/m

Moments on wall

Wall stem	$M_{stem} = F_{stem} \times x_{stem}$ = **20.1** kNm/m

Wall base	$M_{base} = F_{base} \times x_{base}$ = **11.2** kNm/m
Surcharge load	$M_{sur} = -F_{sur\_h} \times x_{sur\_h}$ = **-31.5** kNm/m
Line loads	$M_P = \gamma_G \times P_{G1} \times p_1 - (\gamma_Q \times P_{Q2} \times (p_2 + t_{base}))$ = **8.8** kNm/m
Moist retained soil	$M_{moist} = -F_{moist\_h} \times x_{moist\_h}$ = **-33.7** kNm/m
Base soil	$M_{pass} = F_{pass\_v} \times x_{pass\_v}$ = **2.1** kNm/m
Total	$M_{total} = M_{stem} + M_{base} + M_{sur} + M_P + M_{moist} + M_{pass}$ = **-23** kNm/m

Check bearing pressure

Propping force to stem	$F_{prop\_stem} = (F_{total\_v} \times l_{base} / 2 - M_{total}) / (h_{prop} + t_{base})$ = **25.9** kN/m
Propping force to base	$F_{prop\_base} = F_{total\_h} - F_{prop\_stem}$ = **48.9** kN/m
Moment from propping force	$M_{prop} = F_{prop\_stem} \times (h_{prop} + t_{base})$ = **54.4** kNm/m
Distance to reaction	$\bar{x} = (M_{total} + M_{prop}) / F_{total\_v}$ = **865** mm
Eccentricity of reaction	$e = \bar{x} - l_{base} / 2$ = **0** mm
Loaded length of base	$l_{load} = l_{base}$ = **1730** mm
Bearing pressure at toe	$q_{toe} = F_{total\_v} / l_{base}$ = **21** kN/m^2
Bearing pressure at heel	$q_{heel} = F_{total\_v} / l_{base}$ = **21** kN/m^2
Factor of safety	$FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel})$ = **7.149**

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

RETAINING WALL DESIGN

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

Tedds calculation version 2.9.17

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

Concrete strength class	C30/37
Characteristic compressive cylinder strength	f_{ck} = **30** N/mm^2
Characteristic compressive cube strength	$f_{ck,cube}$ = **37** N/mm^2
Mean value of compressive cylinder strength	$f_{cm} = f_{ck} + 8$ N/mm^2 = **38** N/mm^2
Mean value of axial tensile strength	$f_{ctm} = 0.3$ N/mm$^2 \times (f_{ck} / 1$ N/mm$^2)^{2/3}$ = **2.9** N/mm^2
5% fractile of axial tensile strength	$f_{ctk,0.05} = 0.7 \times f_{ctm}$ = **2.0** N/mm^2
Secant modulus of elasticity of concrete	$E_{cm} = 22$ kN/mm$^2 \times (f_{cm} / 10$ N/mm$^2)^{0.3}$ = **32837** N/mm^2
Partial factor for concrete - Table 2.1N	γ_C = **1.50**
Compressive strength coefficient - cl.3.1.6(1)	α_{cc} = **0.85**
Design compressive concrete strength - exp.3.15	$f_{cd} = \alpha_{cc} \times f_{ck} / \gamma_C$ = **17.0** N/mm^2
Maximum aggregate size	h_{agg} = **20** mm
Ultimate strain - Table 3.1	ε_{cu2} = **0.0035**
Shortening strain - Table 3.1	ε_{cu3} = **0.0035**
Effective compression zone height factor	λ = **0.80**
Effective strength factor	η = **1.00**
Bending coefficient k_1	K_1 = **0.40**
Bending coefficient k_2	$K_2 = 1.00 \times (0.6 + 0.0014/\varepsilon_{cu2})$ = **1.00**
Bending coefficient k_3	K_3 =**0.40**
Bending coefficient k_4	$K_4 = 1.00 \times (0.6 + 0.0014/\varepsilon_{cu2})$ =**1.00**

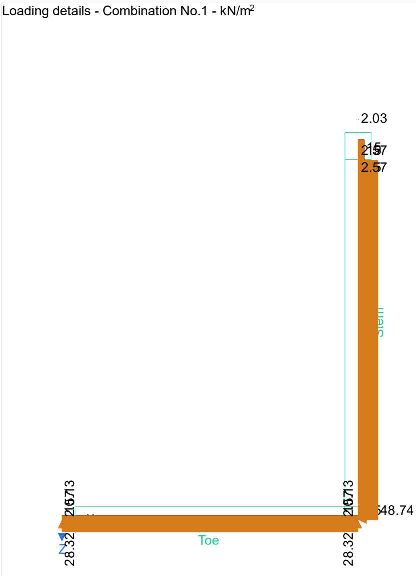
Reinforcement details

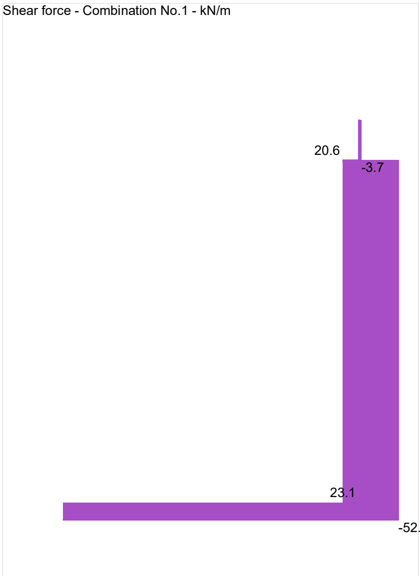
Characteristic yield strength of reinforcement	f_{yk} = **500** N/mm^2
Modulus of elasticity of reinforcement	E_s = **200000** N/mm^2
Partial factor for reinforcing steel - Table 2.1N	γ_S = **1.15**

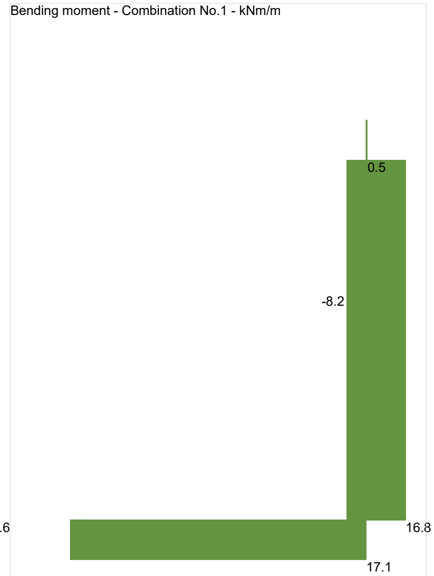
Design yield strength of reinforcement	$f_{yd} = f_{yk} / \gamma_S$ = **435** N/mm^2

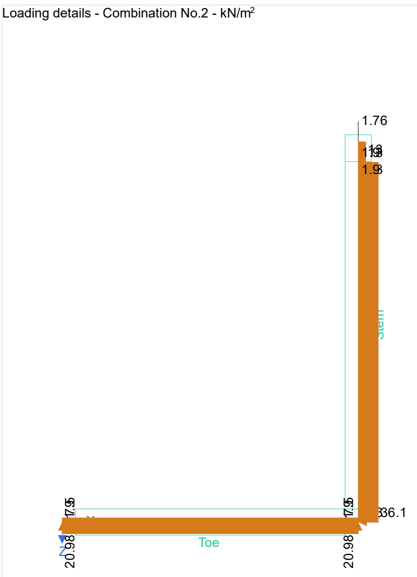
Cover to reinforcement

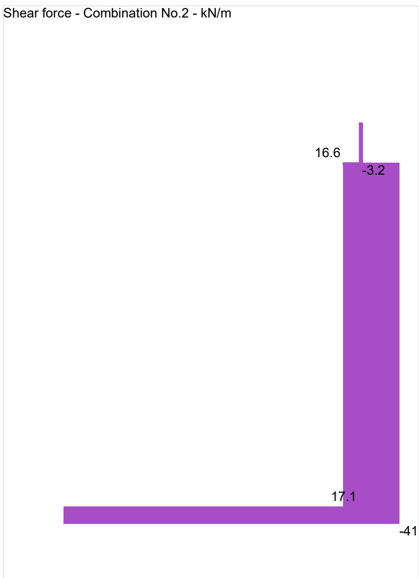
Front face of stem	c_{sf} = **40** mm
Rear face of stem	c_{sr} = **50** mm
Top face of base	c_{bt} = **50** mm
Bottom face of base	c_{bb} = **75** mm

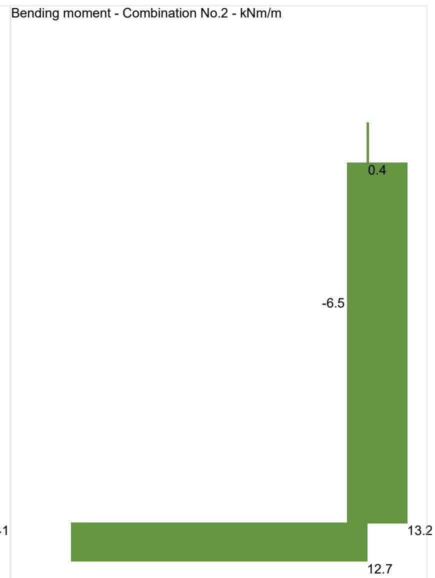












Check stem design at 895 mm

Depth of section	h = **250** mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 1	M = **8.2** kNm/m
Depth to tension reinforcement	$d = h - c_{sf} - \phi_{sx} - \phi_{sfM} / 2$ = **194** mm

	$K = M / (d^2 \times f_{ck})$ = **0.007**
	$K' = (2 \times \eta \times \alpha_{cc}/\gamma_C)\times(1 - \lambda \times (\delta - K_1)/(2 \times K_2))\times(\lambda \times (\delta - K_1)/(2 \times K_2))$
	K' = **0.207**
	K' > K - No compression reinforcement is required
Lever arm	$z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_C))^{0.5}, 0.95) \times d$ = **184** mm
Depth of neutral axis	$x = 2.5 \times (d – z)$ = **24** mm
Area of tension reinforcement required	$A_{sfM.req} = M / (f_{yd} \times z)$ = **102** mm^2/m
Tension reinforcement provided	12 dia.bars @ 200 c/c
Area of tension reinforcement provided	$A_{sfM.prov} = \pi \times \phi_{sfM}^2 / (4 \times s_{sfM})$ = **565** mm^2/m
Minimum area of reinforcement - exp.9.1N	$A_{sfM.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d$ = **292** mm^2/m
Maximum area of reinforcement - cl.9.2.1.1(3)	$A_{sfM.max} = 0.04 \times h$ = **10000** mm^2/m
	$\max(A_{sfM.req}, A_{sfM.min}) / A_{sfM.prov}$ = **0.517**

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

Library item: Rectangular single output

Deflection control - Section 7.4

Reference reinforcement ratio	$\rho_0 = \sqrt{(f_{ck} / 1 N/mm^2)} / 1000$ = **0.005**
Required tension reinforcement ratio	$\rho = A_{sfM.req} / d$ = **0.001**
Required compression reinforcement ratio	$\rho' = A_{sfM.2.req} / d_2$ = **0.000**
Structural system factor - Table 7.4N	K_b = **1**
Reinforcement factor - exp.7.17	$K_s = \min(500 N/mm^2 / (f_{yk} \times A_{sfM.req} / A_{sfM.prov}), 1.5)$ = **1.5**
Limiting span to depth ratio - exp.7.16.a	$\min(K_s \times K_b \times [11 + 1.5 \times \sqrt{(f_{ck} / 1 N/mm^2)} \times \rho_0 / \rho + 3.2 \times \sqrt{(f_{ck} / 1 N/mm^2)} \times (\rho_0 / \rho - 1)^{3/2}], 40 \times K_b)$ = **40**
Actual span to depth ratio	h_{prop} / d = **9.3**

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

Crack control - Section 7.3

Limiting crack width	w_{max} = **0.3** mm
Variable load factor - EN1990 – Table A1.1	ψ_2 = **0.6**
Serviceability bending moment	M_{sls} = **5** kNm/m
Tensile stress in reinforcement	$\sigma_s = M_{sls} / (A_{sfM.prov} \times z)$ = **47.9** N/mm^2
Load duration	Long term
Load duration factor	k_t = **0.4**
Effective area of concrete in tension	$A_{c.eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$
	$A_{c.eff}$ = **75250** mm^2/m
Mean value of concrete tensile strength	$f_{ct.eff} = f_{ctm}$ = **2.9** N/mm^2
Reinforcement ratio	$\rho_{p.eff} = A_{sfM.prov} / A_{c.eff}$ = **0.008**
Modular ratio	$\alpha_e = E_s / E_{cm}$ = **6.091**
Bond property coefficient	k_1 = **0.8**
Strain distribution coefficient	k_2 = **0.5**
	k_3 = **3.4**
	k_4 = **0.425**
Maximum crack spacing - exp.7.11	$s_{r.max} = k_3 \times c_{sf} + k_1 \times k_2 \times k_4 \times \phi_{sfM} / \rho_{p.eff}$ = **407** mm
Maximum crack width - exp.7.8	$w_k = s_{r.max} \times \max(\sigma_s – k_t \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_e \times \rho_{p.eff}), 0.6 \times \sigma_s) / E_s$
	w_k = **0.059** mm
	w_k / w_{max} = **0.195**

PASS - Maximum crack width is less than limiting crack width

Check stem design at base of stem

Depth of section	h = **250** mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 1	M = **16.8** kNm/m
Depth to tension reinforcement	$d = h - c_{sr} - \phi_{sr} / 2$ = **194** mm
	$K = M / (d^2 \times f_{ck})$ = **0.015**
	$K' = (2 \times \eta \times \alpha_{cc}/\gamma_C)\times(1 - \lambda \times (\delta - K_1)/(2 \times K_2))\times(\lambda \times (\delta - K_1)/(2 \times K_2))$
	K' = **0.207**

K' > K - No compression reinforcement is required

Lever arm	$z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_C))^{0.5}, 0.95) \times d$ = **184** mm
Depth of neutral axis	$x = 2.5 \times (d - z)$ = **24** mm
Area of tension reinforcement required	$A_{sr.req} = M / (f_{yd} \times z)$ = **210** mm^2/m
Tension reinforcement provided	12 dia.bars @ 200 c/c
Area of tension reinforcement provided	$A_{sr.prov} = \pi \times \phi_{sr}^2 / (4 \times s_{sr})$ = **565** mm^2/m
Minimum area of reinforcement - exp.9.1N	$A_{sr.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d$ = **292** mm^2/m
Maximum area of reinforcement - cl.9.2.1.1(3)	$A_{sr.max} = 0.04 \times h$ = **10000** mm^2/m
	$\max(A_{sr.req}, A_{sr.min}) / A_{sr.prov}$ = **0.517**

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

Library item: Rectangular single output

Deflection control - Section 7.4

Reference reinforcement ratio	$\rho_0 = \sqrt{(f_{ck} / 1 N/mm^2)} / 1000$ = **0.005**
Required tension reinforcement ratio	$\rho = A_{sr.req} / d$ = **0.001**
Required compression reinforcement ratio	$\rho' = A_{sr.2.req} / d_2$ = **0.000**
Structural system factor - Table 7.4N	K_b = **1**
Reinforcement factor - exp.7.17	$K_s = \min(500 N/mm^2 / (f_{yk} \times A_{sr.req} / A_{sr.prov}), 1.5)$ = **1.5**
Limiting span to depth ratio - exp.7.16.a	$\min(K_s \times K_b \times [11 + 1.5 \times \sqrt{(f_{ck} / 1 N/mm^2)} \times \rho_0 / \rho + 3.2 \times \sqrt{(f_{ck} / 1 N/mm^2)} \times (\rho_0 / \rho - 1)^{3/2}], 40 \times K_b)$ = **40**
Actual span to depth ratio	h_{prop} / d = **9.3**

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

Crack control - Section 7.3

Limiting crack width	w_{max} = **0.3** mm
Variable load factor - EN1990 – Table A1.1	ψ_2 = **0.6**
Serviceability bending moment	M_{sls} = **10.5** kNm/m
Tensile stress in reinforcement	$\sigma_s = M_{sls} / (A_{sr.prov} \times z)$ = **100.6** N/mm^2
Load duration	Long term
Load duration factor	k_t = **0.4**
Effective area of concrete in tension	$A_{c.eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$
	$A_{c.eff}$ = **75250** mm^2/m
Mean value of concrete tensile strength	$f_{ct.eff} = f_{ctm}$ = **2.9** N/mm^2
Reinforcement ratio	$\rho_{p.eff} = A_{sr.prov} / A_{c.eff}$ = **0.008**
Modular ratio	$\alpha_e = E_s / E_{cm}$ = **6.091**
Bond property coefficient	k_1 = **0.8**
Strain distribution coefficient	k_2 = **0.5**
	k_3 = **3.4**
	k_4 = **0.425**

Maximum crack spacing - exp.7.11	$s_{r.max} = k_3 \times c_{sr} + k_1 \times k_2 \times k_4 \times \phi_{sr} / \rho_{p.eff}$ = **441** mm
Maximum crack width - exp.7.8	$w_k = s_{r.max} \times \max(\sigma_s - k_t \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_e \times \rho_{p.eff}), 0.6 \times \sigma_s) / E_s$
	w_k = **0.133** mm
	w_k / w_{max} = **0.444**

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force	V = **52.6** kN/m
	$C_{Rd,c} = 0.18 / \gamma_C$ = **0.120**
	$k = \min(1 + \sqrt{(200\ mm / d)}, 2)$ = **2.000**
Longitudinal reinforcement ratio	$\rho_l = \min(A_{sr.prov} / d, 0.02)$ = **0.003**
	$v_{min} = 0.035\ N^{1/2}/mm \times k^{3/2} \times f_{ck}^{0.5}$ = **0.542** N/mm^2
Design shear resistance - exp.6.2a & 6.2b	$V_{Rd.c} = \max(C_{Rd.c} \times k \times (100\ N^2/mm^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$
	$V_{Rd.c}$ = **105.2** kN/m
	$V / V_{Rd.c}$ = **0.500**

PASS - Design shear resistance exceeds design shear force

Check stem design at prop

Depth of section	h = **250** mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 1	M = **0.5** kNm/m
Depth to tension reinforcement	$d = h - c_{sr} - \phi_{sr1} / 2$ = **194** mm
	$K = M / (d^2 \times f_{ck})$ = **0.000**
	$K' = (2 \times \eta \times \alpha_{cc}/\gamma_C)\times(1 - \lambda \times (\delta - K_1)/(2 \times K_2))\times(\lambda \times (\delta - K_1)/(2 \times K_2))$
	K' = **0.207**

K' > K - No compression reinforcement is required

Lever arm	$z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_C))^{0.5}, 0.95) \times d$ = **184** mm
Depth of neutral axis	$x = 2.5 \times (d - z)$ = **24** mm
Area of tension reinforcement required	$A_{sr1.req} = M / (f_{yd} \times z)$ = **6** mm^2/m
Tension reinforcement provided	12 dia.bars @ 200 c/c
Area of tension reinforcement provided	$A_{sr1.prov} = \pi \times \phi_{sr1}^2 / (4 \times s_{sr1})$ = **565** mm^2/m
Minimum area of reinforcement - exp.9.1N	$A_{sr1.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d$ = **292** mm^2/m
Maximum area of reinforcement - cl.9.2.1.1(3)	$A_{sr1.max} = 0.04 \times h$ = **10000** mm^2/m
	$\max(A_{sr1.req}, A_{sr1.min}) / A_{sr1.prov}$ = **0.517**

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

Library item: Rectangular single output

Deflection control - Section 7.4

Reference reinforcement ratio	$\rho_0 = \sqrt{(f_{ck} / 1\ N/mm^2)} / 1000$ = **0.005**
Required tension reinforcement ratio	$\rho = A_{sr1.req} / d$ = **0.000**
Required compression reinforcement ratio	$\rho' = A_{sr1.2.req} / d_2$ = **0.000**
Structural system factor - Table 7.4N	K_b = **0.4**
Reinforcement factor - exp.7.17	$K_s = \min(500\ N/mm^2 / (f_{yk} \times A_{sr1.req} / A_{sr1.prov}), 1.5)$ = **1.5**
Limiting span to depth ratio - exp.7.16.a	$\min(K_s \times K_b \times [11 + 1.5 \times \sqrt{(f_{ck} / 1\ N/mm^2)} \times \rho_0 / \rho + 3.2 \times \sqrt{(f_{ck} / 1\ N/mm^2)} \times (\rho_0 / \rho - 1)^{3/2}], 40 \times K_b)$ = **16**
Actual span to depth ratio	$(h_{stem} - h_{prop}) / d$ = **1**

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

Crack control - Section 7.3

Limiting crack width	w_{max} = **0.3** mm
Variable load factor - EN1990 – Table A1.1	ψ_2 = **0.6**
Serviceability bending moment	M_{sls} = **0.2** kNm/m
Tensile stress in reinforcement	$\sigma_s = M_{sls} / (A_{sr1.prov} \times z)$ = **1.9** N/mm^2
Load duration	Long term
Load duration factor	k_t = **0.4**
Effective area of concrete in tension	$A_{c.eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$
	$A_{c.eff}$ = **75250** mm^2/m
Mean value of concrete tensile strength	$f_{ct.eff} = f_{ctm}$ = **2.9** N/mm^2
Reinforcement ratio	$\rho_{p.eff} = A_{sr1.prov} / A_{c.eff}$ = **0.008**
Modular ratio	$\alpha_e = E_s / E_{cm}$ = **6.091**
Bond property coefficient	k_1 = **0.8**
Strain distribution coefficient	k_2 = **0.5**
	k_3 = **3.4**
	k_4 = **0.425**
Maximum crack spacing - exp.7.11	$s_{r.max} = k_3 \times c_{sr} + k_1 \times k_2 \times k_4 \times \phi_{sr1} / \rho_{p.eff}$ = **441** mm
Maximum crack width - exp.7.8	$w_k = s_{r.max} \times \max(\sigma_s - k_t \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_e \times \rho_{p.eff}), 0.6 \times \sigma_s) / E_s$
	w_k = **0.002** mm
	w_k / w_{max} = **0.008**

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force	V = **20.6** kN/m
	$C_{Rd,c} = 0.18 / \gamma_C$ = **0.120**
	$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2)$ = **2.000**
Longitudinal reinforcement ratio	$\rho_l = \min(A_{sr1.prov} / d, 0.02)$ = **0.003**
	$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5}$ = **0.542** N/mm^2
Design shear resistance - exp.6.2a & 6.2b	$V_{Rd.c} = \max(C_{Rd.c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$
	$V_{Rd.c}$ = **105.2** kN/m
	$V / V_{Rd.c}$ = **0.196**

PASS - Design shear resistance exceeds design shear force

Horizontal reinforcement parallel to face of stem - Section 9.6

Minimum area of reinforcement – cl.9.6.3(1)	$A_{sx.req} = \max(0.25 \times A_{sr.prov}, 0.001 \times t_{stem})$ = **250** mm^2/m
Maximum spacing of reinforcement – cl.9.6.3(2)	s_{sx_max} = **400** mm
Transverse reinforcement provided	10 dia.bars @ 200 c/c
Area of transverse reinforcement provided	$A_{sx.prov} = \pi \times \phi_{sx}^2 / (4 \times s_{sx})$ = **393** mm^2/m

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

Check base design at toe

Depth of section	h = **300** mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 1	M = **17.1** kNm/m
Depth to tension reinforcement	$d = h - c_{bb} - \phi_{bb} / 2$ = **219** mm
	$K = M / (d^2 \times f_{ck})$ = **0.012**
	$K' = (2 \times \eta \times \alpha_{cc}/\gamma_C)\times(1 - \lambda \times (\delta - K_1)/(2 \times K_2))\times(\lambda \times (\delta - K_1)/(2 \times K_2))$
	K' = **0.207**

K' > K - No compression reinforcement is required

Lever arm	$z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_C))^{0.5}, 0.95) \times d$ = **208** mm
Depth of neutral axis	$x = 2.5 \times (d - z)$ = **27** mm
Area of tension reinforcement required	$A_{bb.req} = M / (f_{yd} \times z)$ = **189** mm²/m
Tension reinforcement provided	12 dia.bars @ 200 c/c
Area of tension reinforcement provided	$A_{bb.prov} = \pi \times \phi_{bb}^2 / (4 \times s_{bb})$ = **565** mm²/m
Minimum area of reinforcement - exp.9.1N	$A_{bb.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d$ = **330** mm²/m
Maximum area of reinforcement - cl.9.2.1.1(3)	$A_{bb.max} = 0.04 \times h$ = **12000** mm²/m
	$\max(A_{bb.req}, A_{bb.min}) / A_{bb.prov}$ = **0.583**

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

Library item: Rectangular single output

Crack control - Section 7.3

Limiting crack width	w_{max} = **0.3** mm
Variable load factor - EN1990 – Table A1.1	ψ_2 = **0.6**
Serviceability bending moment	M_{sls} = **12.7** kNm/m
Tensile stress in reinforcement	$\sigma_s = M_{sls} / (A_{bb.prov} \times z)$ = **107.8** N/mm²
Load duration	Long term
Load duration factor	k_t = **0.4**
Effective area of concrete in tension	$A_{c.eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$
	$A_{c.eff}$ = **90875** mm²/m
Mean value of concrete tensile strength	$f_{ct.eff} = f_{ctm}$ = **2.9** N/mm²
Reinforcement ratio	$\rho_{p.eff} = A_{bb.prov} / A_{c.eff}$ = **0.006**
Modular ratio	$\alpha_e = E_s / E_{cm}$ = **6.091**
Bond property coefficient	k_1 = **0.8**
Strain distribution coefficient	k_2 = **0.5**
	k_3 = **3.4**
	k_4 = **0.425**
Maximum crack spacing - exp.7.11	$s_{r.max} = k_3 \times c_{bb} + k_1 \times k_2 \times k_4 \times \phi_{bb} / \rho_{p.eff}$ = **583** mm
Maximum crack width - exp.7.8	$w_k = s_{r.max} \times \max(\sigma_s - k_t \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_e \times \rho_{p.eff}), 0.6 \times \sigma_s) / E_s$
	w_k = **0.189** mm
	w_k / w_{max} = **0.628**

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

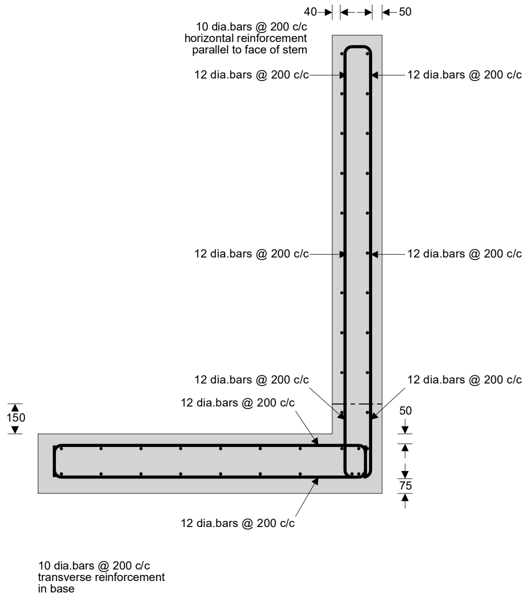
Design shear force	V = **23.1** kN/m
	$C_{Rd,c} = 0.18 / \gamma_C$ = **0.120**
	$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2)$ = **1.956**
Longitudinal reinforcement ratio	$\rho_l = \min(A_{bb.prov} / d, 0.02)$ = **0.003**
	$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5}$ = **0.524** N/mm²
Design shear resistance - exp.6.2a & 6.2b	$V_{Rd.c} = \max(C_{Rd.c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$
	$V_{Rd.c}$ = **114.8** kN/m
	$V / V_{Rd.c}$ = **0.202**

PASS - Design shear resistance exceeds design shear force

Secondary transverse reinforcement to base - Section 9.3

Minimum area of reinforcement – cl.9.3.1.1(2)	$A_{bx.req} = 0.2 \times A_{bb.prov}$ = **113** mm²/m
Maximum spacing of reinforcement – cl.9.3.1.1(3)	s_{bx_max} = **450** mm
Transverse reinforcement provided	10 dia.bars @ 200 c/c
Area of transverse reinforcement provided	$A_{bx.prov} = \pi \times \phi_{bx}^2 / (4 \times s_{bx})$ = **393** mm²/m

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



Reinforcement details

Basement Retaining Wall

DESIGN LOADING CALCULATIONS

ROOF

Dead $DL_1 = 1.51 \times 6.0/2$

$= 4.53$ KN/m.

Imposed $IL_1 = 0.6 \times 6.0/2$

$= 1.8$ KN/m

LOFT FLOOR

$DL_2 = 1.4 \times 4.0/2$

$= 2.8$ KN/m.

$IL_2 = 1.5 \times 4.0/2$

$= 3.0$ KN/m.

Existing WALL

$DL_3 = 4.45 \times 3.0$

$= 13.35$ KN/m

GROUND FLOOR

$DL_4 = 7.25 \times 6.0/2$

$= 21.75$ KN/m.

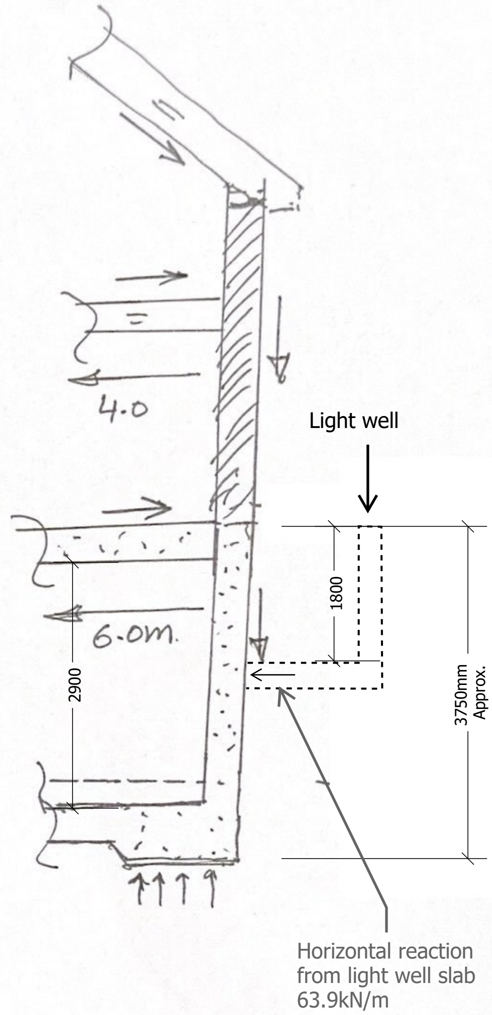
$IL_4 = 1.5 \times 6.0/2$

$= 4.5$ KN/m.

Basement WALL

$DL_5 = 7.45 \times$ ~~6.0~~ 3.8

$= 28.31$ KN/m



Basement FLOOR

$DL_6 = 9.4 \times 6.0/2$

$= 28.2$ KN/m.

$IL_6 = 1.5 \times 3.0$

$= 4.5$ KN/m.

TOTAL Dead LOAD

$= (4.53 + 2.8 + 13.35 + 21.75 + 28.31 + 28.2)$ ~~4.5~~

DL = 98.94 KN/m

TOTAL Imposed LOADING $= (1.8 + 3.0 + 4.5 + 4.5)$

IL ⇒ **UDL = 13.8 KN/m**

RETAINING WALL ANALYSIS **Basement Retaining Wall**

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

Tedds calculation version 2.9.17

Analysis summary

Design summary

Overall design utilisation 0.883

Overall design status Pass

Description	Unit	Capacity	Applied	F o S	Result
Bearing pressure	kN/m²	200	146.8	1.363	PASS

Design summary

Description	Unit	Provided	Required	Utilisation	Result
Shear resistance	kN/m	145.7	225.7	0.645	PASS
Stem p0 - Shear resistance	kN/m	132.9	60.1	0.453	PASS
Stem p1 front face - Flexural reinforcement	mm²/m	565.5	407.3	0.720	PASS
Stem p1 - Shear resistance	kN/m	132.9	51.3	0.386	PASS
Base bottom face - Flexural reinforcement	mm²/m	1005.3	888.0	0.883	PASS
Base - Shear resistance	kN/m	225.7	145.7	0.645	PASS

Retaining wall details

Stem type Propped cantilever

Stem height h_{stem} = **2900** mm

Prop height h_{prop} = **2000** mm

Stem thickness t_{stem} = **300** mm

Angle to rear face of stem α = **90** deg

Stem density γ_{stem} = **25** kN/m^3

Toe length l_{toe} = **1200** mm

Base thickness t_{base} = **600** mm

Base density γ_{base} = **25** kN/m^3

Height of retained soil h_{ret} = **1200** mm

Angle of soil surface β = **0** deg

Depth of cover d_{cover} = **200** mm

Depth of excavation d_{exc} = **200** mm

Height of water h_{water} = **800** mm

Water density γ_w = **9.8** kN/m^3

Retained soil properties

Soil type Stiff clay

Moist density γ_{mr} = **19** kN/m^3

Saturated density γ_{sr} = **19** kN/m^3

Base soil properties

Soil type Stiff clay

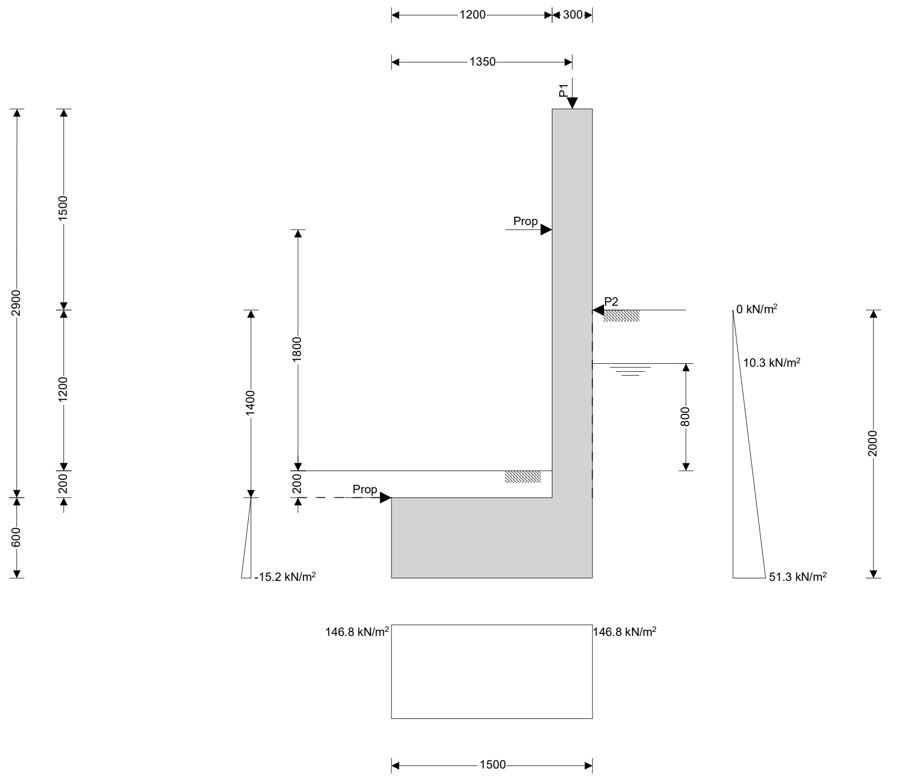
Soil density γ_b = **19** kN/m^3

Loading details

Vertical line load at 1350 mm P_{G1} = **98.9** kN/m

P_{Q1} = **13.8** kN/m

Horizontal line load at 1400 mm P_{G2} = **63.9** kN/m



General arrangement - sketch pressures relate to bearing check

Calculate retaining wall geometry

Base length	$l_{base} = l_{toe} + t_{stem}$ = **1500** mm
Saturated soil height	$h_{sat} = h_{water} + d_{cover}$ = **1000** mm
Moist soil height	$h_{moist} = h_{ret} - h_{water}$ = **400** mm
Retained surface length	$l_{sur} = l_{heel}$ = **0** mm
Effective height of wall	$h_{eff} = h_{base} + d_{cover} + h_{ret}$ = **2000** mm
Area of wall stem	$A_{stem} = h_{stem} \times t_{stem}$ = **0.87** m^2
- Distance to vertical component	$x_{stem} = l_{toe} + t_{stem} / 2$ = **1350** mm
Area of wall base	$A_{base} = l_{base} \times t_{base}$ = **0.9** m^2
- Distance to vertical component	$x_{base} = l_{base} / 2$ = **750** mm
Area of base soil	$A_{pass} = d_{cover} \times l_{toe}$ = **0.24** m^2
- Distance to vertical component	$x_{pass\_v} = l_{base} - (d_{cover} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{pass}$ = **600** mm
- Distance to horizontal component	$x_{pass\_h} = (d_{cover} + h_{base}) / 3$ = **267** mm

Design approach 1

Partial factors on actions - Combination 1

Partial factor set	User defined
Permanent unfavourable action	γ_G = **1.350**
Permanent favourable action	γ_{Gf} = **1.000**
Variable unfavourable action	γ_Q = **1.500**
Variable favourable action	γ_{Qf} = **0.000**

Partial factors for soil parameters – Combination 1

Soil parameter set | User defined

Soil parameter set	User defined
Angle of shearing resistance	$\gamma_{\phi'}$ = **1.00**
Undrained shear strength	γ_{cu} = **1.00**
Weight density	γ_{γ} = **1.00**

Retained soil properties

Design moist density	$\gamma_{mr}' = \gamma_{mr} / \gamma_{\gamma}$ = **19** kN/m^3
Design saturated density	$\gamma_{sr}' = \gamma_{sr} / \gamma_{\gamma}$ = **19** kN/m^3

Base soil properties

Design soil density	$\gamma_{b}' = \gamma_{b} / \gamma_{\gamma}$ = **19** kN/m^3

Soil coefficients

Coefficient of friction to back of wall	K_{fr} = **0.325**
Coefficient of friction to front of wall	K_{fb} = **0.325**
Coefficient of friction beneath base	K_{fbb} = **0.325**
At rest pressure coefficient	K_0 = **1.000**
Passive pressure coefficient	K_P = **1.000**

Bearing pressure check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem}$ = **29.4** kN/m
Wall base	$F_{base} = \gamma_G \times A_{base} \times \gamma_{base}$ = **30.4** kN/m
Line loads	$F_{P\_v} = \gamma_G \times P_{G1} + \gamma_Q \times P_{Q1}$ = **154.3** kN/m
Base soil	$F_{pass\_v} = \gamma_G \times A_{pass} \times \gamma_b'$ = **6.2** kN/m
Total	$F_{total\_v} = F_{stem} + F_{base} + F_{P\_v} + F_{water\_v} + F_{pass\_v}$ = **220.2** kN/m

Horizontal forces on wall

Line loads	$F_{P\_h} = \gamma_G \times P_{G2}$ = **86.3** kN/m
Saturated retained soil	$F_{sat\_h} = \gamma_G \times K_0 \times (\gamma_{sr}' - \gamma_w') \times (h_{sat} + h_{base})^2 / 2$ = **15.9** kN/m
Water	$F_{water\_h} = \gamma_G \times \gamma_w' \times (h_{water} + d_{cover} + h_{base})^2 / 2$ = **17** kN/m
Moist retained soil	$F_{moist\_h} = \gamma_G \times K_0 \times \gamma_{mr}' \times ((h_{eff} - h_{sat} - h_{base})^2 / 2 + (h_{eff} - h_{sat} - h_{base}) \times (h_{sat} + h_{base}))$ = **18.5** kN/m
Base soil	$F_{pass\_h} = -\gamma_{Gf} \times K_P \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2$ = **-6.1** kN/m
Total	$F_{total\_h} = F_{P\_h} + F_{sat\_h} + F_{water\_h} + F_{moist\_h} + F_{pass\_h}$ = **131.5** kN/m

Moments on wall

Wall stem	$M_{stem} = F_{stem} \times x_{stem}$ = **39.6** kNm/m
Wall base	$M_{base} = F_{base} \times x_{base}$ = **22.8** kNm/m
Line loads	$M_P = (\gamma_G \times P_{G1} + \gamma_Q \times P_{Q1}) \times p_1 - (\gamma_G \times P_{G2} \times (p_2 + t_{base}))$ = **35.7** kNm/m
Saturated retained soil	$M_{sat} = -F_{sat\_h} \times x_{sat\_h}$ = **-8.5** kNm/m
Water	$M_{water} = -F_{water\_h} \times x_{water\_h}$ = **-9** kNm/m
Moist retained soil	$M_{moist} = -F_{moist\_h} \times x_{moist\_h}$ = **-16.7** kNm/m
Base soil	$M_{pass} = F_{pass\_v} \times x_{pass\_v}$ = **3.7** kNm/m
Total	$M_{total} = M_{stem} + M_{base} + M_P + M_{sat} + M_{water} + M_{moist} + M_{pass}$ = **67.6** kNm/m

Check bearing pressure

Propping force to stem	$F_{prop\_stem} = (F_{total\_v} \times l_{base} / 2 - M_{total}) / (h_{prop} + t_{base})$ = **37.5** kN/m
Propping force to base	$F_{prop\_base} = F_{total\_h} - F_{prop\_stem}$ = **94** kN/m

Moment from propping force	$M_{prop} = F_{prop\_stem} \times (h_{prop} + t_{base})$ = **97.5** kNm/m
Distance to reaction	$\bar{x} = (M_{total} + M_{prop}) / F_{total\_v}$ = **750** mm
Eccentricity of reaction	$e = \bar{x} - l_{base} / 2$ = **0** mm
Loaded length of base	$l_{load} = l_{base}$ = **1500** mm
Bearing pressure at toe	$q_{toe} = F_{total\_v} / l_{base}$ = **146.8** kN/m^2
Bearing pressure at heel	$q_{heel} = F_{total\_v} / l_{base}$ = **146.8** kN/m^2
Factor of safety	$FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel})$ = **1.363**

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

Design approach 1

Partial factors on actions - Combination 2

Partial factor set	User defined
Permanent unfavourable action	γ_G = **1.000**
Permanent favourable action	γ_{Gf} = **1.000**
Variable unfavourable action	γ_Q = **1.300**
Variable favourable action	γ_{Qf} = **0.000**

Partial factors for soil parameters – Combination 2

Soil parameter set	User defined
Angle of shearing resistance	$\gamma_{\phi'}$ = **1.25**
Undrained shear strength	γ_{cu} = **1.40**
Weight density	γ_γ = **1.00**

Retained soil properties

Design moist density	$\gamma_{mr}' = \gamma_{mr} / \gamma_\gamma$ = **19** kN/m^3
Design saturated density	$\gamma_{sr}' = \gamma_{sr} / \gamma_\gamma$ = **19** kN/m^3

Base soil properties

Design soil density	$\gamma_b' = \gamma_b / \gamma_\gamma$ = **19** kN/m^3

Soil coefficients

Coefficient of friction to back of wall	K_{fr} = **0.325**
Coefficient of friction to front of wall	K_{fb} = **0.325**
Coefficient of friction beneath base	K_{fbb} = **0.325**
At rest pressure coefficient	K_0 = **1.000**
Passive pressure coefficient	K_P = **1.000**

Bearing pressure check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem}$ = **21.8** kN/m
Wall base	$F_{base} = \gamma_G \times A_{base} \times \gamma_{base}$ = **22.5** kN/m
Line loads	$F_{P\_v} = \gamma_G \times P_{G1} + \gamma_Q \times P_{Q1}$ = **116.9** kN/m
Base soil	$F_{pass\_v} = \gamma_G \times A_{pass} \times \gamma_b'$ = **4.6** kN/m
Total	$F_{total\_v} = F_{stem} + F_{base} + F_{P\_v} + F_{water\_v} + F_{pass\_v}$ = **165.7** kN/m

Horizontal forces on wall

Line loads	$F_{P\_h} = \gamma_G \times P_{G2}$ = **63.9** kN/m
Saturated retained soil	$F_{sat\_h} = \gamma_G \times K_0 \times (\gamma_{sr}' - \gamma_w') \times (h_{sat} + h_{base})^2 / 2$ = **11.8** kN/m
Water	$F_{water\_h} = \gamma_G \times \gamma_w' \times (h_{water} + d_{cover} + h_{base})^2 / 2$ = **12.6** kN/m

Moist retained soil	$F_{moist\_h} = \gamma_G \times K_0 \times \gamma_{mr}' \times ((h_{eff} - h_{sat} - h_{base})^2 / 2 + (h_{eff} - h_{sat} - h_{base}) \times (h_{sat} + h_{base})) =$ **13.7** kN/m
Base soil	$F_{pass\_h} = -\gamma_{Gf} \times K_P \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2 =$ **-6.1** kN/m
Total	$F_{total\_h} = F_{P\_h} + F_{sat\_h} + F_{water\_h} + F_{moist\_h} + F_{pass\_h} =$ **95.8** kN/m

Moments on wall

Wall stem	$M_{stem} = F_{stem} \times x_{stem} =$ **29.4** kNm/m
Wall base	$M_{base} = F_{base} \times x_{base} =$ **16.9** kNm/m
Line loads	$M_P = (\gamma_G \times P_{G1} + \gamma_Q \times P_{Q1}) \times p_1 - (\gamma_G \times P_{G2} \times (p_2 + t_{base})) =$ **30** kNm/m
Saturated retained soil	$M_{sat} = -F_{sat\_h} \times x_{sat\_h} =$ **-6.3** kNm/m
Water	$M_{water} = -F_{water\_h} \times x_{water\_h} =$ **-6.7** kNm/m
Moist retained soil	$M_{moist} = -F_{moist\_h} \times x_{moist\_h} =$ **-12.4** kNm/m
Base soil	$M_{pass} = F_{pass\_v} \times x_{pass\_v} =$ **2.7** kNm/m
Total	$M_{total} = M_{stem} + M_{base} + M_P + M_{sat} + M_{water} + M_{moist} + M_{pass} =$ **53.6** kNm/m

Check bearing pressure

Propping force to stem	$F_{prop\_stem} = (F_{total\_v} \times l_{base} / 2 - M_{total}) / (h_{prop} + t_{base}) =$ **27.2** kN/m
Propping force to base	$F_{prop\_base} = F_{total\_h} - F_{prop\_stem} =$ **68.7** kN/m
Moment from propping force	$M_{prop} = F_{prop\_stem} \times (h_{prop} + t_{base}) =$ **70.6** kNm/m
Distance to reaction	$\bar{x} = (M_{total} + M_{prop}) / F_{total\_v} =$ **750** mm
Eccentricity of reaction	$e = \bar{x} - l_{base} / 2 =$ **0** mm
Loaded length of base	$l_{load} = l_{base} =$ **1500** mm
Bearing pressure at toe	$q_{toe} = F_{total\_v} / l_{base} =$ **110.5** kN/m^2
Bearing pressure at heel	$q_{heel} = F_{total\_v} / l_{base} =$ **110.5** kN/m^2
Factor of safety	$FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel}) =$ **1.811**

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

RETAINING WALL DESIGN

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

Tedds calculation version 2.9.17

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

Concrete strength class	C35/45
Characteristic compressive cylinder strength	$f_{ck} =$ **35** N/mm^2
Characteristic compressive cube strength	$f_{ck,cube} =$ **45** N/mm^2
Mean value of compressive cylinder strength	$f_{cm} = f_{ck} + 8$ N/mm^2 = **43** N/mm^2
Mean value of axial tensile strength	$f_{ctm} = 0.3$ N/mm$^2 \times (f_{ck} / 1$ N/mm$^2)^{2/3}$ = **3.2** N/mm^2
5% fractile of axial tensile strength	$f_{ctk,0.05} = 0.7 \times f_{ctm} =$ **2.2** N/mm^2
Secant modulus of elasticity of concrete	$E_{cm} = 22$ kN/mm$^2 \times (f_{cm} / 10$ N/mm$^2)^{0.3}$ = **34077** N/mm^2
Partial factor for concrete - Table 2.1N	$\gamma_C =$ **1.50**
Compressive strength coefficient - cl.3.1.6(1)	$\alpha_{cc} =$ **0.85**
Design compressive concrete strength - exp.3.15	$f_{cd} = \alpha_{cc} \times f_{ck} / \gamma_C =$ **19.8** N/mm^2
Maximum aggregate size	$h_{agg} =$ **20** mm
Ultimate strain - Table 3.1	$\varepsilon_{cu2} =$ **0.0035**
Shortening strain - Table 3.1	$\varepsilon_{cu3} =$ **0.0035**
Effective compression zone height factor	$\lambda =$ **0.80**
Effective strength factor	$\eta =$ **1.00**
Bending coefficient k_1	$K_1 =$ **0.40**

Bending coefficient k_2 $K_2 = 1.00 \times (0.6 + 0.0014/\varepsilon_{cu2}) = \mathbf{1.00}$

Bending coefficient k_3 $K_3 = \mathbf{0.40}$

Bending coefficient k_4 $K_4 = 1.00 \times (0.6 + 0.0014/\varepsilon_{cu2}) = \mathbf{1.00}$

Reinforcement details

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

Modulus of elasticity of reinforcement E_s = **200000** N/mm^2

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

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

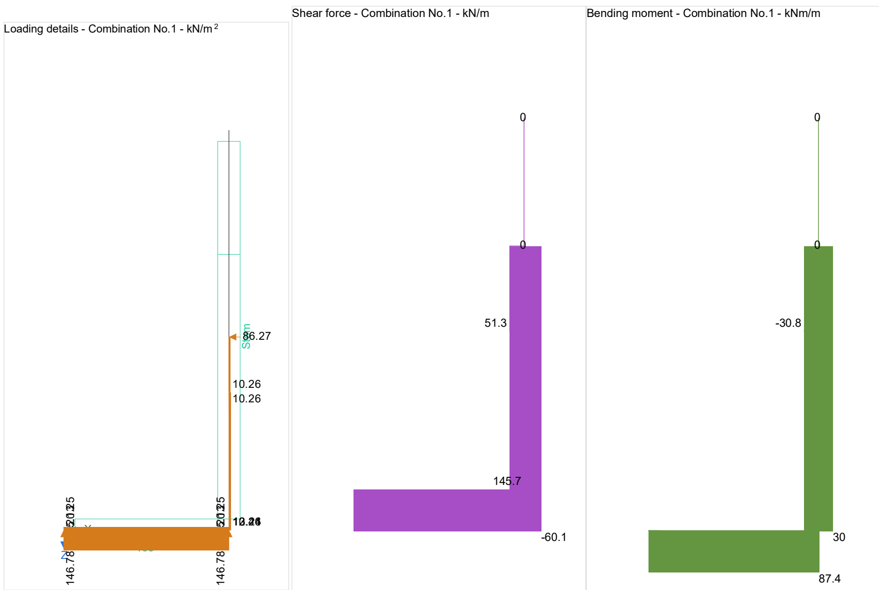
Cover to reinforcement

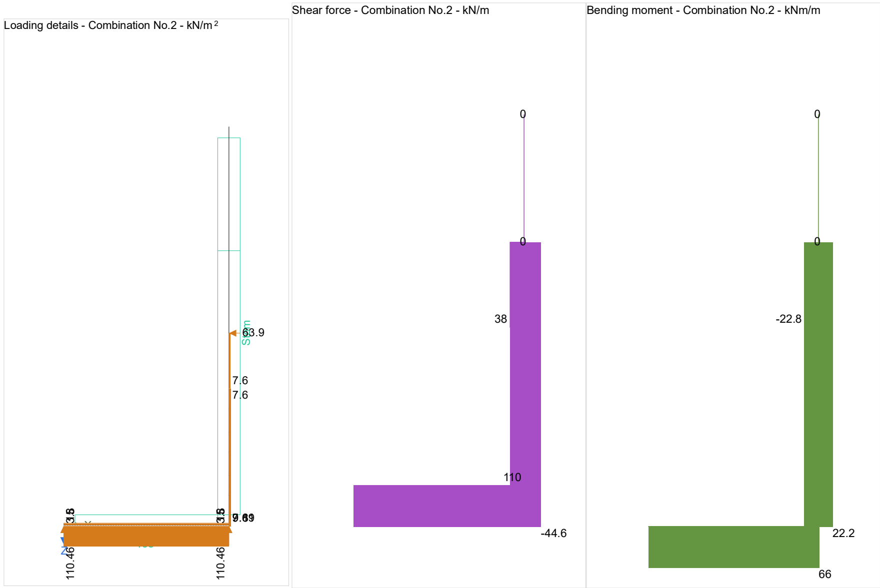
Front face of stem c_{sf} = **40** mm

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

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

Bottom face of base c_{bb} = **60** mm





Check stem design at 1100 mm

Depth of section — h = **300** mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 1 — M = **30.8** kNm/m

Depth to tension reinforcement — $d = h - c_{sf} - \phi_{sx} - \phi_{sfM} / 2 =$ **244** mm

$K = M / (d^2 \times f_{ck}) =$ **0.015**

$K' = (2 \times \eta \times \alpha_{cc}/\gamma_C)\times(1 - \lambda \times (\delta - K_1)/(2 \times K_2))\times(\lambda \times (\delta - K_1)/(2 \times K_2))$

$K' =$ **0.207**

K' > K - No compression reinforcement is required

Lever arm — $z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_C))^{0.5}, 0.95) \times d =$ **232** mm

Depth of neutral axis — $x = 2.5 \times (d – z) =$ **31** mm

Area of tension reinforcement required — $A_{sfM.req} = M / (f_{yd} \times z) =$ **305** mm²/m

Tension reinforcement provided — 12 dia.bars @ 150 c/c

Area of tension reinforcement provided — $A_{sfM.prov} = \pi \times \phi_{sfM}^2 / (4 \times s_{sfM}) =$ **754** mm²/m

Minimum area of reinforcement - exp.9.1N — $A_{sfM.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d =$ **407** mm²/m

Maximum area of reinforcement - cl.9.2.1.1(3) — $A_{sfM.max} = 0.04 \times h =$ **12000** mm²/m

$\max(A_{sfM.req}, A_{sfM.min}) / A_{sfM.prov} =$ **0.54**

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

Library item: Rectangular single output

Deflection control - Section 7.4

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

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

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

Structural system factor - Table 7.4N — $K_b =$ **1**

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

Limiting span to depth ratio - exp.7.16.a — $\min(K_s \times K_b \times [11 + 1.5 \times \sqrt{}(f_{ck} / 1\ N/mm^2) \times \rho_0 / \rho + 3.2 \times \sqrt{}(f_{ck} / 1\ N/mm^2) \times (\rho_0 / \rho - 1)^{3/2}], 40 \times K_b) =$ **40**

Actual span to depth ratio — $h_{prop} / d =$ **8.2**

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

Crack control - Section 7.3

Limiting crack width	w_{max} = **0.3** mm
Variable load factor - EN1990 – Table A1.1	ψ_2 = **0.6**
Serviceability bending moment	M_{sls} = **22.8** kNm/m
Tensile stress in reinforcement	$\sigma_s = M_{sls} / (A_{sfM.prov} \times z)$ = **130.3** N/mm²
Load duration	Long term
Load duration factor	k_t = **0.4**
Effective area of concrete in tension	$A_{c.eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$
	$A_{c.eff}$ = **89833** mm²/m
Mean value of concrete tensile strength	$f_{ct.eff} = f_{ctm}$ = **3.2** N/mm²
Reinforcement ratio	$\rho_{p.eff} = A_{sfM.prov} / A_{c.eff}$ = **0.008**
Modular ratio	$\alpha_e = E_s / E_{cm}$ = **5.869**
Bond property coefficient	k_1 = **0.8**
Strain distribution coefficient	k_2 = **0.5**
	k_3 = **3.4**
	k_4 = **0.425**
Maximum crack spacing - exp.7.11	$s_{r.max} = k_3 \times c_{sf} + k_1 \times k_2 \times k_4 \times \phi_{sfM} / \rho_{p.eff}$ = **379** mm
Maximum crack width - exp.7.8	$w_k = s_{r.max} \times \max(\sigma_s - k_t \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_e \times \rho_{p.eff}), 0.6 \times \sigma_s) / E_s$
	w_k = **0.148** mm
	w_k / w_{max} = **0.494**

PASS - Maximum crack width is less than limiting crack width

Check stem design at base of stem

Depth of section	h = **300** mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 1	M = **30** kNm/m
Depth to tension reinforcement	$d = h - c_{sr} - \phi_{sr} / 2$ = **244** mm
	$K = M / (d^2 \times f_{ck})$ = **0.014**
	$K' = (2 \times \eta \times \alpha_{cc}/\gamma_C)\times(1 - \lambda \times (\delta - K_1)/(2 \times K_2))\times(\lambda \times (\delta - K_1)/(2 \times K_2))$
	K' = **0.207**

K' > K - No compression reinforcement is required

Lever arm	$z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_C))^{0.5}, 0.95) \times d$ = **232** mm
Depth of neutral axis	$x = 2.5 \times (d - z)$ = **31** mm
Area of tension reinforcement required	$A_{sr.req} = M / (f_{yd} \times z)$ = **298** mm²/m
Tension reinforcement provided	12 dia.bars @ 150 c/c
Area of tension reinforcement provided	$A_{sr.prov} = \pi \times \phi_{sr}^2 / (4 \times s_{sr})$ = **754** mm²/m
Minimum area of reinforcement - exp.9.1N	$A_{sr.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d$ = **407** mm²/m
Maximum area of reinforcement - cl.9.2.1.1(3)	$A_{sr.max} = 0.04 \times h$ = **12000** mm²/m
	$\max(A_{sr.req}, A_{sr.min}) / A_{sr.prov}$ = **0.54**

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

Library item: Rectangular single output

Deflection control - Section 7.4

Reference reinforcement ratio	$\rho_0 = \sqrt{(f_{ck} / 1\ N/mm^2)} / 1000$ = **0.006**
Required tension reinforcement ratio	$\rho = A_{sr.req} / d$ = **0.001**
Required compression reinforcement ratio	$\rho' = A_{sr.2.req} / d_2$ = **0.000**
Structural system factor - Table 7.4N	K_b = **1**
Reinforcement factor - exp.7.17	$K_s = \min(500\ N/mm^2 / (f_{yk} \times A_{sr.req} / A_{sr.prov}), 1.5)$ = **1.5**

Limiting span to depth ratio - exp.7.16.a	$\min(K_s \times K_b \times [11 + 1.5 \times \sqrt{(f_{ck} / 1\ N/mm^2)} \times \rho_0 / \rho + 3.2 \times \sqrt{(f_{ck} / 1\ N/mm^2)} \times (\rho_0 / \rho - 1)^{3/2}], 40 \times K_b)$ = **40**
Actual span to depth ratio	h_{prop} / d = **8.2**
	PASS - Span to depth ratio is less than deflection control limit
Crack control - Section 7.3	
Limiting crack width	w_{max} = **0.3** mm
Variable load factor - EN1990 – Table A1.1	ψ_2 = **0.6**
Serviceability bending moment	M_{sls} = **22.2** kNm/m
Tensile stress in reinforcement	$\sigma_s = M_{sls} / (A_{sr.prov} \times z)$ = **127.1** N/mm^2
Load duration	Long term
Load duration factor	k_t = **0.4**
Effective area of concrete in tension	$A_{c.eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$
	$A_{c.eff}$ = **89833** mm^2/m
Mean value of concrete tensile strength	$f_{ct.eff} = f_{ctm}$ = **3.2** N/mm^2
Reinforcement ratio	$\rho_{p.eff} = A_{sr.prov} / A_{c.eff}$ = **0.008**
Modular ratio	$\alpha_e = E_s / E_{cm}$ = **5.869**
Bond property coefficient	k_1 = **0.8**
Strain distribution coefficient	k_2 = **0.5**
	k_3 = **3.4**
	k_4 = **0.425**
Maximum crack spacing - exp.7.11	$s_{r.max} = k_3 \times c_{sr} + k_1 \times k_2 \times k_4 \times \phi_{sr} / \rho_{p.eff}$ = **413** mm
Maximum crack width - exp.7.8	$w_k = s_{r.max} \times \max(\sigma_s – k_t \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_e \times \rho_{p.eff}), 0.6 \times \sigma_s) / E_s$
	w_k = **0.157** mm
	w_k / w_{max} = **0.525**
	PASS - Maximum crack width is less than limiting crack width
Rectangular section in shear - Section 6.2	
Design shear force	V = **60.1** kN/m
	$C_{Rd,c} = 0.18 / \gamma_C$ = **0.120**
	$k = \min(1 + \sqrt{(200\ mm / d)}, 2)$ = **1.905**
Longitudinal reinforcement ratio	$\rho_l = \min(A_{sr.prov} / d, 0.02)$ = **0.003**
	$v_{min} = 0.035\ N^{1/2}/mm \times k^{3/2} \times f_{ck}^{0.5}$ = **0.545** N/mm^2
Design shear resistance - exp.6.2a & 6.2b	$V_{Rd.c} = \max(C_{Rd.c} \times k \times (100\ N^2/mm^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$
	$V_{Rd.c}$ = **132.9** kN/m
	$V / V_{Rd.c}$ = **0.453**
	PASS - Design shear resistance exceeds design shear force
Check stem design at prop	
Depth of section	h = **300** mm
Rectangular section in shear - Section 6.2	
Design shear force	V = **51.3** kN/m
	$C_{Rd,c} = 0.18 / \gamma_C$ = **0.120**
	$k = \min(1 + \sqrt{(200\ mm / d)}, 2)$ = **1.905**
Longitudinal reinforcement ratio	$\rho_l = \min(A_{sr1.prov} / d, 0.02)$ = **0.002**
	$v_{min} = 0.035\ N^{1/2}/mm \times k^{3/2} \times f_{ck}^{0.5}$ = **0.545** N/mm^2
Design shear resistance - exp.6.2a & 6.2b	$V_{Rd.c} = \max(C_{Rd.c} \times k \times (100\ N^2/mm^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$
	$V_{Rd.c}$ = **132.9** kN/m

$V / V_{Rd.c}$ = **0.386**

PASS - Design shear resistance exceeds design shear force

Horizontal reinforcement parallel to face of stem - Section 9.6

Minimum area of reinforcement – cl.9.6.3(1)	$A_{sx.req} = \max(0.25 \times A_{sr.prov}, 0.001 \times t_{stem})$ = **300** mm²/m
Maximum spacing of reinforcement – cl.9.6.3(2)	s_{sx_max} = **400** mm
Transverse reinforcement provided	10 dia.bars @ 200 c/c
Area of transverse reinforcement provided	$A_{sx.prov} = \pi \times \phi_{sx}^2 / (4 \times s_{sx})$ = **393** mm²/m

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

Check base design at toe

Depth of section	h = **600** mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 1	M = **87.4** kNm/m
Depth to tension reinforcement	$d = h - c_{bb} - \phi_{bb} / 2$ = **532** mm
	$K = M / (d^2 \times f_{ck})$ = **0.009**
	$K' = (2 \times \eta \times \alpha_{cc}/\gamma_C)\times(1 - \lambda \times (\delta - K_1)/(2 \times K_2))\times(\lambda \times (\delta - K_1)/(2 \times K_2))$
	K' = **0.207**

K' > K - No compression reinforcement is required

Lever arm	$z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_C))^{0.5}, 0.95) \times d$ = **505** mm
Depth of neutral axis	$x = 2.5 \times (d – z)$ = **67** mm
Area of tension reinforcement required	$A_{bb.req} = M / (f_{yd} \times z)$ = **398** mm²/m
Tension reinforcement provided	16 dia.bars @ 200 c/c
Area of tension reinforcement provided	$A_{bb.prov} = \pi \times \phi_{bb}^2 / (4 \times s_{bb})$ = **1005** mm²/m
Minimum area of reinforcement - exp.9.1N	$A_{bb.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d$ = **888** mm²/m
Maximum area of reinforcement - cl.9.2.1.1(3)	$A_{bb.max} = 0.04 \times h$ = **24000** mm²/m
	$\max(A_{bb.req}, A_{bb.min}) / A_{bb.prov}$ = **0.883**

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

Library item: Rectangular single output

Crack control - Section 7.3

Limiting crack width	w_{max} = **0.3** mm
Variable load factor - EN1990 – Table A1.1	ψ_2 = **0.6**
Serviceability bending moment	M_{sls} = **64** kNm/m
Tensile stress in reinforcement	$\sigma_s = M_{sls} / (A_{bb.prov} \times z)$ = **126** N/mm²
Load duration	Long term
Load duration factor	k_t = **0.4**
Effective area of concrete in tension	$A_{c.eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$
	$A_{c.eff}$ = **170000** mm²/m
Mean value of concrete tensile strength	$f_{ct.eff} = f_{ctm}$ = **3.2** N/mm²
Reinforcement ratio	$\rho_{p.eff} = A_{bb.prov} / A_{c.eff}$ = **0.006**
Modular ratio	$\alpha_e = E_s / E_{cm}$ = **5.869**
Bond property coefficient	k_1 = **0.8**
Strain distribution coefficient	k_2 = **0.5**
	k_3 = **3.4**
	k_4 = **0.425**
Maximum crack spacing - exp.7.11	$s_{r.max} = k_3 \times c_{bb} + k_1 \times k_2 \times k_4 \times \phi_{bb} / \rho_{p.eff}$ = **664** mm
Maximum crack width - exp.7.8	$w_k = s_{r.max} \times \max(\sigma_s – k_t \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_e \times \rho_{p.eff}), 0.6 \times \sigma_s) / E_s$
	w_k = **0.251** mm

w_k / w_{max} = **0.836**

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force — V = **145.7** kN/m

$C_{Rd,c}$ = 0.18 / γ_C = **0.120**

k = min(1 + $\sqrt{}$(200 mm / d), 2) = **1.613**

Longitudinal reinforcement ratio — ρ_l = min($A_{bb.prov}$ / d, 0.02) = **0.002**

v_{min} = 0.035 $N^{1/2}$/mm $\times$ $k^{3/2}$ $\times$ $f_{ck}^{0.5}$ = **0.424** N/mm^2

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

$V_{Rd.c}$ = **225.7** kN/m

V / $V_{Rd.c}$ = **0.645**

PASS - Design shear resistance exceeds design shear force

Secondary transverse reinforcement to base - Section 9.3

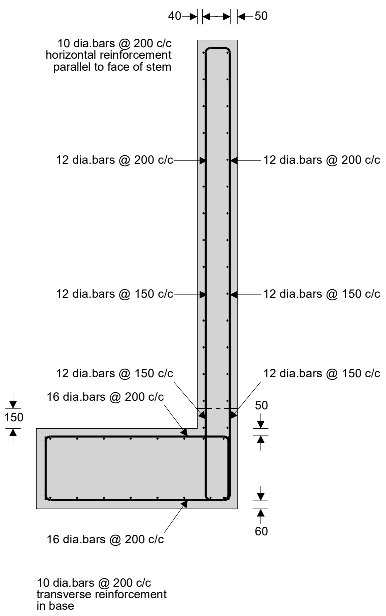
Minimum area of reinforcement – cl.9.3.1.1(2) — $A_{bx.req}$ = 0.2 $\times$ $A_{bb.prov}$ = **201** mm^2/m

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

Transverse reinforcement provided — 10 dia.bars @ 200 c/c

Area of transverse reinforcement provided — $A_{bx.prov}$ = π $\times$ ϕ_{bx}^2 / (4 $\times$ s_{bx}) = **393** mm^2/m

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



Reinforcement details

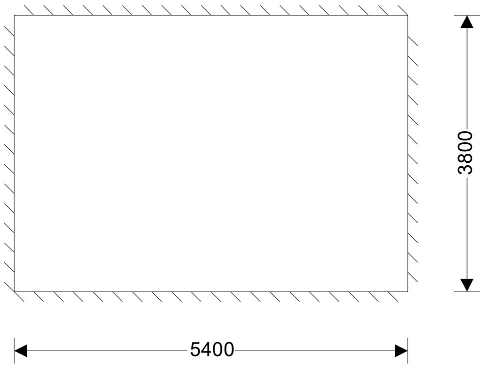
RC SLAB DESIGN **Basement Slab**

In accordance with EN1992-1-1:2004 incorporating corrigendum January 2008 and the UK national annex

Tedds calculation version 1.0.22

Design summary

Description	Unit	Provided	Required	Utilisation	Result
Short span					
Reinf. at midspan	mm^2/m	754	407	0.540	PASS
Bar spacing at midspan	mm	150	300	0.500	PASS
Shear at discont. supp	kN/m	132.9	10.7	0.080	PASS
Deflection ratio		15.57	40.00	0.389	PASS
Long span					
Reinf. at midspan	mm^2/m	754	387	0.514	PASS
Bar spacing at midspan	mm	150	300	0.500	PASS
Shear at discont. supp	kN/m	128.7	10.7	0.083	PASS
Cover					
Min cover bottom	mm	50	17	0.340	PASS



Slab definition

Slab reference name **Basement Floor Slab**

Type of slab **Two way spanning with restrained edges**

Overall slab depth h = **300** mm

Shorter effective span of panel l_x = **3800** mm

Longer effective span of panel l_y = **5400** mm

Support conditions **Four edges discontinuous**

Bottom outer layer of reinforcement **Short span direction**

Loading

Characteristic permanent action G_k = **2.5** kN/m^2

Characteristic variable action Q_k = **1.5** kN/m^2

Partial factor for permanent action γ_G = **1.35**

Partial factor for variable action γ_Q = **1.50**

Quasi-permanent value of variable action ψ_2 = **0.30**

Design ultimate load $q = \gamma_G \times G_k + \gamma_Q \times Q_k$ = **5.6** kN/m^2

Quasi-permanent load $q_{SLS} = 1.0 \times G_k + \psi_2 \times Q_k$ = **3.0** kN/m^2

Concrete properties

Concrete strength class C35/45

Characteristic cylinder strength f_{ck} = **35** N/mm^2

Partial factor (Table 2.1N)	γ_C = **1.50**
Compressive strength factor (cl. 3.1.6)	α_{cc} = **0.85**
Design compressive strength (cl. 3.1.6)	f_{cd} = **19.8** N/mm^2
Mean axial tensile strength (Table 3.1)	$f_{ctm} = 0.30$ N/mm^2 $\times$ (f_{ck} / 1 N/mm^2)$^{2/3}$ = **3.2** N/mm^2
Maximum aggregate size	d_g = **20** mm

Reinforcement properties

Characteristic yield strength	f_{yk} = **500** N/mm^2
Partial factor (Table 2.1N)	γ_S = **1.15**
Design yield strength (fig. 3.8)	$f_{yd} = f_{yk} / \gamma_S$ = **434.8** N/mm^2

Concrete cover to reinforcement

Nominal cover to outer bottom reinforcement	c_{nom_b} = **50** mm
Fire resistance period to bottom of slab	R_{btm} = **60** min
Axia distance to bottom reinft (Table 5.8)	a_{fi_b} = **10** mm
Min. btm cover requirement with regard to bond	c_{min,b_b} = **12** mm
Reinforcement fabrication	**Subject to QA system**
Cover allowance for deviation	Δc_{dev} = **5** mm
Min. required nominal cover to bottom reinft	$c_{nom\_b\_min}$ = **17.0** mm

PASS - There is sufficient cover to the bottom reinforcement

Reinforcement design at midspan in short span direction (cl.6.1)

Bending moment coefficient	β_{sx_p} = **0.0881**
Design bending moment	$M_{x\_p} = \beta_{sx\_p} \times q \times l_x^2$ = **7.2** kNm/m
Reinforcement provided	12 mm dia. bars at 150 mm centres
Area provided	A_{sx_p} = 754 mm^2/m
Effective depth to tension reinforcement	$d_{x\_p} = h - c_{nom\_b} - \phi_{x\_p} / 2$ = **244.0** mm
K factor	$K = M_{x\_p} / (b \times d_{x\_p}^2 \times f_{ck})$ = **0.003**
Redistribution ratio	δ = 1.0
K' factor	$K' = 0.598 \times \delta - 0.18 \times \delta^2 - 0.21$ = **0.208**

K < K' - Compression reinforcement is not required

Lever arm	$z = \min(0.95 \times d_{x\_p}, d_{x\_p}/2 \times (1 + \sqrt{(1 - 3.53 \times K)}))$ = **231.8** mm
Area of reinforcement required for bending	$A_{sx\_p\_m} = M_{x\_p} / (f_{yd} \times z)$ = **71** mm^2/m
Minimum area of reinforcement required	$A_{sx\_p\_min} = \max(0.26 \times (f_{ctm}/f_{yk}) \times b \times d_{x\_p}, 0.0013 \times b \times d_{x\_p})$ = **407** mm^2/m
Area of reinforcement required	$A_{sx\_p\_req} = \max(A_{sx\_p\_m}, A_{sx\_p\_min})$ = **407** mm^2/m

PASS - Area of reinforcement provided exceeds area required

Check reinforcement spacing

Reinforcement service stress	$\sigma_{sx\_p} = (f_{yk} / \gamma_S) \times \min((A_{sx\_p\_m}/A_{sx\_p}), 1.0) \times q_{SLS} / q$ = **21.5** N/mm^2
Maximum allowable spacing (Table 7.3N)	$s_{max\_x\_p}$ = **300** mm
Actual bar spacing	s_{x_p} = **150** mm

PASS - The reinforcement spacing is acceptable

Reinforcement design at midspan in long span direction (cl.6.1)

Bending moment coefficient	β_{sy_p} = **0.0560**
Design bending moment	$M_{y\_p} = \beta_{sy\_p} \times q \times l_x^2$ = **4.5** kNm/m
Reinforcement provided	12 mm dia. bars at 150 mm centres
Area provided	A_{sy_p} = 754 mm^2/m
Effective depth to tension reinforcement	$d_{y\_p} = h - c_{nom\_b} - \phi_{x\_p} - \phi_{y\_p} / 2$ = **232.0** mm
K factor	$K = M_{y\_p} / (b \times d_{y\_p}^2 \times f_{ck})$ = **0.002**

Redistribution ratio	$\delta = 1.0$
K' factor	$K' = 0.598 \times \delta - 0.18 \times \delta^2 - 0.21 =$ **0.208**

K < K' - Compression reinforcement is not required

Lever arm	$z = \min(0.95 \times d_{y\_p}, d_{y\_p}/2 \times (1 + \sqrt{(1 - 3.53 \times K)})) =$ **220.4** mm
Area of reinforcement required for bending	$A_{sy\_p\_m} = M_{y\_p} / (f_{yd} \times z) =$ **47** mm^2/m
Minimum area of reinforcement required	$A_{sy\_p\_min} = \max(0.26 \times (f_{ctm}/f_{yk}) \times b \times d_{y\_p}, 0.0013 \times b \times d_{y\_p}) =$ **387** mm^2/m
Area of reinforcement required	$A_{sy\_p\_req} = \max(A_{sy\_p\_m}, A_{sy\_p\_min}) =$ **387** mm^2/m

PASS - Area of reinforcement provided exceeds area required

Check reinforcement spacing

Reinforcement service stress	$\sigma_{sy\_p} = (f_{yk} / \gamma_S) \times \min((A_{sy\_p\_m}/A_{sy\_p}), 1.0) \times q_{SLS} / q =$ **14.4** N/mm^2
Maximum allowable spacing (Table 7.3N)	$s_{max\_y\_p} =$ **300** mm
Actual bar spacing	$s_{y\_p} =$ **150** mm

PASS - The reinforcement spacing is acceptable

Shear capacity check at short span discontinuous support

Shear force	$V_{x\_d} = q \times l_x / 2 =$ **10.7** kN/m
Reinforcement provided	**12 mm dia. bars at 150 mm centres**
Area provided	$A_{sx\_d} =$ **754** mm^2/m
Effective depth	$d_{x\_d} = d_{x\_p} =$ **244.0** mm
Effective depth factor	$k = \min(2.0, 1 + (200 \text{ mm} / d_{x\_d})^{0.5}) =$ **1.905**
Reinforcement ratio	$\rho_l = \min(0.02, A_{sx\_d} / (b \times d_{x\_d})) =$ **0.0031**
Minimum shear resistance	$V_{Rd,c\_min} = 0.035 \text{ N/mm}^2 \times k^{1.5} \times (f_{ck} / 1 \text{ N/mm}^2)^{0.5} \times b \times d_{x\_d}$
	$V_{Rd,c\_min} =$ **132.9** kN/m
Shear resistance constant (cl. 6.2.2)	$C_{Rd,c} = 0.18 \text{ N/mm}^2 / \gamma_C =$ **0.12** N/mm^2
Shear resistance	

$V_{Rd,c\_x\_d} = \max(V_{Rd,c\_min}, C_{Rd,c} \times k \times (100 \times \rho_l \times (f_{ck}/1 \text{ N/mm}^2))^{0.333} \times b \times d_{x\_d}) =$ **132.9** kN/m

PASS - Shear capacity is adequate (0.080)

Shear capacity check at long span discontinuous support

Shear force	$V_{y\_d} = q \times l_x / 2 =$ **10.7** kN/m
Reinforcement provided	**12 mm dia. bars at 150 mm centres**
Area provided	$A_{sy\_d} =$ **754** mm^2/m
Effective depth	$d_{y\_d} = d_{y\_p} =$ **232.0** mm
Effective depth factor	$k = \min(2.0, 1 + (200 \text{ mm} / d_{y\_d})^{0.5}) =$ **1.928**
Reinforcement ratio	$\rho_l = \min(0.02, A_{sy\_d} / (b \times d_{y\_d})) =$ **0.0032**
Minimum shear resistance	$V_{Rd,c\_min} = 0.035 \text{ N/mm}^2 \times k^{1.5} \times (f_{ck} / 1 \text{ N/mm}^2)^{0.5} \times b \times d_{y\_d}$
	$V_{Rd,c\_min} =$ **128.7** kN/m
Shear resistance constant (cl. 6.2.2)	$C_{Rd,c} = 0.18 \text{ N/mm}^2 / \gamma_C =$ **0.12** N/mm^2
Shear resistance	

$V_{Rd,c\_y\_d} = \max(V_{Rd,c\_min}, C_{Rd,c} \times k \times (100 \times \rho_l \times (f_{ck}/1 \text{ N/mm}^2))^{0.333} \times b \times d_{y\_d}) =$ **128.7** kN/m

PASS - Shear capacity is adequate (0.083)

Basic span-to-depth deflection ratio check (cl. 7.4.2)

Reference reinforcement ratio	$\rho_0 = (f_{ck} / 1 \text{ N/mm}^2)^{0.5} / 1000 =$ **0.0059**
Required tension reinforcement ratio	$\rho = \max(0.0035, A_{sx\_p\_req} / (b \times d_{x\_p})) =$ **0.0035**
Required compression reinforcement ratio	$\rho' = A_{scx\_p\_req} / (b \times d_{x\_p}) =$ **0.0000**
Stuctural system factor (Table 7.4N)	$K_\delta =$ **1.0**
Basic limit span-to-depth ratio (Exp. 7.16)	

$ratio_{lim\_x\_bas} = K_{\delta} \times [11 + 1.5\times(f_{ck}/1\ N/mm^2)^{0.5}\times\rho_0/\rho + 3.2\times(f_{ck}/1\ N/mm^2)^{0.5}\times(\rho_0/\rho - 1)^{1.5}]$ = **36.86**

Mod span-to-depth ratio limit

$ratio_{lim\_x} = \min(40 \times K_{\delta}, \min(1.5, (500\ N/mm^2/ f_{yk}) \times (A_{sx\_p} / A_{sx\_p\_m})) \times ratio_{lim\_x\_bas})$ = **40.00**

Actual span-to-eff. depth ratio $ratio_{act\_x} = l_x / d_{x\_p}$ = **15.57**

PASS - Actual span-to-effective depth ratio is acceptable

Reinforcement summary

Midspan in short span direction	**12 mm dia. bars at 150 mm centres B1**
Midspan in long span direction	**12 mm dia. bars at 150 mm centres B2**
Discontinuous support in short span direction	**12 mm dia. bars at 150 mm centres B1**
Discontinuous support in long span direction	**12 mm dia. bars at 150 mm centres B2**

Reinforcement sketch

The following sketch is indicative only. Note that additional reinforcement may be required in accordance with clauses 9.2.1.2, 9.2.1.4 and 9.2.1.5 of EN 1992-1-1:2004 to meet detailing rules.