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Contract No:	**24100.D041**
Date:	**DECEMEBER 2024**
By:	**JD**

24100 – D041

47 BRO DARWEL

MERTHYR VALLEYS HOMES

STRUCTURAL CALCULATIONS PACKAGE

DOCUMENT INDEX SHEET

Contract: **Nick Daley – Merthyr Valleys Homes** Project No: **24100**

Title: Structural Calculation	Sheets/Page No
Structural calculations	SC 01-03
Tedds calculations	TC 01-55

Date	Detail of Revision	Rev No
06.12.24	**First Issue**	**-**

Prepared By:	Jayden Danter	**Checked By:**	Billy Hayton	**Authorised By:**	Darren Badham
Signed:		**Signed:**		**Signed:**	
Date of Issue:	**06/12/24**				

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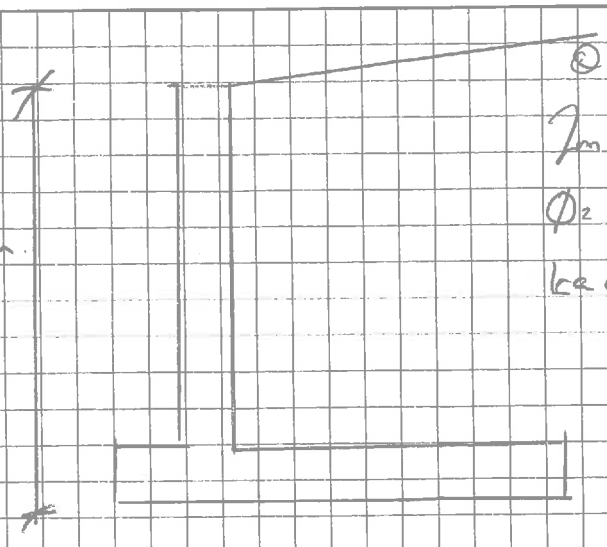
Project Title: 47 BRO DOWEL			Proj. No: 24100
Element Title: RETAINING WALL REINFORCEMENT			Sheet No: 1
Des'd by: JD	Date:	Chk'd by: BH	Date:

REF	INPUT	OUTPUT



$f_{soil} = 0.72 \times 2.45^2 \times 18 \times 0.5 = 39kN$

$f_q = 0.72 \times 2.5kN/m^2 \times 2.45m = 4.5kN$

Moments.

$(39 \times 2.45 \times 0.33) + (4.5 \times 2.45 \times 0.5)$

$= 37.16kNm$

$ULS = 37.1 \times 1.45 = 54kNm$

STEM - ~~TRY~~ 225mm.

$d = 225 - 40 - 10 - 8 = 167mm$

$K = 54 \times 10^6 / 32 \times 167^2 \times 1000 = 0.06$

$z/d = 0.94$

$AS = 54 \times 10^6 / 0.87 \times 500 \times 0.94 \times 167$ — 790mm²

~~B785 MESH + ADDITIONAL BARS~~ = OK

H10 @ 100 FF1
H10 @ 200 NF1

H12 STARTER BARS @ 100 NF1 + FF1

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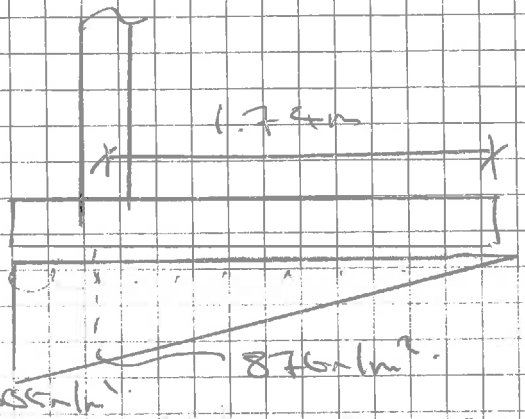
Project Title: 47 BRO DOWEL			Proj. No: 24100
Element Title: RETAINING WALL REINFORCEMENT			Sheet No: 2
Des'd by: JD	Date:	Chk'd by: BH	Date:

REF	INPUT	OUTPUT
SLIDING	$F_H = 43.5 kN$.	
	$F_V = 91.76 kN$.	
ϕ BASE < 35°	$\tan\phi$. $\tan 35° = 0.7$.	
	$0.7 \times 91.7 = 65 kN$.	
	$65/43.5 < 1.5$ ∴ OK	
	CONCRETE:	
	STEM OK	
	BASE. MAX. = $100 kN/m^2$	



$M = (87 \times 1.74 \times 0.5) \times 1.74/3 = 45 kN.m$

$(ULS) = 45 \times 1.5 = 68 kN.m$.

$68 \times 10^6 / 32 \times 1000 \times 240^2 = 0.036$

$z/d < 0.95$

$AS = 68 \times 10^6 / 0.87 \times 500 \times 0.95 \times 240$

$= 685 mm^2$ ∴ ~~B785 MESH~~ OK

H12 @ 150 T1&T2 + B1&B2

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Project Title: 47 BRO DOWEL			Proj. No: 24100
Element Title: RETAINING WALL REINFORCEMENT			Sheet No: 3
Des'd by: JD	Date:	Chk'd by: BH	Date:

REF	INPUT	OUTPUT
	TAKE MOMENTS ABOUT CENTRE = 0.9m	
	BASE = 0.3 x 25 x 1.8m = 13.5kN @ 0 =	0kN.m
	STEM = 0.225 x 25 x 2.15 = 12.1kN @ 0.62 =	7.5
	Soil 1 = 1.425 x 2.15 x 18 = 55kN @ -0.2m =	-11.2
	Soil 2 = 1.425 x 0.3 x 0.5 x 8 = 6.8kN @ -0.28m =	-1.7kN.
	Q = 1.425 x 2.5 = 3.6kN @ 0.2 =	-0.72kN
	TOTAL 91.7kN	-6.12kN.m
BEARING	F/A + M/Z.	
	91.7/1.8 + ((91.7 - 6.12) x 6 / 1.8² =	108kN/m².
	∴ INCREASE TO 2m WIDTH	OK. 100k.n²
	31/91.7 = e = 0.33m.	
	2m/6 = 0.33 ∴ MIDDLE THIRD OK	
OVERTURNING	M = 37.1kN.m.	
	RESTORING. TAKEN MOMENTS @ TOE	
	BASE = 13.5 x 1m = 13.5	
	STEM = 12.1 x 0.28m = 3kN.m.	
	SOIL 2 = 56 x 1.2m = 67kN.m	
	83kN.m	
	83/37.1 = 2.2 > 1.5 OK	

RETAINING WALL ANALYSIS

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

Tedds calculation version 2.9.22

Analysis summary

Design summary

Overall design utilisation 0.804

Overall design status Pass

Description	Unit	Capacity	Applied	F o S	Result
Sliding stability	kN/m	54.4	41.7	1.306	PASS
Overturning stability	kNm/m	119.8	43.7	2.745	PASS
Bearing pressure	kN/m^2	109.6	81.2	1.349	PASS

Design summary

Description	Unit	Provided	Required	Utilisation	Result
Shear resistance	kN/m	114.8	19.5	0.170	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	19.5	0.170	PASS
Min. transverse stem reinf.	mm^2/m	392.7	225.0	0.573	PASS
Min. transverse base reinf.	mm^2/m	392.7	113.1	0.288	PASS

Retaining wall details

Stem type Cantilever

Stem height h_{stem} = **2175** mm

Stem thickness t_{stem} = **225** mm

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

Stem density γ_{stem} = **25** kN/m^3

Toe length l_{toe} = **150** mm

Heel length l_{heel} = **1625** mm

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

Base density γ_{base} = **25** kN/m^3

Height of retained soil h_{ret} = **2175** mm

Angle of soil surface β = **18** deg

Depth of cover d_{cover} = **0** mm

Retained soil properties

Soil type Medium dense well graded sand

Moist density γ_{mr} = **21** kN/m^3

Saturated density γ_{sr} = **23** kN/m^3

Characteristic effective shear resistance angle $\phi'_{r.k}$ = **35** deg

Characteristic wall friction angle $\delta_{r.k}$ = **17.5** deg

Base soil properties

Soil type Medium dense well graded sand

Soil density γ_b = **18** kN/m^3

Characteristic cohesion $c'_{b.k}$ = **0** kN/m^2

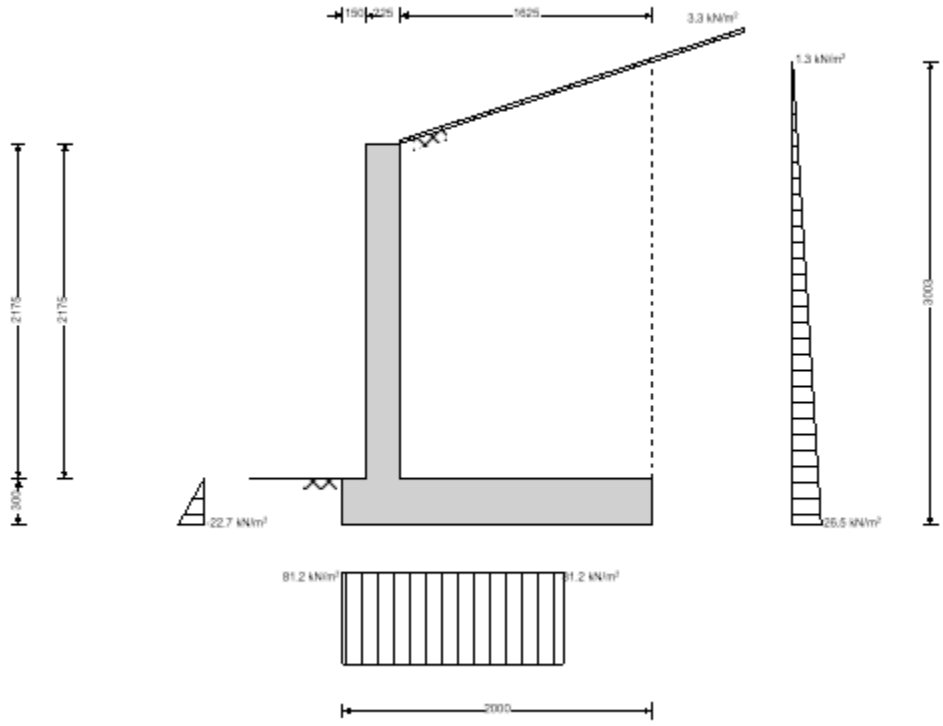
Characteristic effective shear resistance angle $\phi'_{b.k}$ = **35** deg

Characteristic wall friction angle $\delta_{b.k}$ = **15** deg

Characteristic base friction angle $\delta_{bb.k}$ = **30** deg

Loading details

Variable surcharge load — $Surcharge_Q$ = **2.5** kN/m²



General arrangement - sketch pressures relate to bearing check

Calculate retaining wall geometry

Base length	$l_{base} = l_{toe} + t_{stem} + l_{heel}$ = **2000** mm
Moist soil height	$h_{moist} = h_{soil}$ = **2175** mm
Length of surcharge load	$l_{sur} = l_{heel}$ = **1625** mm
- Distance to vertical component	$x_{sur_v} = l_{base} - l_{heel} / 2$ = **1188** mm
Effective height of wall	$h_{eff} = h_{base} + d_{cover} + h_{ret} + l_{sur} \times \tan(\beta)$ = **3003** mm
- Distance to horizontal component	$x_{sur_h} = h_{eff} / 2$ = **1501** mm
Area of wall stem	$A_{stem} = h_{stem} \times t_{stem}$ = **0.489** m²
- Distance to vertical component	$x_{stem} = l_{toe} + t_{stem} / 2$ = **263** mm
Area of wall base	$A_{base} = l_{base} \times t_{base}$ = **0.6** m²
- Distance to vertical component	$x_{base} = l_{base} / 2$ = **1000** mm
Area of moist soil	$A_{moist} = h_{moist} \times l_{heel} + \tan(\beta) \times l_{heel}^2 / 2$ = **3.963** m²
- Distance to vertical component	$x_{moist_v} = l_{base} - (h_{moist} \times l_{heel}^2 / 2 + \tan(\beta) \times l_{heel}^3 / 6) / A_{moist}$ = **1217** mm
- Distance to horizontal component	$x_{moist_h} = h_{eff} / 3$ = **1001** mm

Design approach 1

Partial factors on actions - Table A.3 - Combination 1

Partial factor set	A1
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 – Table A.4 - Combination 1

Soil parameter set	M1
Angle of shearing resistance	$\gamma_{\phi'}$ = **1.00**
Effective cohesion	$\gamma_{c'}$ = **1.00**
Weight density	γ_γ = **1.00**

Retained soil properties

Design moist density	$\gamma_{mr}' = \gamma_{mr} / \gamma_\gamma$ = **21** kN/m^3
Design saturated density	$\gamma_{sr}' = \gamma_{sr} / \gamma_\gamma$ = **23** kN/m^3
Design effective shear resistance angle	$\phi'_{r.d} = \text{atan}(\tan(\phi'_{r.k}) / \gamma_{\phi'})$ = **35** deg
Design wall friction angle	$\delta_{r.d} = \text{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'})$ = **17.5** deg

Base soil properties

Design soil density	$\gamma_b' = \gamma_b / \gamma_\gamma$ = **18** kN/m^3
Design effective shear resistance angle	$\phi'_{b.d} = \text{atan}(\tan(\phi'_{b.k}) / \gamma_{\phi'})$ = **35** deg
Design wall friction angle	$\delta_{b.d} = \text{atan}(\tan(\delta_{b.k}) / \gamma_{\phi'})$ = **15** deg
Design base friction angle	$\delta_{bb.d} = \text{atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'})$ = **30** deg
Design effective cohesion	$c'_{b.d} = c'_{b.k} / \gamma_{c'}$ = **0** kN/m^2

Using Coulomb theory

Active pressure coefficient	$K_A = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times [1 + \sqrt{[\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))]]^2})$ = **0.310**
Passive pressure coefficient	$K_P = \sin(90 - \phi'_{b.d})^2 / (\sin(90 + \delta_{b.d}) \times [1 - \sqrt{[\sin(\phi'_{b.d} + \delta_{b.d}) \times \sin(\phi'_{b.d}) / (\sin(90 + \delta_{b.d}))]]^2})$ = **6.555**

Sliding check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem}$ = **12.2** kN/m
Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base}$ = **15** kN/m
Moist retained soil	$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}'$ = **83.2** kN/m
Total	$F_{total_v} = F_{stem} + F_{base} + F_{moist_v}$ = **110.5** kN/m

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff}$ = **3.3** kN/m
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times h_{eff}^2 / 2$ = **37.8** kN/m
Total	$F_{total_h} = F_{sur_h} + F_{moist_h}$ = **41.2** kN/m

Check stability against sliding

Base soil resistance	$F_{exc_h} = \gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2$ = **5.1** kN/m
Base friction	$F_{friction} = F_{total_v} \times \tan(\delta_{bb.d})$ = **63.8** kN/m
Resistance to sliding	$F_{rest} = F_{exc_h} + F_{friction}$ = **68.9** kN/m
Factor of safety	$FoS_{sl} = F_{rest} / F_{total_h}$ = **1.674**

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem}$ = **12.2** kN/m

Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} =$ **15** kN/m
Moist retained soil	$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' =$ **83.2** kN/m
Total	$F_{total_v} = F_{stem} + F_{base} + F_{moist_v} =$ **110.5** kN/m

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} =$ **3.3** kN/m
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 =$ **37.8** kN/m
Base soil	$F_{exc_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 =$ **-5.1** kN/m
Total	$F_{total_h} = F_{sur_h} + F_{moist_h} + F_{exc_h} =$ **36** kN/m

Overturning moments on wall

Surcharge load	$M_{sur_OT} = F_{sur_h} \times x_{sur_h} =$ **5** kNm/m
Moist retained soil	$M_{moist_OT} = F_{moist_h} \times x_{moist_h} =$ **37.9** kNm/m
Total	$M_{total_OT} = M_{sur_OT} + M_{moist_OT} =$ **42.9** kNm/m

Restoring moments on wall

Wall stem	$M_{stem_R} = F_{stem} \times x_{stem} =$ **3.2** kNm/m
Wall base	$M_{base_R} = F_{base} \times x_{base} =$ **15** kNm/m
Moist retained soil	$M_{moist_R} = F_{moist_v} \times x_{moist_v} =$ **101.3** kNm/m
Base soil	$M_{exc_R} = -F_{exc_h} \times x_{exc_h} =$ **0.5** kNm/m
Total	$M_{total_R} = M_{stem_R} + M_{base_R} + M_{moist_R} + M_{exc_R} =$ **120** kNm/m

Check stability against overturning

Factor of safety: $FoS_{ot} = M_{total_R} / M_{total_OT} =$ **2.799**

PASS - Maximum restoring moment is greater than overturning moment

Bearing pressure check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem} =$ **16.5** kN/m
Wall base	$F_{base} = \gamma_G \times A_{base} \times \gamma_{base} =$ **20.3** kN/m
Surcharge load	$F_{sur_v} = \gamma_Q \times \text{Surcharge}_Q \times l_{heel} =$ **6.1** kN/m
Moist retained soil	$F_{moist_v} = \gamma_G \times A_{moist} \times \gamma_{mr}' =$ **112.4** kN/m
Total	$F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{moist_v} =$ **155.2** kN/m

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} =$ **3.3** kN/m
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 =$ **37.8** kN/m
Base soil	$F_{pass_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2 =$ **-5.1** kN/m
Total	$F_{total_h} = \max(F_{sur_h} + F_{moist_h} + F_{pass_h} - F_{total_v} \times \tan(\delta_{bb.d}), 0 \text{ kN/m}) =$ **0** kN/m

Moments on wall

Wall stem	$M_{stem} = F_{stem} \times x_{stem} =$ **4.3** kNm/m
Wall base	$M_{base} = F_{base} \times x_{base} =$ **20.3** kNm/m
Surcharge load	$M_{sur} = F_{sur_v} \times x_{sur_v} - F_{sur_h} \times x_{sur_h} =$ **2.2** kNm/m
Moist retained soil	$M_{moist} = F_{moist_v} \times x_{moist_v} - F_{moist_h} \times x_{moist_h} =$ **98.9** kNm/m
Base soil	$M_{pass} = -F_{pass_h} \times x_{pass_h} =$ **0.5** kNm/m
Total	$M_{total} = M_{stem} + M_{base} + M_{sur} + M_{moist} + M_{pass} =$ **126.2** kNm/m

Check bearing pressure

Distance to reaction: $\bar{x} = M_{total} / F_{total_v} =$ **813** mm

Eccentricity of reaction	$e = \bar{x} - l_{base} / 2 =$ **-187** mm
Loaded length of base	$l_{load} = 2 \times \bar{x} =$ **1626** mm
Bearing pressure at toe	$q_{toe} = F_{total_v} / l_{load} =$ **95.5** kN/m²
Bearing pressure at heel	$q_{heel} =$ **0** kN/m²
Effective overburden pressure	$q = (t_{base} + d_{cover}) \times \gamma_b' =$ **5.4** kN/m²
Design effective overburden pressure	$q' = q / \gamma_\gamma =$ **5.4** kN/m²
Bearing resistance factors	$N_q = Exp(\pi \times \tan(\phi'_{b.d})) \times (\tan(45 \text{ deg} + \phi'_{b.d} / 2))^2 =$ **33.296**
	$N_c = (N_q - 1) \times \cot(\phi'_{b.d}) =$ **46.124**
	$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b.d}) =$ **45.228**
Foundation shape factors	$s_q = 1$
	$s_\gamma = 1$
	$s_c = 1$
Load inclination factors	$H = F_{sur_h} + F_{moist_h} + F_{pass_h} =$ **36** kN/m
	$V = F_{total_v} =$ **155.2** kN/m
	$m = 2$
	$i_q = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^m =$ **0.59**
	$i_\gamma = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^{(m+1)} =$ **0.453**
	$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b.d})) =$ **0.577**
Net ultimate bearing capacity	
	$n_f = c'_{b.d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_b' \times l_{load} \times N_\gamma \times s_\gamma \times i_\gamma =$ **405.6** kN/m²
Factor of safety	$FoS_{bp} = n_f / \max(q_{toe}, q_{heel}) =$ **4.248**
	PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

Design approach 1

Partial factors on actions - Table A.3 - Combination 2

Partial factor set	A2
Permanent unfavourable action	$\gamma_G =$ **1.000**
Permanent favourable action	$\gamma_{Gf} =$ **1.000**
Variable unfavourable action	$\gamma_Q =$ **1.300**
Variable favourable action	$\gamma_{Qf} =$ **0.000**

Partial factors for soil parameters – Table A.4 - Combination 2

Soil parameter set	M2
Angle of shearing resistance	$\gamma_{\phi'} =$ **1.25**
Effective cohesion	$\gamma_{c'} =$ **1.25**
Weight density	$\gamma_\gamma =$ **1.00**

Retained soil properties

Design moist density	$\gamma_{mr}' = \gamma_{mr} / \gamma_\gamma =$ **21** kN/m³
Design saturated density	$\gamma_{sr}' = \gamma_{sr} / \gamma_\gamma =$ **23** kN/m³
Design effective shear resistance angle	$\phi'_{r.d} = \text{atan}(\tan(\phi'_{r.k}) / \gamma_{\phi'}) =$ **29.3** deg
Design wall friction angle	$\delta_{r.d} = \text{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'}) =$ **14.2** deg

Base soil properties

Design soil density	$\gamma_b' = \gamma_b / \gamma_\gamma =$ **18** kN/m³
Design effective shear resistance angle	$\phi'_{b.d} = \text{atan}(\tan(\phi'_{b.k}) / \gamma_{\phi'}) =$ **29.3** deg
Design wall friction angle	$\delta_{b.d} = \text{atan}(\tan(\delta_{b.k}) / \gamma_{\phi'}) =$ **12.1** deg
Design base friction angle	$\delta_{bb.d} = \text{atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'}) =$ **24.8** deg

Design effective cohesion $c'_{b.d} = c'_{b.k} / \gamma_{c'} = \mathbf{0}$ kN/m²

Using Coulomb theory

Active pressure coefficient $K_A = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times [1 + \sqrt{[\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))]]^2}) = \mathbf{0.411}$

Passive pressure coefficient $K_P = \sin(90 - \phi'_{b.d})^2 / (\sin(90 + \delta_{b.d}) \times [1 - \sqrt{[\sin(\phi'_{b.d} + \delta_{b.d}) \times \sin(\phi'_{b.d}) / (\sin(90 + \delta_{b.d}))]]^2}) = \mathbf{4.303}$

Sliding check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = \mathbf{12.2}$ kN/m
Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = \mathbf{15}$ kN/m
Moist retained soil	$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' = \mathbf{83.2}$ kN/m
Total	$F_{total_v} = F_{stem} + F_{base} + F_{moist_v} = \mathbf{110.5}$ kN/m

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} = \mathbf{3.9}$ kN/m
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 = \mathbf{37.8}$ kN/m
Total	$F_{total_h} = F_{sur_h} + F_{moist_h} = \mathbf{41.7}$ kN/m

Check stability against sliding

Base soil resistance	$F_{exc_h} = \gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = \mathbf{3.4}$ kN/m
Base friction	$F_{friction} = F_{total_v} \times \tan(\delta_{bb.d}) = \mathbf{51}$ kN/m
Resistance to sliding	$F_{rest} = F_{exc_h} + F_{friction} = \mathbf{54.4}$ kN/m
Factor of safety	$FoS_{sl} = F_{rest} / F_{total_h} = \mathbf{1.306}$

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = \mathbf{12.2}$ kN/m
Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = \mathbf{15}$ kN/m
Moist retained soil	$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' = \mathbf{83.2}$ kN/m
Total	$F_{total_v} = F_{stem} + F_{base} + F_{moist_v} = \mathbf{110.5}$ kN/m

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} = \mathbf{3.9}$ kN/m
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 = \mathbf{37.8}$ kN/m
Base soil	$F_{exc_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = \mathbf{-3.4}$ kN/m
Total	$F_{total_h} = F_{sur_h} + F_{moist_h} + F_{exc_h} = \mathbf{38.3}$ kN/m

Overturning moments on wall

Surcharge load	$M_{sur_OT} = F_{sur_h} \times x_{sur_h} = \mathbf{5.8}$ kNm/m
Moist retained soil	$M_{moist_OT} = F_{moist_h} \times x_{moist_h} = \mathbf{37.8}$ kNm/m
Total	$M_{total_OT} = M_{sur_OT} + M_{moist_OT} = \mathbf{43.7}$ kNm/m

Restoring moments on wall

Wall stem	$M_{stem_R} = F_{stem} \times x_{stem} = \mathbf{3.2}$ kNm/m
Wall base	$M_{base_R} = F_{base} \times x_{base} = \mathbf{15}$ kNm/m
Moist retained soil	$M_{moist_R} = F_{moist_v} \times x_{moist_v} = \mathbf{101.3}$ kNm/m
Base soil	$M_{exc_R} = -F_{exc_h} \times x_{exc_h} = \mathbf{0.3}$ kNm/m
Total	$M_{total_R} = M_{stem_R} + M_{base_R} + M_{moist_R} + M_{exc_R} = \mathbf{119.8}$ kNm/m

Check stability against overturning

Factor of safety $FoS_{ot} = M_{total_R} / M_{total_OT} = \mathbf{2.745}$

PASS - Maximum restoring moment is greater than overturning moment

Bearing pressure check

Vertical forces on wall

Wall stem $F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem} = \mathbf{12.2}$ kN/m

Wall base $F_{base} = \gamma_G \times A_{base} \times \gamma_{base} = \mathbf{15}$ kN/m

Surcharge load $F_{sur_v} = \gamma_Q \times Surcharge_Q \times l_{heel} = \mathbf{5.3}$ kN/m

Moist retained soil $F_{moist_v} = \gamma_G \times A_{moist} \times \gamma_{mr}' = \mathbf{83.2}$ kN/m

Total $F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{moist_v} = \mathbf{115.7}$ kN/m

Horizontal forces on wall

Surcharge load $F_{sur_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times Surcharge_Q \times h_{eff} = \mathbf{3.9}$ kN/m

Moist retained soil $F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 = \mathbf{37.8}$ kN/m

Base soil $F_{pass_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2 = \mathbf{-3.4}$ kN/m

Total $F_{total_h} = \max(F_{sur_h} + F_{moist_h} + F_{pass_h} - F_{total_v} \times \tan(\delta_{bb.d}), 0\ kN/m) = \mathbf{0}$ kN/m

Moments on wall

Wall stem $M_{stem} = F_{stem} \times x_{stem} = \mathbf{3.2}$ kNm/m

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

Surcharge load $M_{sur} = F_{sur_v} \times x_{sur_v} - F_{sur_h} \times x_{sur_h} = \mathbf{0.4}$ kNm/m

Moist retained soil $M_{moist} = F_{moist_v} \times x_{moist_v} - F_{moist_h} \times x_{moist_h} = \mathbf{63.5}$ kNm/m

Base soil $M_{pass} = -F_{pass_h} \times x_{pass_h} = \mathbf{0.3}$ kNm/m

Total $M_{total} = M_{stem} + M_{base} + M_{sur} + M_{moist} + M_{pass} = \mathbf{82.4}$ kNm/m

Check bearing pressure

Distance to reaction $\bar{x} = M_{total} / F_{total_v} = \mathbf{712}$ mm

Eccentricity of reaction $e = \bar{x} - l_{base} / 2 = \mathbf{-288}$ mm

Loaded length of base $l_{load} = 2 \times \bar{x} = \mathbf{1425}$ mm

Bearing pressure at toe $q_{toe} = F_{total_v} / l_{load} = \mathbf{81.2}$ kN/m^2

Bearing pressure at heel $q_{heel} = \mathbf{0}$ kN/m^2

Effective overburden pressure $q = (t_{base} + d_{cover}) \times \gamma_b' = \mathbf{5.4}$ kN/m^2

Design effective overburden pressure $q' = q / \gamma_\gamma = \mathbf{5.4}$ kN/m^2

Bearing resistance factors $N_q = Exp(\pi \times \tan(\phi'_{b.d})) \times (\tan(45\ deg + \phi'_{b.d} / 2))^2 = \mathbf{16.921}$

$N_c = (N_q - 1) \times \cot(\phi'_{b.d}) = \mathbf{28.422}$

$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b.d}) = \mathbf{17.837}$

Foundation shape factors $s_q = 1$

$s_\gamma = 1$

$s_c = 1$

Load inclination factors $H = F_{sur_h} + F_{moist_h} + F_{pass_h} = \mathbf{38.3}$ kN/m

$V = F_{total_v} = \mathbf{115.7}$ kN/m

$m = 2$

$i_q = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^m = \mathbf{0.448}$

$i_\gamma = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^{(m+1)} = \mathbf{0.3}$

$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b.d})) = \mathbf{0.414}$

Net ultimate bearing capacity

$n_f = c'_{b.d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_b' \times l_{load} \times N_\gamma \times s_\gamma \times i_\gamma =$ **109.6** kN/m²

Factor of safety $FoS_{bp} = n_f / \max(q_{toe}, q_{heel}) =$ **1.349**

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

RETAINING WALL DESIGN

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

Tedds calculation version 2.9.22

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

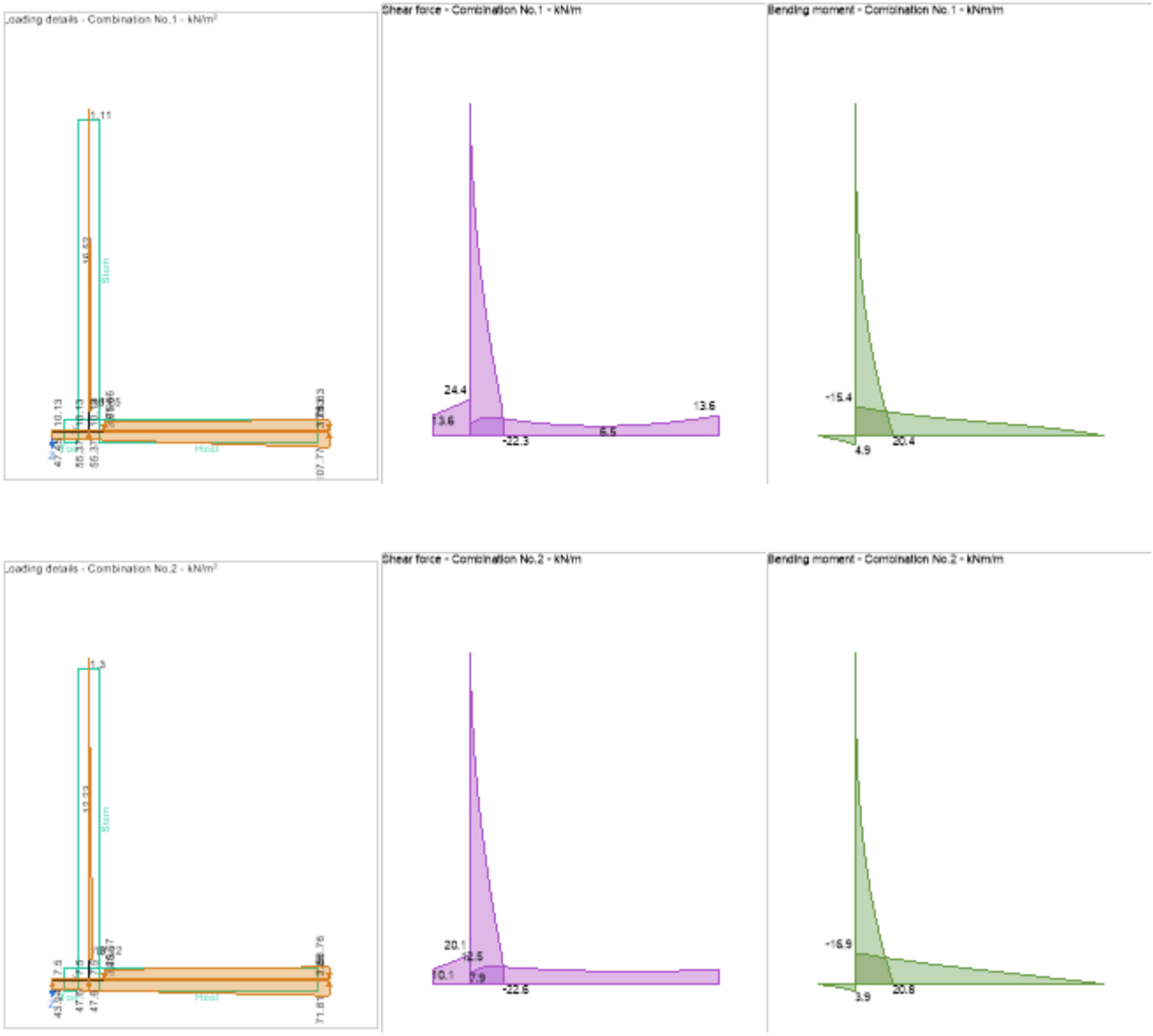
Concrete strength class	C30/37
Characteristic compressive cylinder strength	f_{ck} = **30** N/mm²
Characteristic compressive cube strength	$f_{ck,cube}$ = **37** N/mm²
Mean value of compressive cylinder strength	$f_{cm} = f_{ck}$ + 8 N/mm² = **38** N/mm²
Mean value of axial tensile strength	f_{ctm} = 0.3 N/mm² × (f_{ck} / 1 N/mm²)$^{2/3}$ = **2.9** N/mm²
5% fractile of axial tensile strength	$f_{ctk,0.05} = 0.7 \times f_{ctm}$ = **2.0** N/mm²
Secant modulus of elasticity of concrete	E_{cm} = 22 kN/mm² × (f_{cm} / 10 N/mm²)$^{0.3}$ = **32837** N/mm²
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/mm²
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/mm²
Modulus of elasticity of reinforcement	E_s = **200000** N/mm²
Partial factor for reinforcing steel - Table 2.1N	γ_S = **1.15**
Design yield strength of reinforcement	$f_{yd} = f_{yk} / \gamma_S$ = **435** N/mm²

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 base of stem

Depth of section — h = **225** mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 2 — M = **17.4** kNm/m

Depth to tension reinforcement — $d = h - c_{sr} - \phi_{sr} / 2 =$ **169** mm

$K = M / (d^2 \times f_{ck}) =$ **0.020**

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

K' = **0.207**

K' > K - No compression reinforcement is required

Lever arm — $z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_c))^{0.5}, 0.95) \times d =$ **161** mm

Depth of neutral axis — $x = 2.5 \times (d - z) =$ **21** mm

Area of tension reinforcement required — $A_{sr.req} = M / (f_{yd} \times z) =$ **250** mm²/m

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

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

Minimum area of reinforcement - exp.9.1N	$A_{sr.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d =$ **255** mm²/m
Maximum area of reinforcement - cl.9.2.1.1(3)	$A_{sr.max} = 0.04 \times h =$ **9000** mm²/m
	$\max(A_{sr.req}, A_{sr.min}) / A_{sr.prov} =$ **0.45**

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	$K_b =$ **0.4**
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	$\min(K_s \times K_b \times [11 + 1.5 \times \sqrt{(f_{ck} / 1\ N/mm^2)} \times \rho_0 / \rho + 3.2 \times \sqrt{(f_{ck} / 1\ N/mm^2)} \times (\rho_0 / \rho - 1)^{3/2}], 40 \times K_b) =$ **16**
Actual span to depth ratio	$h_{stem} / d =$ **12.9**

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	$\psi_2 =$ **0.6**
Serviceability bending moment	$M_{sls} =$ **11.7** kNm/m
Tensile stress in reinforcement	$\sigma_s = M_{sls} / (A_{sr.prov} \times z) =$ **129** N/mm²
Load duration	Long term
Load duration factor	$k_t =$ **0.4**
Effective area of concrete in tension	$A_{c.eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$
	$A_{c.eff} =$ **67958** mm²/m
Mean value of concrete tensile strength	$f_{ct.eff} = f_{ctm} =$ **2.9** N/mm²
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	$s_{r.max} = k_3 \times c_{sr} + k_1 \times k_2 \times k_4 \times \phi_{sr} / \rho_{p.eff} =$ **415** mm
Maximum crack width - exp.7.8	$w_k = s_{r.max} \times \max(\sigma_s - k_t \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_e \times \rho_{p.eff}), 0.6 \times \sigma_s) / E_s$
	$w_k =$ **0.161** mm
	$w_k / w_{max} =$ **0.535**

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force	$V =$ **22.6** 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/mm²
Design shear resistance - exp.6.2a & 6.2b	$V_{Rd.c} = \max(C_{Rd.c} \times k \times (100\ N^2/mm^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$
	$V_{Rd.c} =$ **91.6** kN/m
	$V / V_{Rd.c} =$ **0.247**

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)	$A_{sx.req} = \max(0.25 \times A_{sr.prov}, 0.001 \times t_{stem}) =$ **225** 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 = **300** mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 1	M = **2.5** kNm/m
Depth to tension reinforcement	$d = h - c_{bb} - \phi_{bb} / 2 =$ **219** mm
	$K = M / (d^2 \times f_{ck}) =$ **0.002**
	$K' = (2 \times \eta \times \alpha_{cc}/\gamma_C) \times (1 - \lambda \times (\delta - K_1)/(2 \times K_2)) \times (\lambda \times (\delta - K_1)/(2 \times K_2))$
	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	$A_{bb.req} = M / (f_{yd} \times z) =$ **27** 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	$\psi_2 =$ **0.6**
Serviceability bending moment	$M_{sls} =$ **1.8** kNm/m
Tensile stress in reinforcement	$\sigma_s = M_{sls} / (A_{bb.prov} \times z) =$ **15.4** 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	$w_k = s_{r.max} \times \max(\sigma_s - k_t \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_e \times \rho_{p.eff}), 0.6 \times \sigma_s) / E_s$
	$w_k =$ **0.027** mm
	$w_k / w_{max} =$ **0.09**

PASS - Maximum crack width is less than limiting crack width

Tekla Tedds	Project				Job no.	
Shear Design 7 Ash Tree Court Cardiff Gate Business Park CF23 8RW	Calcs for				Start page no./Revision 12	
	Calcs by J	Calcs date 04/12/2024	Checked by	Checked date	Approved by	Approved date

Rectangular section in shear - Section 6.2

Design shear force	V = **19.5** kN/m
	$C_{Rd,c}$ = 0.18 / γ_C = **0.120**
	k = min(1 + √(200 mm / d), 2) = **1.956**
Longitudinal reinforcement ratio	ρ_l = min($A_{bb.prov}$ / d, 0.02) = **0.003**
	v_{min} = 0.035 $N^{1/2}/mm \times k^{3/2} \times f_{ck}^{0.5}$ = **0.524** 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}) × d
	$V_{Rd.c}$ = **114.8** kN/m
	$V / V_{Rd.c}$ = **0.170**
	PASS - Design shear resistance exceeds design shear force

Check base design at heel

Depth of section	h = **300** mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 2	M = **15.7** kNm/m
Depth to tension reinforcement	d = h - c_{bt} - ϕ_{bt} / 2 = **244** 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 × (1 - 2 × K / ($\eta \times \alpha_{cc}$ / γ_C))$^{0.5}$, 0.95) × d = **232** mm
Depth of neutral axis	x = 2.5 × (d – z) = **31** mm
Area of tension reinforcement required	$A_{bt.req}$ = M / (f_{yd} × z) = **156** mm^2/m
Tension reinforcement provided	12 dia.bars @ 200 c/c
Area of tension reinforcement provided	$A_{bt.prov}$ = $\pi \times \phi_{bt}^2$ / (4 × s_{bt}) = **565** mm^2/m
Minimum area of reinforcement - exp.9.1N	$A_{bt.min}$ = max(0.26 × f_{ctm} / f_{yk}, 0.0013) × d = **368** mm^2/m
Maximum area of reinforcement - cl.9.2.1.1(3)	$A_{bt.max}$ = 0.04 × h = **12000** mm^2/m
	max($A_{bt.req}$, $A_{bt.min}$) / $A_{bt.prov}$ = **0.65**
	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} = **9.7** kNm/m
Tensile stress in reinforcement	σ_s = M_{sls} / ($A_{bt.prov}$ × z) = **73.7** 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 × (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} = **2.9** N/mm^2
Reinforcement ratio	$\rho_{p.eff}$ = $A_{bt.prov}$ / $A_{c.eff}$ = **0.006**
Modular ratio	α_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	$s_{r.max}$ = $k_3 \times c_{bt} + k_1 \times k_2 \times k_4 \times \phi_{bt}$ / $\rho_{p.eff}$ = **494** 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 = **0.109** mm

w_k / w_{max} = **0.364**

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force

V = **13.2** kN/m

$C_{Rd,c} = 0.18 / \gamma_C$ = **0.120**

$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2)$ = **1.905**

Longitudinal reinforcement ratio

$\rho_l = \min(A_{bt.prov} / d, 0.02)$ = **0.002**

$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5}$ = **0.504** N/mm²

Design shear resistance - exp.6.2a & 6.2b

$V_{Rd.c} = \max(C_{Rd.c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$

$V_{Rd.c}$ = **123** kN/m

$V / V_{Rd.c}$ = **0.107**

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

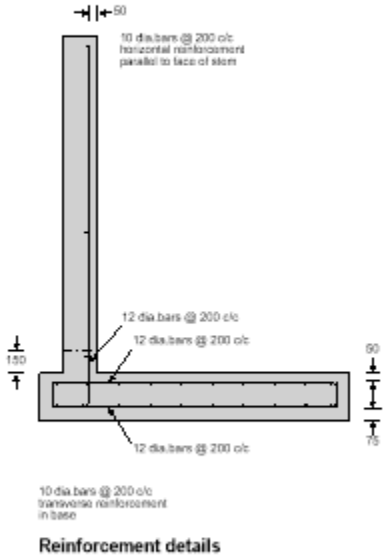
Transverse reinforcement provided

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

RETAINING WALL ANALYSIS

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

Tedds calculation version 2.9.22

Analysis summary

Design summary

Overall design utilisation 0.796

Overall design status Pass

Description	Unit	Capacity	Applied	F o S	Result
Sliding stability	kN/m	46.1	36.2	1.274	PASS
Overturning stability	kNm/m	90.6	35.3	2.566	PASS
Bearing pressure	kN/m^2	98.1	78.1	1.256	PASS

Design summary

Description	Unit	Provided	Required	Utilisation	Result
Shear resistance	kN/m	114.8	16.8	0.146	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	16.8	0.146	PASS
Min. transverse stem reinf.	mm^2/m	392.7	225.0	0.573	PASS
Min. transverse base reinf.	mm^2/m	392.7	113.1	0.288	PASS

Retaining wall details

Stem type Cantilever

Stem height h_{stem} = **2025** mm

Stem thickness t_{stem} = **225** mm

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

Stem density γ_{stem} = **25** kN/m^3

Toe length l_{toe} = **150** mm

Heel length l_{heel} = **1425** mm

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

Base density γ_{base} = **25** kN/m^3

Height of retained soil h_{ret} = **2025** mm

Angle of soil surface β = **18** deg

Depth of cover d_{cover} = **0** mm

Retained soil properties

Soil type Medium dense well graded sand

Moist density γ_{mr} = **21** kN/m^3

Saturated density γ_{sr} = **23** kN/m^3

Characteristic effective shear resistance angle $\phi'_{r.k}$ = **35** deg

Characteristic wall friction angle $\delta_{r.k}$ = **17.5** deg

Base soil properties

Soil type Medium dense well graded sand

Soil density γ_b = **18** kN/m^3

Characteristic cohesion $c'_{b.k}$ = **0** kN/m^2

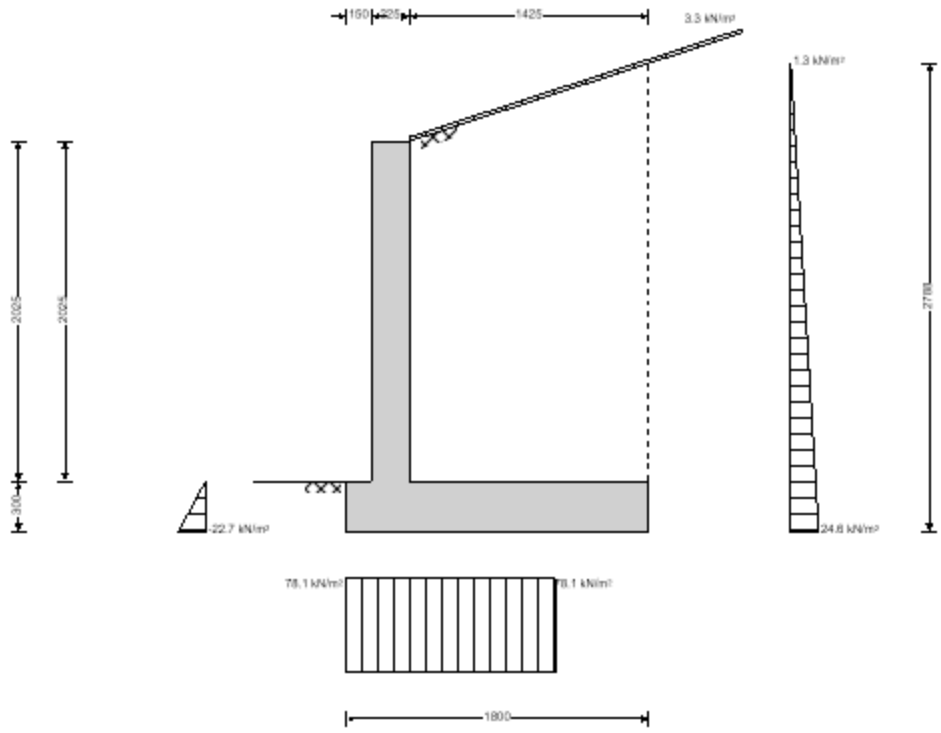
Characteristic effective shear resistance angle $\phi'_{b.k}$ = **35** deg

Characteristic wall friction angle $\delta_{b.k}$ = **15** deg

Characteristic base friction angle $\delta_{bb.k}$ = **30** deg

Loading details

Variable surcharge load — $Surcharge_Q$ = **2.5** kN/m²



General arrangement - sketch pressures relate to bearing check

Calculate retaining wall geometry

Base length	$l_{base} = l_{toe} + t_{stem} + l_{heel}$ = **1800** mm
Moist soil height	$h_{moist} = h_{soil}$ = **2025** mm
Length of surcharge load	$l_{sur} = l_{heel}$ = **1425** mm
- Distance to vertical component	$x_{sur_v} = l_{base} - l_{heel} / 2$ = **1088** mm
Effective height of wall	$h_{eff} = h_{base} + d_{cover} + h_{ret} + l_{sur} \times \tan(\beta)$ = **2788** mm
- Distance to horizontal component	$x_{sur_h} = h_{eff} / 2$ = **1394** mm
Area of wall stem	$A_{stem} = h_{stem} \times t_{stem}$ = **0.456** m²
- Distance to vertical component	$x_{stem} = l_{toe} + t_{stem} / 2$ = **263** mm
Area of wall base	$A_{base} = l_{base} \times t_{base}$ = **0.54** m²
- Distance to vertical component	$x_{base} = l_{base} / 2$ = **900** mm
Area of moist soil	$A_{moist} = h_{moist} \times l_{heel} + \tan(\beta) \times l_{heel}^2 / 2$ = **3.216** m²
- Distance to vertical component	$x_{moist_v} = l_{base} - (h_{moist} \times l_{heel}^2 / 2 + \tan(\beta) \times l_{heel}^3 / 6) / A_{moist}$ = **1112** mm
- Distance to horizontal component	$x_{moist_h} = h_{eff} / 3$ = **929** mm

Design approach 1

Partial factors on actions - Table A.3 - Combination 1

Partial factor set	A1
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 – Table A.4 - Combination 1

Soil parameter set M1

Angle of shearing resistance $\gamma_{\phi'}$ = **1.00**

Effective cohesion $\gamma_{c'}$ = **1.00**

Weight density γ_γ = **1.00**

Retained soil properties

Design moist density $\gamma_{mr}' = \gamma_{mr} / \gamma_\gamma$ = **21** kN/m^3

Design saturated density $\gamma_{sr}' = \gamma_{sr} / \gamma_\gamma$ = **23** kN/m^3

Design effective shear resistance angle $\phi'_{r.d} = \text{atan}(\tan(\phi'_{r.k}) / \gamma_{\phi'})$ = **35** deg

Design wall friction angle $\delta_{r.d} = \text{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'})$ = **17.5** deg

Base soil properties

Design soil density $\gamma_b' = \gamma_b / \gamma_\gamma$ = **18** kN/m^3

Design effective shear resistance angle $\phi'_{b.d} = \text{atan}(\tan(\phi'_{b.k}) / \gamma_{\phi'})$ = **35** deg

Design wall friction angle $\delta_{b.d} = \text{atan}(\tan(\delta_{b.k}) / \gamma_{\phi'})$ = **15** deg

Design base friction angle $\delta_{bb.d} = \text{atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'})$ = **30** deg

Design effective cohesion $c'_{b.d} = c'_{b.k} / \gamma_{c'}$ = **0** kN/m^2

Using Coulomb theory

Active pressure coefficient $K_A = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times [1 + \sqrt{[\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))]]^2})$ = **0.310**

Passive pressure coefficient $K_P = \sin(90 - \phi'_{b.d})^2 / (\sin(90 + \delta_{b.d}) \times [1 - \sqrt{[\sin(\phi'_{b.d} + \delta_{b.d}) \times \sin(\phi'_{b.d}) / (\sin(90 + \delta_{b.d}))]]^2})$ = **6.555**

Sliding check

Vertical forces on wall

Wall stem $F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem}$ = **11.4** kN/m

Wall base $F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base}$ = **13.5** kN/m

Moist retained soil $F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}'$ = **67.5** kN/m

Total $F_{total_v} = F_{stem} + F_{base} + F_{moist_v}$ = **92.4** kN/m

Horizontal forces on wall

Surcharge load $F_{sur_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff}$ = **3.1** kN/m

Moist retained soil $F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times h_{eff}^2 / 2$ = **32.6** kN/m

Total $F_{total_h} = F_{sur_h} + F_{moist_h}$ = **35.7** kN/m

Check stability against sliding

Base soil resistance $F_{exc_h} = \gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2$ = **5.1** kN/m

Base friction $F_{friction} = F_{total_v} \times \tan(\delta_{bb.d})$ = **53.4** kN/m

Resistance to sliding $F_{rest} = F_{exc_h} + F_{friction}$ = **58.5** kN/m

Factor of safety $FoS_{sl} = F_{rest} / F_{total_h}$ = **1.638**

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem $F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem}$ = **11.4** kN/m

Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} =$ **13.5** kN/m
Moist retained soil	$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' =$ **67.5** kN/m
Total	$F_{total_v} = F_{stem} + F_{base} + F_{moist_v} =$ **92.4** kN/m

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} =$ **3.1** kN/m
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 =$ **32.6** kN/m
Base soil	$F_{exc_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 =$ **-5.1** kN/m
Total	$F_{total_h} = F_{sur_h} + F_{moist_h} + F_{exc_h} =$ **30.6** kN/m

Overturning moments on wall

Surcharge load	$M_{sur_OT} = F_{sur_h} \times x_{sur_h} =$ **4.3** kNm/m
Moist retained soil	$M_{moist_OT} = F_{moist_h} \times x_{moist_h} =$ **30.3** kNm/m
Total	$M_{total_OT} = M_{sur_OT} + M_{moist_OT} =$ **34.6** kNm/m

Restoring moments on wall

Wall stem	$M_{stem_R} = F_{stem} \times x_{stem} =$ **3** kNm/m
Wall base	$M_{base_R} = F_{base} \times x_{base} =$ **12.2** kNm/m
Moist retained soil	$M_{moist_R} = F_{moist_v} \times x_{moist_v} =$ **75.1** kNm/m
Base soil	$M_{exc_R} = -F_{exc_h} \times x_{exc_h} =$ **0.5** kNm/m
Total	$M_{total_R} = M_{stem_R} + M_{base_R} + M_{moist_R} + M_{exc_R} =$ **90.7** kNm/m

Check stability against overturning

Factor of safety: $FoS_{ot} = M_{total_R} / M_{total_OT} =$ **2.621**

PASS - Maximum restoring moment is greater than overturning moment

Bearing pressure check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem} =$ **15.4** kN/m
Wall base	$F_{base} = \gamma_G \times A_{base} \times \gamma_{base} =$ **18.2** kN/m
Surcharge load	$F_{sur_v} = \gamma_Q \times \text{Surcharge}_Q \times l_{heel} =$ **5.3** kN/m
Moist retained soil	$F_{moist_v} = \gamma_G \times A_{moist} \times \gamma_{mr}' =$ **91.2** kN/m
Total	$F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{moist_v} =$ **130.1** kN/m

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} =$ **3.1** kN/m
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 =$ **32.6** kN/m
Base soil	$F_{pass_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2 =$ **-5.1** kN/m
Total	$F_{total_h} = \max(F_{sur_h} + F_{moist_h} + F_{pass_h} - F_{total_v} \times \tan(\delta_{bb.d}), 0 \text{ kN/m}) =$ **0** kN/m

Moments on wall

Wall stem	$M_{stem} = F_{stem} \times x_{stem} =$ **4** kNm/m
Wall base	$M_{base} = F_{base} \times x_{base} =$ **16.4** kNm/m
Surcharge load	$M_{sur} = F_{sur_v} \times x_{sur_v} - F_{sur_h} \times x_{sur_h} =$ **1.5** kNm/m
Moist retained soil	$M_{moist} = F_{moist_v} \times x_{moist_v} - F_{moist_h} \times x_{moist_h} =$ **71.1** kNm/m
Base soil	$M_{pass} = -F_{pass_h} \times x_{pass_h} =$ **0.5** kNm/m
Total	$M_{total} = M_{stem} + M_{base} + M_{sur} + M_{moist} + M_{pass} =$ **93.5** kNm/m

Check bearing pressure

Distance to reaction: $\bar{x} = M_{total} / F_{total_v} =$ **719** mm

Eccentricity of reaction	$e = \bar{x} - l_{base} / 2 =$ **-181** mm
Loaded length of base	$l_{load} = 2 \times \bar{x} =$ **1437** mm
Bearing pressure at toe	$q_{toe} = F_{total_v} / l_{load} =$ **90.5** kN/m²
Bearing pressure at heel	$q_{heel} =$ **0** kN/m²
Effective overburden pressure	$q = (t_{base} + d_{cover}) \times \gamma_b' =$ **5.4** kN/m²
Design effective overburden pressure	$q' = q / \gamma_\gamma =$ **5.4** kN/m²
Bearing resistance factors	$N_q = Exp(\pi \times \tan(\phi'_{b.d})) \times (\tan(45 \text{ deg} + \phi'_{b.d} / 2))^2 =$ **33.296**
	$N_c = (N_q - 1) \times \cot(\phi'_{b.d}) =$ **46.124**
	$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b.d}) =$ **45.228**
Foundation shape factors	$s_q = 1$
	$s_\gamma = 1$
	$s_c = 1$
Load inclination factors	$H = F_{sur_h} + F_{moist_h} + F_{pass_h} =$ **30.6** kN/m
	$V = F_{total_v} =$ **130.1** kN/m
	$m = 2$
	$i_q = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^m =$ **0.585**
	$i_\gamma = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^{(m+1)} =$ **0.448**
	$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b.d})) =$ **0.572**
Net ultimate bearing capacity	
	$n_f = c'_{b.d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_b' \times l_{load} \times N_\gamma \times s_\gamma \times i_\gamma =$ **367.1** kN/m²
Factor of safety	$FoS_{bp} = n_f / \max(q_{toe}, q_{heel}) =$ **4.056**
	PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

Design approach 1

Partial factors on actions - Table A.3 - Combination 2

Partial factor set	A2
Permanent unfavourable action	$\gamma_G =$ **1.000**
Permanent favourable action	$\gamma_{Gf} =$ **1.000**
Variable unfavourable action	$\gamma_Q =$ **1.300**
Variable favourable action	$\gamma_{Qf} =$ **0.000**

Partial factors for soil parameters – Table A.4 - Combination 2

Soil parameter set	M2
Angle of shearing resistance	$\gamma_{\phi'} =$ **1.25**
Effective cohesion	$\gamma_{c'} =$ **1.25**
Weight density	$\gamma_\gamma =$ **1.00**

Retained soil properties

Design moist density	$\gamma_{mr}' = \gamma_{mr} / \gamma_\gamma =$ **21** kN/m³
Design saturated density	$\gamma_{sr}' = \gamma_{sr} / \gamma_\gamma =$ **23** kN/m³
Design effective shear resistance angle	$\phi'_{r.d} = \text{atan}(\tan(\phi'_{r.k}) / \gamma_{\phi'}) =$ **29.3** deg
Design wall friction angle	$\delta_{r.d} = \text{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'}) =$ **14.2** deg

Base soil properties

Design soil density	$\gamma_b' = \gamma_b / \gamma_\gamma =$ **18** kN/m³
Design effective shear resistance angle	$\phi'_{b.d} = \text{atan}(\tan(\phi'_{b.k}) / \gamma_{\phi'}) =$ **29.3** deg
Design wall friction angle	$\delta_{b.d} = \text{atan}(\tan(\delta_{b.k}) / \gamma_{\phi'}) =$ **12.1** deg
Design base friction angle	$\delta_{bb.d} = \text{atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'}) =$ **24.8** deg

Design effective cohesion $c'_{b.d} = c'_{b.k} / \gamma_{c'} = \mathbf{0}$ kN/m²

Using Coulomb theory

Active pressure coefficient $K_A = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times [1 + \sqrt{[\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))]]^2}) = \mathbf{0.411}$

Passive pressure coefficient $K_P = \sin(90 - \phi'_{b.d})^2 / (\sin(90 + \delta_{b.d}) \times [1 - \sqrt{[\sin(\phi'_{b.d} + \delta_{b.d}) \times \sin(\phi'_{b.d}) / (\sin(90 + \delta_{b.d}))]]^2}) = \mathbf{4.303}$

Sliding check

Vertical forces on wall

Wall stem $F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = \mathbf{11.4}$ kN/m

Wall base $F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = \mathbf{13.5}$ kN/m

Moist retained soil $F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' = \mathbf{67.5}$ kN/m

Total $F_{total_v} = F_{stem} + F_{base} + F_{moist_v} = \mathbf{92.4}$ kN/m

Horizontal forces on wall

Surcharge load $F_{sur_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} = \mathbf{3.6}$ kN/m

Moist retained soil $F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 = \mathbf{32.6}$ kN/m

Total $F_{total_h} = F_{sur_h} + F_{moist_h} = \mathbf{36.2}$ kN/m

Check stability against sliding

Base soil resistance $F_{exc_h} = \gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = \mathbf{3.4}$ kN/m

Base friction $F_{friction} = F_{total_v} \times \tan(\delta_{bb.d}) = \mathbf{42.7}$ kN/m

Resistance to sliding $F_{rest} = F_{exc_h} + F_{friction} = \mathbf{46.1}$ kN/m

Factor of safety $FoS_{sl} = F_{rest} / F_{total_h} = \mathbf{1.274}$

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem $F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = \mathbf{11.4}$ kN/m

Wall base $F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = \mathbf{13.5}$ kN/m

Moist retained soil $F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' = \mathbf{67.5}$ kN/m

Total $F_{total_v} = F_{stem} + F_{base} + F_{moist_v} = \mathbf{92.4}$ kN/m

Horizontal forces on wall

Surcharge load $F_{sur_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} = \mathbf{3.6}$ kN/m

Moist retained soil $F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 = \mathbf{32.6}$ kN/m

Base soil $F_{exc_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = \mathbf{-3.4}$ kN/m

Total $F_{total_h} = F_{sur_h} + F_{moist_h} + F_{exc_h} = \mathbf{32.8}$ kN/m

Overturning moments on wall

Surcharge load $M_{sur_OT} = F_{sur_h} \times x_{sur_h} = \mathbf{5}$ kNm/m

Moist retained soil $M_{moist_OT} = F_{moist_h} \times x_{moist_h} = \mathbf{30.3}$ kNm/m

Total $M_{total_OT} = M_{sur_OT} + M_{moist_OT} = \mathbf{35.3}$ kNm/m

Restoring moments on wall

Wall stem $M_{stem_R} = F_{stem} \times x_{stem} = \mathbf{3}$ kNm/m

Wall base $M_{base_R} = F_{base} \times x_{base} = \mathbf{12.2}$ kNm/m

Moist retained soil $M_{moist_R} = F_{moist_v} \times x_{moist_v} = \mathbf{75.1}$ kNm/m

Base soil $M_{exc_R} = -F_{exc_h} \times x_{exc_h} = \mathbf{0.3}$ kNm/m

Total $M_{total_R} = M_{stem_R} + M_{base_R} + M_{moist_R} + M_{exc_R} = \mathbf{90.6}$ kNm/m

Check stability against overturning

Factor of safety $FoS_{ot} = M_{total_R} / M_{total_OT} = \mathbf{2.566}$

PASS - Maximum restoring moment is greater than overturning moment

Bearing pressure check

Vertical forces on wall

Wall stem $F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem} = \mathbf{11.4}$ kN/m

Wall base $F_{base} = \gamma_G \times A_{base} \times \gamma_{base} = \mathbf{13.5}$ kN/m

Surcharge load $F_{sur_v} = \gamma_Q \times Surcharge_Q \times l_{heel} = \mathbf{4.6}$ kN/m

Moist retained soil $F_{moist_v} = \gamma_G \times A_{moist} \times \gamma_{mr}' = \mathbf{67.5}$ kN/m

Total $F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{moist_v} = \mathbf{97}$ kN/m

Horizontal forces on wall

Surcharge load $F_{sur_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times Surcharge_Q \times h_{eff} = \mathbf{3.6}$ kN/m

Moist retained soil $F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 = \mathbf{32.6}$ kN/m

Base soil $F_{pass_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2 = \mathbf{-3.4}$ kN/m

Total $F_{total_h} = \max(F_{sur_h} + F_{moist_h} + F_{pass_h} - F_{total_v} \times \tan(\delta_{bb.d}), 0\ kN/m) = \mathbf{0}$ kN/m

Moments on wall

Wall stem $M_{stem} = F_{stem} \times x_{stem} = \mathbf{3}$ kNm/m

Wall base $M_{base} = F_{base} \times x_{base} = \mathbf{12.2}$ kNm/m

Surcharge load $M_{sur} = F_{sur_v} \times x_{sur_v} - F_{sur_h} \times x_{sur_h} = \mathbf{0}$ kNm/m

Moist retained soil $M_{moist} = F_{moist_v} \times x_{moist_v} - F_{moist_h} \times x_{moist_h} = \mathbf{44.8}$ kNm/m

Base soil $M_{pass} = -F_{pass_h} \times x_{pass_h} = \mathbf{0.3}$ kNm/m

Total $M_{total} = M_{stem} + M_{base} + M_{sur} + M_{moist} + M_{pass} = \mathbf{60.3}$ kNm/m

Check bearing pressure

Distance to reaction $\bar{x} = M_{total} / F_{total_v} = \mathbf{621}$ mm

Eccentricity of reaction $e = \bar{x} - l_{base} / 2 = \mathbf{-279}$ mm

Loaded length of base $l_{load} = 2 \times \bar{x} = \mathbf{1243}$ mm

Bearing pressure at toe $q_{toe} = F_{total_v} / l_{load} = \mathbf{78.1}$ kN/m^2

Bearing pressure at heel $q_{heel} = \mathbf{0}$ kN/m^2

Effective overburden pressure $q = (t_{base} + d_{cover}) \times \gamma_b' = \mathbf{5.4}$ kN/m^2

Design effective overburden pressure $q' = q / \gamma_\gamma = \mathbf{5.4}$ kN/m^2

Bearing resistance factors $N_q = Exp(\pi \times \tan(\phi'_{b.d})) \times (\tan(45\ deg + \phi'_{b.d} / 2))^2 = \mathbf{16.921}$

$N_c = (N_q - 1) \times \cot(\phi'_{b.d}) = \mathbf{28.422}$

$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b.d}) = \mathbf{17.837}$

Foundation shape factors $s_q = 1$

$s_\gamma = 1$

$s_c = 1$

Load inclination factors $H = F_{sur_h} + F_{moist_h} + F_{pass_h} = \mathbf{32.8}$ kN/m

$V = F_{total_v} = \mathbf{97}$ kN/m

$m = 2$

$i_q = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^m = \mathbf{0.439}$

$i_\gamma = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^{(m+1)} = \mathbf{0.291}$

$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b.d})) = \mathbf{0.404}$

Net ultimate bearing capacity

$n_f = c'_{b.d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_b' \times l_{load} \times N_\gamma \times s_\gamma \times i_\gamma =$ **98.1** kN/m²

Factor of safety $FoS_{bp} = n_f / \max(q_{toe}, q_{heel}) =$ **1.256**

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

RETAINING WALL DESIGN

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

Tedds calculation version 2.9.22

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

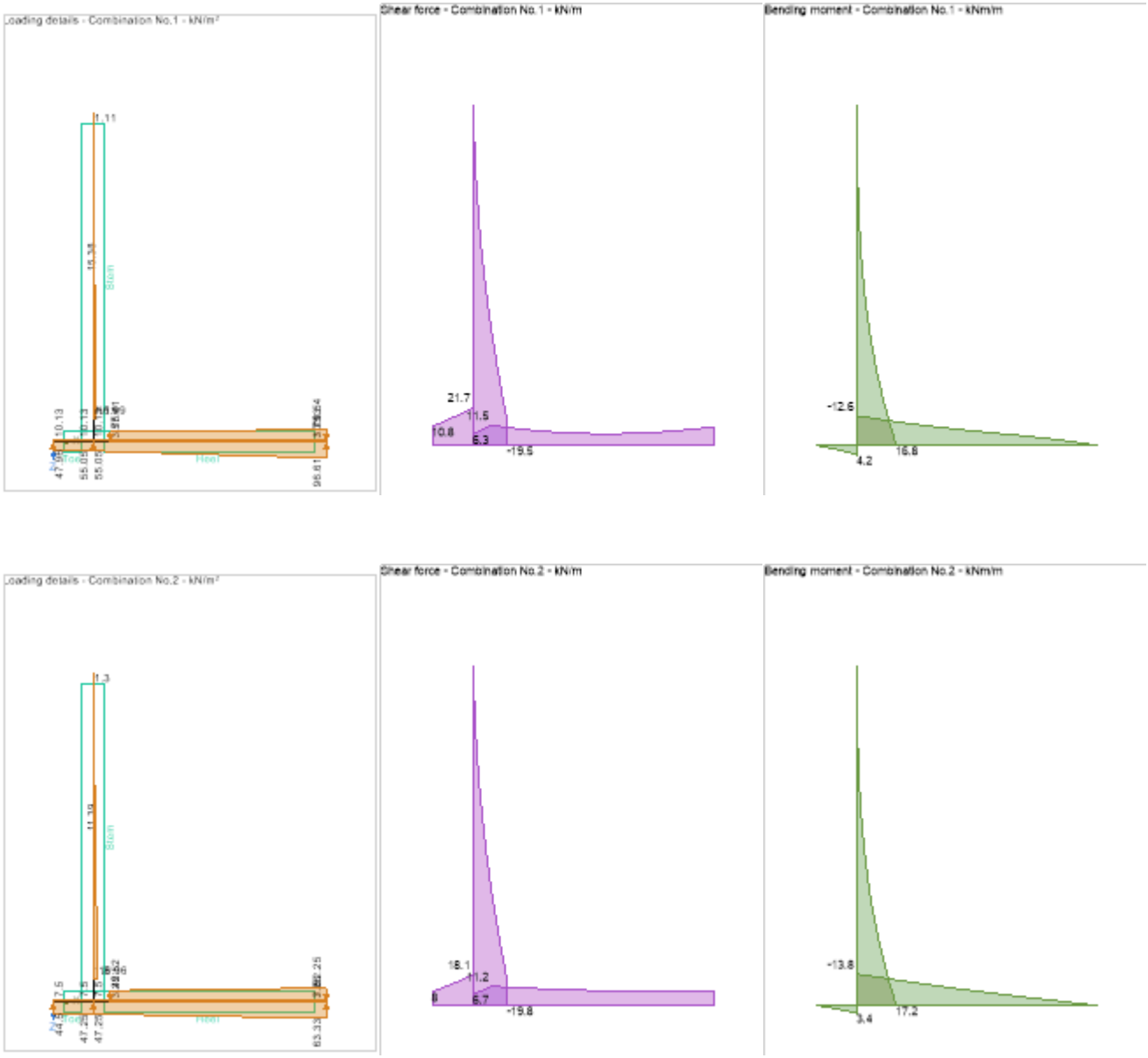
Concrete strength class	C30/37
Characteristic compressive cylinder strength	f_{ck} = **30** N/mm²
Characteristic compressive cube strength	$f_{ck,cube}$ = **37** N/mm²
Mean value of compressive cylinder strength	$f_{cm} = f_{ck}$ + 8 N/mm² = **38** N/mm²
Mean value of axial tensile strength	f_{ctm} = 0.3 N/mm² × (f_{ck} / 1 N/mm²)$^{2/3}$ = **2.9** N/mm²
5% fractile of axial tensile strength	$f_{ctk,0.05} = 0.7 \times f_{ctm}$ = **2.0** N/mm²
Secant modulus of elasticity of concrete	E_{cm} = 22 kN/mm² × (f_{cm} / 10 N/mm²)$^{0.3}$ = **32837** N/mm²
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/mm²
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/mm²
Modulus of elasticity of reinforcement	E_s = **200000** N/mm²
Partial factor for reinforcing steel - Table 2.1N	γ_S = **1.15**
Design yield strength of reinforcement	$f_{yd} = f_{yk} / \gamma_S$ = **435** N/mm²

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 base of stem

Depth of section — h = **225** mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 2 — M = **14.3** kNm/m

Depth to tension reinforcement — $d = h - c_{sr} - \phi_{sr} / 2$ = **170** mm

$K = M / (d^2 \times f_{ck})$ = **0.016**

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

K' = **0.207**

K' > K - No compression reinforcement is required

Lever arm — $z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_C))^{0.5}, 0.95) \times d$ = **161** mm

Depth of neutral axis — $x = 2.5 \times (d - z)$ = **21** mm

Area of tension reinforcement required — $A_{sr.req} = M / (f_{yd} \times z)$ = **203** mm²/m

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

Area of tension reinforcement provided	$A_{sr.prov} = \pi \times \phi_{sr}^2 / (4 \times s_{sr}) =$ **393** mm²/m
Minimum area of reinforcement - exp.9.1N	$A_{sr.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d =$ **256** mm²/m
Maximum area of reinforcement - cl.9.2.1.1(3)	$A_{sr.max} = 0.04 \times h =$ **9000** mm²/m
	$\max(A_{sr.req}, A_{sr.min}) / A_{sr.prov} =$ **0.652**

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	$K_b =$ **0.4**
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	$\min(K_s \times K_b \times [11 + 1.5 \times \sqrt{(f_{ck} / 1\ N/mm^2)} \times \rho_0 / \rho + 3.2 \times \sqrt{(f_{ck} / 1\ N/mm^2)} \times (\rho_0 / \rho - 1)^{3/2}], 40 \times K_b) =$ **16**
Actual span to depth ratio	$h_{stem} / d =$ **11.9**

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	$\psi_2 =$ **0.6**
Serviceability bending moment	$M_{sls} =$ **9.5** kNm/m
Tensile stress in reinforcement	$\sigma_s = M_{sls} / (A_{sr.prov} \times z) =$ **150** N/mm²
Load duration	Long term
Load duration factor	$k_t =$ **0.4**
Effective area of concrete in tension	$A_{c.eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$
	$A_{c.eff} =$ **67917** mm²/m
Mean value of concrete tensile strength	$f_{ct.eff} = f_{ctm} =$ **2.9** N/mm²
Reinforcement ratio	$\rho_{p.eff} = A_{sr.prov} / A_{c.eff} =$ **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	$s_{r.max} = k_3 \times c_{sr} + k_1 \times k_2 \times k_4 \times \phi_{sr} / \rho_{p.eff} =$ **464** mm
Maximum crack width - exp.7.8	$w_k = s_{r.max} \times \max(\sigma_s - k_t \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_e \times \rho_{p.eff}), 0.6 \times \sigma_s) / E_s$
	$w_k =$ **0.209** mm
	$w_k / w_{max} =$ **0.696**

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force	$V =$ **19.8** kN/m
	$C_{Rd,c} = 0.18 / \gamma_C =$ **0.120**
	$k = \min(1 + \sqrt{(200\ mm / d)}, 2) =$ **2.000**
Longitudinal reinforcement ratio	$\rho_l = \min(A_{sr.prov} / d, 0.02) =$ **0.002**
	$v_{min} = 0.035\ N^{1/2}/mm \times k^{3/2} \times f_{ck}^{0.5} =$ **0.542** N/mm²
Design shear resistance - exp.6.2a & 6.2b	$V_{Rd.c} = \max(C_{Rd.c} \times k \times (100\ N^2/mm^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$
	$V_{Rd.c} =$ **92.2** kN/m
	$V / V_{Rd.c} =$ **0.215**

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) $A_{sx.req} = \max(0.25 \times A_{sr.prov}, 0.001 \times t_{stem}) =$ **225** 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 = **300** mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 1 M = **2.1** kNm/m

Depth to tension reinforcement $d = h - c_{bb} - \phi_{bb} / 2 =$ **219** mm

$K = M / (d^2 \times f_{ck}) =$ **0.001**

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

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 $A_{bb.req} = M / (f_{yd} \times z) =$ **23** 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 $\psi_2 =$ **0.6**

Serviceability bending moment $M_{sls} =$ **1.5** kNm/m

Tensile stress in reinforcement $\sigma_s = M_{sls} / (A_{bb.prov} \times z) =$ **12.8** 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 $w_k = s_{r.max} \times \max(\sigma_s - k_t \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_e \times \rho_{p.eff}), 0.6 \times \sigma_s) / E_s$

$w_k =$ **0.022** mm

$w_k / w_{max} =$ **0.074**

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force

$V = \mathbf{16.8}$ kN/m

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

$k = \min(1 + \sqrt{(200\ mm / d)}, 2) = \mathbf{1.956}$

Longitudinal reinforcement ratio

$\rho_l = \min(A_{bb.prov} / d, 0.02) = \mathbf{0.003}$

$v_{min} = 0.035\ N^{1/2}/mm \times k^{3/2} \times f_{ck}^{0.5} = \mathbf{0.524}$ N/mm²

Design shear resistance - exp.6.2a & 6.2b

$V_{Rd.c} = \max(C_{Rd.c} \times k \times (100\ N^2/mm^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$

$V_{Rd.c} = \mathbf{114.8}$ kN/m

$V / V_{Rd.c} = \mathbf{0.146}$

PASS - Design shear resistance exceeds design shear force

Check base design at heel

Depth of section

$h = \mathbf{300}$ mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 2

$M = \mathbf{12.8}$ kNm/m

Depth to tension reinforcement

$d = h - c_{bt} - \phi_{bt} / 2 = \mathbf{244}$ mm

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

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

$K' = \mathbf{0.207}$

K' > K - No compression reinforcement is required

Lever arm

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

Depth of neutral axis

$x = 2.5 \times (d - z) = \mathbf{31}$ mm

Area of tension reinforcement required

$A_{bt.req} = M / (f_{yd} \times z) = \mathbf{127}$ mm²/m

Tension reinforcement provided

12 dia.bars @ 200 c/c

Area of tension reinforcement provided

$A_{bt.prov} = \pi \times \phi_{bt}^2 / (4 \times s_{bt}) = \mathbf{565}$ mm²/m

Minimum area of reinforcement - exp.9.1N

$A_{bt.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = \mathbf{368}$ mm²/m

Maximum area of reinforcement - cl.9.2.1.1(3)

$A_{bt.max} = 0.04 \times h = \mathbf{12000}$ mm²/m

$\max(A_{bt.req}, A_{bt.min}) / A_{bt.prov} = \mathbf{0.65}$

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

$w_{max} = \mathbf{0.3}$ mm

Variable load factor - EN1990 – Table A1.1

$\psi_2 = \mathbf{0.6}$

Serviceability bending moment

$M_{sls} = \mathbf{7.8}$ kNm/m

Tensile stress in reinforcement

$\sigma_s = M_{sls} / (A_{bt.prov} \times z) = \mathbf{59.7}$ N/mm²

Load duration

Long term

Load duration factor

$k_t = \mathbf{0.4}$

Effective area of concrete in tension

$A_{c.eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$

$A_{c.eff} = \mathbf{89833}$ mm²/m

Mean value of concrete tensile strength

$f_{ct.eff} = f_{ctm} = \mathbf{2.9}$ N/mm²

Reinforcement ratio

$\rho_{p.eff} = A_{bt.prov} / A_{c.eff} = \mathbf{0.006}$

Modular ratio

$\alpha_e = E_s / E_{cm} = \mathbf{6.091}$

Bond property coefficient

$k_1 = \mathbf{0.8}$

Strain distribution coefficient

$k_2 = \mathbf{0.5}$

$k_3 = \mathbf{3.4}$

$k_4 = \mathbf{0.425}$

Maximum crack spacing - exp.7.11	$s_{r.max} = k_3 \times c_{bt} + k_1 \times k_2 \times k_4 \times \phi_{bt} / \rho_{p.eff}$ = **494** 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 = **0.089** mm
	w_k / w_{max} = **0.295**
	PASS - Maximum crack width is less than limiting crack width

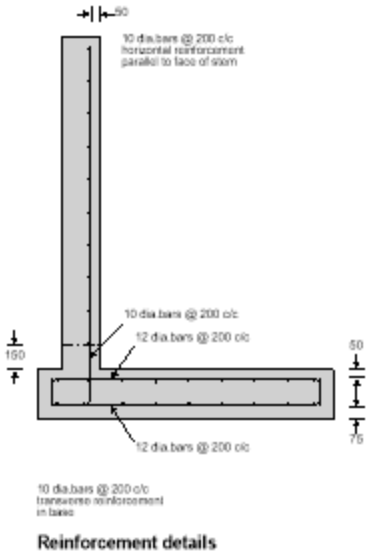
Rectangular section in shear - Section 6.2

Design shear force	V = **11.5** kN/m
	$C_{Rd,c} = 0.18 / \gamma_C$ = **0.120**
	$k = \min(1 + \sqrt{}(200 \text{ mm} / d), 2)$ = **1.905**
Longitudinal reinforcement ratio	$\rho_l = \min(A_{bt.prov} / d, 0.02)$ = **0.002**
	$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5}$ = **0.504** N/mm²
Design shear resistance - exp.6.2a & 6.2b	$V_{Rd.c} = \max(C_{Rd.c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$
	$V_{Rd.c}$ = **123** kN/m
	$V / V_{Rd.c}$ = **0.094**
	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

RETAINING WALL ANALYSIS

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

Tedds calculation version 2.9.22

Analysis summary

Design summary

Overall design utilisation 0.775

Overall design status Pass

Description	Unit	Capacity	Applied	F o S	Result
Sliding stability	kN/m	41	31.8	1.290	PASS
Overturning stability	kNm/m	75.6	29.1	2.599	PASS
Bearing pressure	kN/m^2	98	72.1	1.358	PASS

Design summary

Description	Unit	Provided	Required	Utilisation	Result
Shear resistance	kN/m	114.8	14.7	0.128	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	14.7	0.128	PASS
Min. transverse stem reinf.	mm^2/m	392.7	225.0	0.573	PASS
Min. transverse base reinf.	mm^2/m	392.7	113.1	0.288	PASS

Retaining wall details

Stem type Cantilever

Stem height h_{stem} = **1875** mm

Stem thickness t_{stem} = **225** mm

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

Stem density γ_{stem} = **25** kN/m^3

Toe length l_{toe} = **150** mm

Heel length l_{heel} = **1325** mm

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

Base density γ_{base} = **25** kN/m^3

Height of retained soil h_{ret} = **1875** mm

Angle of soil surface β = **18** deg

Depth of cover d_{cover} = **0** mm

Retained soil properties

Soil type Medium dense well graded sand

Moist density γ_{mr} = **21** kN/m^3

Saturated density γ_{sr} = **23** kN/m^3

Characteristic effective shear resistance angle $\phi'_{r.k}$ = **35** deg

Characteristic wall friction angle $\delta_{r.k}$ = **17.5** deg

Base soil properties

Soil type Medium dense well graded sand

Soil density γ_b = **18** kN/m^3

Characteristic cohesion $c'_{b.k}$ = **0** kN/m^2

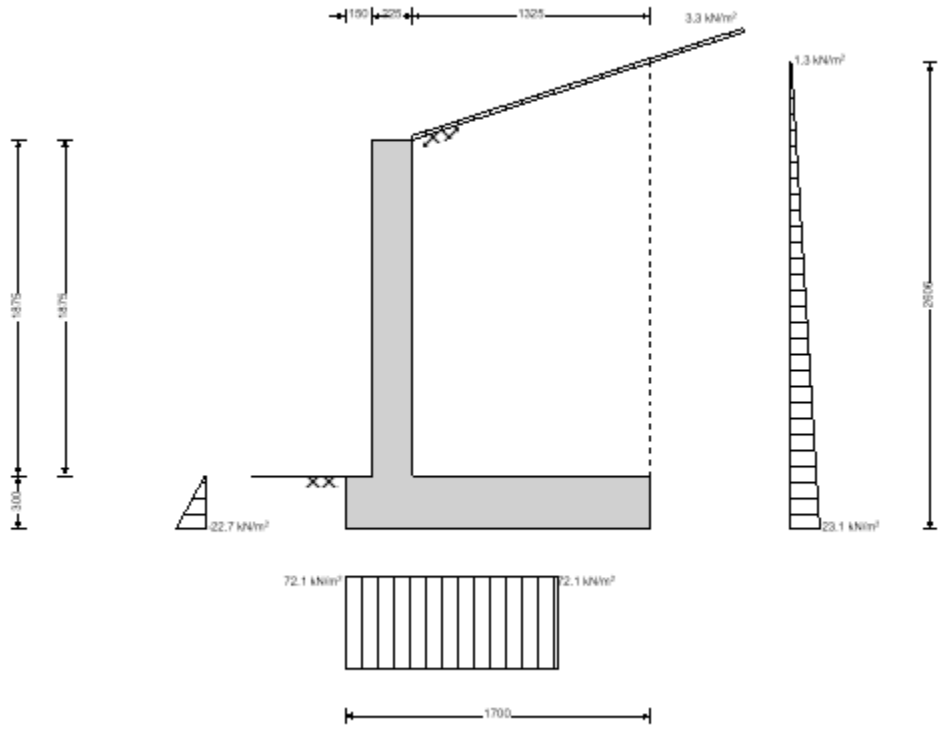
Characteristic effective shear resistance angle $\phi'_{b.k}$ = **35** deg

Characteristic wall friction angle $\delta_{b.k}$ = **15** deg

Characteristic base friction angle $\delta_{bb.k}$ = **30** deg

Loading details

Variable surcharge load — $Surcharge_Q$ = **2.5** kN/m²



General arrangement - sketch pressures relate to bearing check

Calculate retaining wall geometry

Base length	$l_{base} = l_{toe} + t_{stem} + l_{heel}$ = **1700** mm
Moist soil height	$h_{moist} = h_{soil}$ = **1875** mm
Length of surcharge load	$l_{sur} = l_{heel}$ = **1325** mm
- Distance to vertical component	$x_{sur_v} = l_{base} - l_{heel} / 2$ = **1038** mm
Effective height of wall	$h_{eff} = h_{base} + d_{cover} + h_{ret} + l_{sur} \times \tan(\beta)$ = **2606** mm
- Distance to horizontal component	$x_{sur_h} = h_{eff} / 2$ = **1303** mm
Area of wall stem	$A_{stem} = h_{stem} \times t_{stem}$ = **0.422** m²
- Distance to vertical component	$x_{stem} = l_{toe} + t_{stem} / 2$ = **263** mm
Area of wall base	$A_{base} = l_{base} \times t_{base}$ = **0.51** m²
- Distance to vertical component	$x_{base} = l_{base} / 2$ = **850** mm
Area of moist soil	$A_{moist} = h_{moist} \times l_{heel} + \tan(\beta) \times l_{heel}^2 / 2$ = **2.77** m²
- Distance to vertical component	$x_{moist_v} = l_{base} - (h_{moist} \times l_{heel}^2 / 2 + \tan(\beta) \times l_{heel}^3 / 6) / A_{moist}$ = **1060** mm
- Distance to horizontal component	$x_{moist_h} = h_{eff} / 3$ = **869** mm

Design approach 1

Partial factors on actions - Table A.3 - Combination 1

Partial factor set	A1
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 – Table A.4 - Combination 1

Soil parameter set	M1
Angle of shearing resistance	$\gamma_{\phi'}$ = **1.00**
Effective cohesion	$\gamma_{c'}$ = **1.00**
Weight density	γ_γ = **1.00**

Retained soil properties

Design moist density	$\gamma_{mr}' = \gamma_{mr} / \gamma_\gamma$ = **21** kN/m^3
Design saturated density	$\gamma_{sr}' = \gamma_{sr} / \gamma_\gamma$ = **23** kN/m^3
Design effective shear resistance angle	$\phi'_{r.d} = \text{atan}(\tan(\phi'_{r.k}) / \gamma_{\phi'})$ = **35** deg
Design wall friction angle	$\delta_{r.d} = \text{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'})$ = **17.5** deg

Base soil properties

Design soil density	$\gamma_b' = \gamma_b / \gamma_\gamma$ = **18** kN/m^3
Design effective shear resistance angle	$\phi'_{b.d} = \text{atan}(\tan(\phi'_{b.k}) / \gamma_{\phi'})$ = **35** deg
Design wall friction angle	$\delta_{b.d} = \text{atan}(\tan(\delta_{b.k}) / \gamma_{\phi'})$ = **15** deg
Design base friction angle	$\delta_{bb.d} = \text{atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'})$ = **30** deg
Design effective cohesion	$c'_{b.d} = c'_{b.k} / \gamma_{c'}$ = **0** kN/m^2

Using Coulomb theory

Active pressure coefficient	$K_A = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times [1 + \sqrt{[\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))]]^2})$ = **0.310**
Passive pressure coefficient	$K_P = \sin(90 - \phi'_{b.d})^2 / (\sin(90 + \delta_{b.d}) \times [1 - \sqrt{[\sin(\phi'_{b.d} + \delta_{b.d}) \times \sin(\phi'_{b.d}) / (\sin(90 + \delta_{b.d}))]]^2})$ = **6.555**

Sliding check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem}$ = **10.5** kN/m
Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base}$ = **12.8** kN/m
Moist retained soil	$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}'$ = **58.2** kN/m
Total	$F_{total_v} = F_{stem} + F_{base} + F_{moist_v}$ = **81.5** kN/m

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff}$ = **2.9** kN/m
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times h_{eff}^2 / 2$ = **28.5** kN/m
Total	$F_{total_h} = F_{sur_h} + F_{moist_h}$ = **31.4** kN/m

Check stability against sliding

Base soil resistance	$F_{exc_h} = \gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2$ = **5.1** kN/m
Base friction	$F_{friction} = F_{total_v} \times \tan(\delta_{bb.d})$ = **47** kN/m
Resistance to sliding	$F_{rest} = F_{exc_h} + F_{friction}$ = **52.2** kN/m
Factor of safety	$FoS_{sl} = F_{rest} / F_{total_h}$ = **1.662**

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem}$ = **10.5** kN/m

Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} =$ **12.8** kN/m
Moist retained soil	$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' =$ **58.2** kN/m
Total	$F_{total_v} = F_{stem} + F_{base} + F_{moist_v} =$ **81.5** kN/m

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} =$ **2.9** kN/m
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 =$ **28.5** kN/m
Base soil	$F_{exc_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 =$ **-5.1** kN/m
Total	$F_{total_h} = F_{sur_h} + F_{moist_h} + F_{exc_h} =$ **26.2** kN/m

Overturning moments on wall

Surcharge load	$M_{sur_OT} = F_{sur_h} \times x_{sur_h} =$ **3.8** kNm/m
Moist retained soil	$M_{moist_OT} = F_{moist_h} \times x_{moist_h} =$ **24.7** kNm/m
Total	$M_{total_OT} = M_{sur_OT} + M_{moist_OT} =$ **28.5** kNm/m

Restoring moments on wall

Wall stem	$M_{stem_R} = F_{stem} \times x_{stem} =$ **2.8** kNm/m
Wall base	$M_{base_R} = F_{base} \times x_{base} =$ **10.8** kNm/m
Moist retained soil	$M_{moist_R} = F_{moist_v} \times x_{moist_v} =$ **61.7** kNm/m
Base soil	$M_{exc_R} = -F_{exc_h} \times x_{exc_h} =$ **0.5** kNm/m
Total	$M_{total_R} = M_{stem_R} + M_{base_R} + M_{moist_R} + M_{exc_R} =$ **75.8** kNm/m

Check stability against overturning

Factor of safety $FoS_{ot} = M_{total_R} / M_{total_OT} =$ **2.659**

PASS - Maximum restoring moment is greater than overturning moment

Bearing pressure check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem} =$ **14.2** kN/m
Wall base	$F_{base} = \gamma_G \times A_{base} \times \gamma_{base} =$ **17.2** kN/m
Surcharge load	$F_{sur_v} = \gamma_Q \times \text{Surcharge}_Q \times l_{heel} =$ **5** kN/m
Moist retained soil	$F_{moist_v} = \gamma_G \times A_{moist} \times \gamma_{mr}' =$ **78.5** kN/m
Total	$F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{moist_v} =$ **114.9** kN/m

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} =$ **2.9** kN/m
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 =$ **28.5** kN/m
Base soil	$F_{pass_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2 =$ **-5.1** kN/m
Total	$F_{total_h} = \max(F_{sur_h} + F_{moist_h} + F_{pass_h} - F_{total_v} \times \tan(\delta_{bb.d}), 0 \text{ kN/m}) =$ **0** kN/m

Moments on wall

Wall stem	$M_{stem} = F_{stem} \times x_{stem} =$ **3.7** kNm/m
Wall base	$M_{base} = F_{base} \times x_{base} =$ **14.6** kNm/m
Surcharge load	$M_{sur} = F_{sur_v} \times x_{sur_v} - F_{sur_h} \times x_{sur_h} =$ **1.4** kNm/m
Moist retained soil	$M_{moist} = F_{moist_v} \times x_{moist_v} - F_{moist_h} \times x_{moist_h} =$ **58.5** kNm/m
Base soil	$M_{pass} = -F_{pass_h} \times x_{pass_h} =$ **0.5** kNm/m
Total	$M_{total} = M_{stem} + M_{base} + M_{sur} + M_{moist} + M_{pass} =$ **78.8** kNm/m

Check bearing pressure

Distance to reaction $\bar{x} = M_{total} / F_{total_v} =$ **685** mm

Eccentricity of reaction	$e = \bar{x} - l_{base} / 2 =$ **-165** mm
Loaded length of base	$l_{load} = 2 \times \bar{x} =$ **1371** mm
Bearing pressure at toe	$q_{toe} = F_{total_v} / l_{load} =$ **83.8** kN/m²
Bearing pressure at heel	$q_{heel} =$ **0** kN/m²
Effective overburden pressure	$q = (t_{base} + d_{cover}) \times \gamma_b' =$ **5.4** kN/m²
Design effective overburden pressure	$q' = q / \gamma_\gamma =$ **5.4** kN/m²
Bearing resistance factors	$N_q = Exp(\pi \times \tan(\phi'_{b.d})) \times (\tan(45 \text{ deg} + \phi'_{b.d} / 2))^2 =$ **33.296**
	$N_c = (N_q - 1) \times \cot(\phi'_{b.d}) =$ **46.124**
	$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b.d}) =$ **45.228**
Foundation shape factors	$s_q = 1$
	$s_\gamma = 1$
	$s_c = 1$
Load inclination factors	$H = F_{sur_h} + F_{moist_h} + F_{pass_h} =$ **26.2** kN/m
	$V = F_{total_v} =$ **114.9** kN/m
	$m = 2$
	$i_q = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^m =$ **0.595**
	$i_\gamma = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^{(m+1)} =$ **0.459**
	$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b.d})) =$ **0.583**
Net ultimate bearing capacity	
	$n_f = c'_{b.d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_b' \times l_{load} \times N_\gamma \times s_\gamma \times i_\gamma =$ **363.5** kN/m²
Factor of safety	$FoS_{bp} = n_f / \max(q_{toe}, q_{heel}) =$ **4.335**
	PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

Design approach 1

Partial factors on actions - Table A.3 - Combination 2

Partial factor set	A2
Permanent unfavourable action	$\gamma_G =$ **1.000**
Permanent favourable action	$\gamma_{Gf} =$ **1.000**
Variable unfavourable action	$\gamma_Q =$ **1.300**
Variable favourable action	$\gamma_{Qf} =$ **0.000**

Partial factors for soil parameters – Table A.4 - Combination 2

Soil parameter set	M2
Angle of shearing resistance	$\gamma_{\phi'} =$ **1.25**
Effective cohesion	$\gamma_{c'} =$ **1.25**
Weight density	$\gamma_\gamma =$ **1.00**

Retained soil properties

Design moist density	$\gamma_{mr}' = \gamma_{mr} / \gamma_\gamma =$ **21** kN/m³
Design saturated density	$\gamma_{sr}' = \gamma_{sr} / \gamma_\gamma =$ **23** kN/m³
Design effective shear resistance angle	$\phi'_{r.d} = \text{atan}(\tan(\phi'_{r.k}) / \gamma_{\phi'}) =$ **29.3** deg
Design wall friction angle	$\delta_{r.d} = \text{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'}) =$ **14.2** deg

Base soil properties

Design soil density	$\gamma_b' = \gamma_b / \gamma_\gamma =$ **18** kN/m³
Design effective shear resistance angle	$\phi'_{b.d} = \text{atan}(\tan(\phi'_{b.k}) / \gamma_{\phi'}) =$ **29.3** deg
Design wall friction angle	$\delta_{b.d} = \text{atan}(\tan(\delta_{b.k}) / \gamma_{\phi'}) =$ **12.1** deg
Design base friction angle	$\delta_{bb.d} = \text{atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'}) =$ **24.8** deg

Design effective cohesion $c'_{b.d} = c'_{b.k} / \gamma_{c'} = \mathbf{0}$ kN/m²

Using Coulomb theory

Active pressure coefficient $K_A = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times [1 + \sqrt{[\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))]]^2}) = \mathbf{0.411}$

Passive pressure coefficient $K_P = \sin(90 - \phi'_{b.d})^2 / (\sin(90 + \delta_{b.d}) \times [1 - \sqrt{[\sin(\phi'_{b.d} + \delta_{b.d}) \times \sin(\phi'_{b.d}) / (\sin(90 + \delta_{b.d}))]]^2}) = \mathbf{4.303}$

Sliding check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = \mathbf{10.5}$ kN/m
Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = \mathbf{12.8}$ kN/m
Moist retained soil	$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' = \mathbf{58.2}$ kN/m
Total	$F_{total_v} = F_{stem} + F_{base} + F_{moist_v} = \mathbf{81.5}$ kN/m

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} = \mathbf{3.4}$ kN/m
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 = \mathbf{28.4}$ kN/m
Total	$F_{total_h} = F_{sur_h} + F_{moist_h} = \mathbf{31.8}$ kN/m

Check stability against sliding

Base soil resistance	$F_{exc_h} = \gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = \mathbf{3.4}$ kN/m
Base friction	$F_{friction} = F_{total_v} \times \tan(\delta_{bb.d}) = \mathbf{37.6}$ kN/m
Resistance to sliding	$F_{rest} = F_{exc_h} + F_{friction} = \mathbf{41}$ kN/m
Factor of safety	$FoS_{sl} = F_{rest} / F_{total_h} = \mathbf{1.29}$

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = \mathbf{10.5}$ kN/m
Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = \mathbf{12.8}$ kN/m
Moist retained soil	$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' = \mathbf{58.2}$ kN/m
Total	$F_{total_v} = F_{stem} + F_{base} + F_{moist_v} = \mathbf{81.5}$ kN/m

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} = \mathbf{3.4}$ kN/m
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 = \mathbf{28.4}$ kN/m
Base soil	$F_{exc_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = \mathbf{-3.4}$ kN/m
Total	$F_{total_h} = F_{sur_h} + F_{moist_h} + F_{exc_h} = \mathbf{28.4}$ kN/m

Overturning moments on wall

Surcharge load	$M_{sur_OT} = F_{sur_h} \times x_{sur_h} = \mathbf{4.4}$ kNm/m
Moist retained soil	$M_{moist_OT} = F_{moist_h} \times x_{moist_h} = \mathbf{24.7}$ kNm/m
Total	$M_{total_OT} = M_{sur_OT} + M_{moist_OT} = \mathbf{29.1}$ kNm/m

Restoring moments on wall

Wall stem	$M_{stem_R} = F_{stem} \times x_{stem} = \mathbf{2.8}$ kNm/m
Wall base	$M_{base_R} = F_{base} \times x_{base} = \mathbf{10.8}$ kNm/m
Moist retained soil	$M_{moist_R} = F_{moist_v} \times x_{moist_v} = \mathbf{61.7}$ kNm/m
Base soil	$M_{exc_R} = -F_{exc_h} \times x_{exc_h} = \mathbf{0.3}$ kNm/m
Total	$M_{total_R} = M_{stem_R} + M_{base_R} + M_{moist_R} + M_{exc_R} = \mathbf{75.6}$ kNm/m

Check stability against overturning

Factor of safety $FoS_{ot} = M_{total_R} / M_{total_OT} = \mathbf{2.599}$

PASS - Maximum restoring moment is greater than overturning moment

Bearing pressure check

Vertical forces on wall

Wall stem $F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem} = \mathbf{10.5}$ kN/m

Wall base $F_{base} = \gamma_G \times A_{base} \times \gamma_{base} = \mathbf{12.8}$ kN/m

Surcharge load $F_{sur_v} = \gamma_Q \times Surcharge_Q \times l_{heel} = \mathbf{4.3}$ kN/m

Moist retained soil $F_{moist_v} = \gamma_G \times A_{moist} \times \gamma_{mr}' = \mathbf{58.2}$ kN/m

Total $F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{moist_v} = \mathbf{85.8}$ kN/m

Horizontal forces on wall

Surcharge load $F_{sur_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times Surcharge_Q \times h_{eff} = \mathbf{3.4}$ kN/m

Moist retained soil $F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 = \mathbf{28.4}$ kN/m

Base soil $F_{pass_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2 = \mathbf{-3.4}$ kN/m

Total $F_{total_h} = \max(F_{sur_h} + F_{moist_h} + F_{pass_h} - F_{total_v} \times \tan(\delta_{bb.d}), 0\ kN/m) = \mathbf{0}$ kN/m

Moments on wall

Wall stem $M_{stem} = F_{stem} \times x_{stem} = \mathbf{2.8}$ kNm/m

Wall base $M_{base} = F_{base} \times x_{base} = \mathbf{10.8}$ kNm/m

Surcharge load $M_{sur} = F_{sur_v} \times x_{sur_v} - F_{sur_h} \times x_{sur_h} = \mathbf{0.1}$ kNm/m

Moist retained soil $M_{moist} = F_{moist_v} \times x_{moist_v} - F_{moist_h} \times x_{moist_h} = \mathbf{37}$ kNm/m

Base soil $M_{pass} = -F_{pass_h} \times x_{pass_h} = \mathbf{0.3}$ kNm/m

Total $M_{total} = M_{stem} + M_{base} + M_{sur} + M_{moist} + M_{pass} = \mathbf{51}$ kNm/m

Check bearing pressure

Distance to reaction $\bar{x} = M_{total} / F_{total_v} = \mathbf{594}$ mm

Eccentricity of reaction $e = \bar{x} - l_{base} / 2 = \mathbf{-256}$ mm

Loaded length of base $l_{load} = 2 \times \bar{x} = \mathbf{1189}$ mm

Bearing pressure at toe $q_{toe} = F_{total_v} / l_{load} = \mathbf{72.1}$ kN/m^2

Bearing pressure at heel $q_{heel} = \mathbf{0}$ kN/m^2

Effective overburden pressure $q = (t_{base} + d_{cover}) \times \gamma_b' = \mathbf{5.4}$ kN/m^2

Design effective overburden pressure $q' = q / \gamma_\gamma = \mathbf{5.4}$ kN/m^2

Bearing resistance factors $N_q = Exp(\pi \times \tan(\phi'_{b.d})) \times (\tan(45\ deg + \phi'_{b.d} / 2))^2 = \mathbf{16.921}$

$N_c = (N_q - 1) \times \cot(\phi'_{b.d}) = \mathbf{28.422}$

$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b.d}) = \mathbf{17.837}$

Foundation shape factors $s_q = 1$

$s_\gamma = 1$

$s_c = 1$

Load inclination factors $H = F_{sur_h} + F_{moist_h} + F_{pass_h} = \mathbf{28.4}$ kN/m

$V = F_{total_v} = \mathbf{85.8}$ kN/m

$m = 2$

$i_q = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^m = \mathbf{0.447}$

$i_\gamma = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^{(m+1)} = \mathbf{0.299}$

$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b.d})) = \mathbf{0.413}$

Net ultimate bearing capacity

$n_f = c'_{b.d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_b' \times l_{load} \times N_\gamma \times s_\gamma \times i_\gamma =$ **98** kN/m²

Factor of safety $FoS_{bp} = n_f / \max(q_{toe}, q_{heel}) =$ **1.358**

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

RETAINING WALL DESIGN

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

Tedds calculation version 2.9.22

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

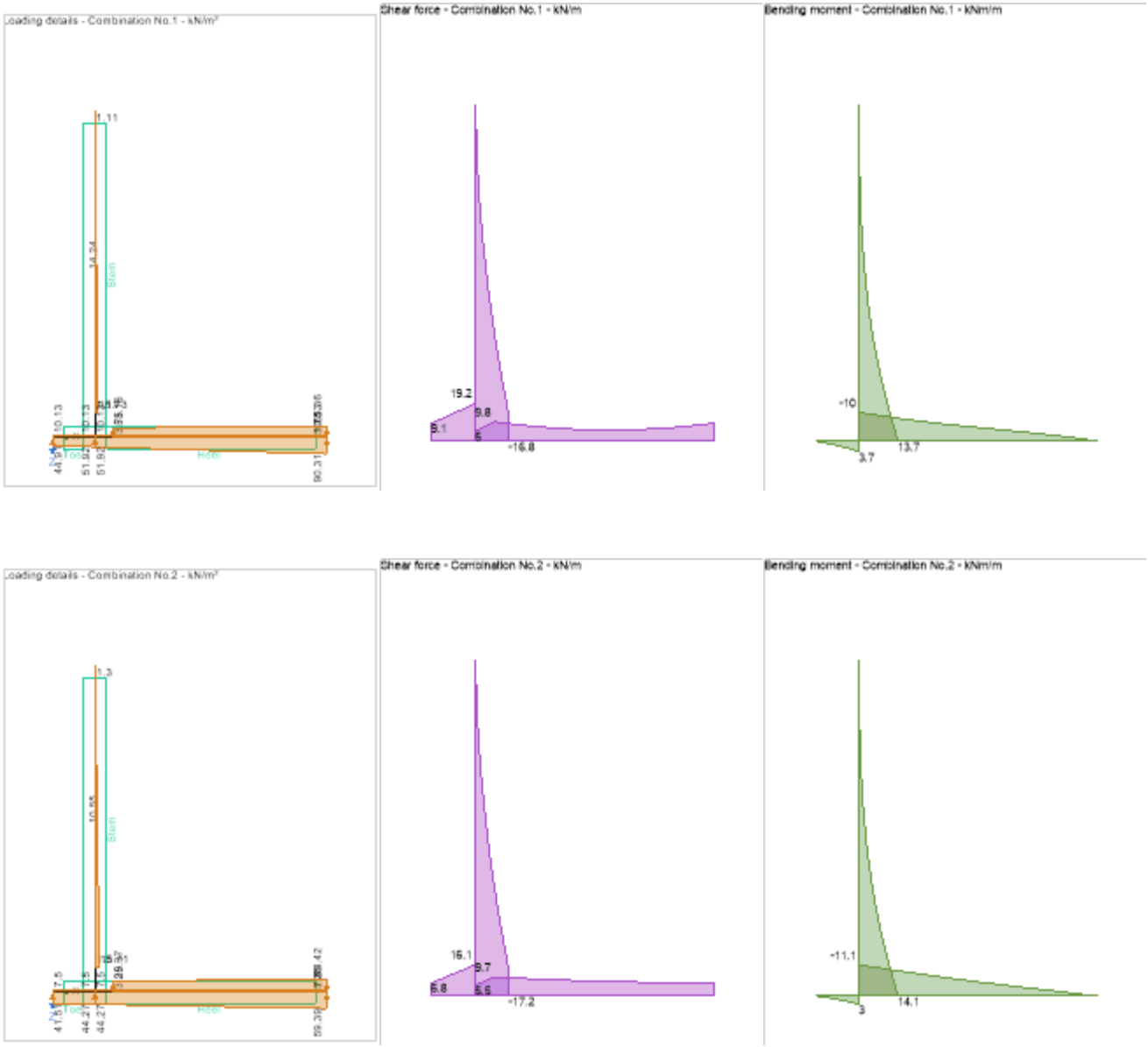
Concrete strength class	C30/37
Characteristic compressive cylinder strength	f_{ck} = **30** N/mm²
Characteristic compressive cube strength	$f_{ck,cube}$ = **37** N/mm²
Mean value of compressive cylinder strength	$f_{cm} = f_{ck}$ + 8 N/mm² = **38** N/mm²
Mean value of axial tensile strength	f_{ctm} = 0.3 N/mm² × (f_{ck} / 1 N/mm²)$^{2/3}$ = **2.9** N/mm²
5% fractile of axial tensile strength	$f_{ctk,0.05} = 0.7 \times f_{ctm}$ = **2.0** N/mm²
Secant modulus of elasticity of concrete	E_{cm} = 22 kN/mm² × (f_{cm} / 10 N/mm²)$^{0.3}$ = **32837** N/mm²
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/mm²
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/mm²
Modulus of elasticity of reinforcement	E_s = **200000** N/mm²
Partial factor for reinforcing steel - Table 2.1N	γ_S = **1.15**
Design yield strength of reinforcement	$f_{yd} = f_{yk} / \gamma_S$ = **435** N/mm²

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 base of stem

Depth of section — h = **225** mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 2 — M = **11.5** kNm/m

Depth to tension reinforcement — d = h - c_{sr} - ϕ_{sr} / 2 = **170** mm

$K = M / (d^2 \times f_{ck})$ = **0.013**

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

K' = **0.207**

K' > K - No compression reinforcement is required

Lever arm — $z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_c))^{0.5}, 0.95) \times d$ = **161** mm

Depth of neutral axis — $x = 2.5 \times (d - z)$ = **21** mm

Area of tension reinforcement required — $A_{sr.req} = M / (f_{yd} \times z)$ = **164** mm^2/m

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

Area of tension reinforcement provided	$A_{sr.prov} = \pi \times \phi_{sr}^2 / (4 \times s_{sr}) =$ **393** mm²/m
Minimum area of reinforcement - exp.9.1N	$A_{sr.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d =$ **256** mm²/m
Maximum area of reinforcement - cl.9.2.1.1(3)	$A_{sr.max} = 0.04 \times h =$ **9000** mm²/m
	$\max(A_{sr.req}, A_{sr.min}) / A_{sr.prov} =$ **0.652**

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	$K_b =$ **0.4**
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	$\min(K_s \times K_b \times [11 + 1.5 \times \sqrt{(f_{ck} / 1\ N/mm^2)} \times \rho_0 / \rho + 3.2 \times \sqrt{(f_{ck} / 1\ N/mm^2)} \times (\rho_0 / \rho - 1)^{3/2}], 40 \times K_b) =$ **16**
Actual span to depth ratio	$h_{stem} / d =$ **11**

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	$\psi_2 =$ **0.6**
Serviceability bending moment	$M_{sls} =$ **7.6** kNm/m
Tensile stress in reinforcement	$\sigma_s = M_{sls} / (A_{sr.prov} \times z) =$ **120** N/mm²
Load duration	Long term
Load duration factor	$k_t =$ **0.4**
Effective area of concrete in tension	$A_{c.eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$
	$A_{c.eff} =$ **67917** mm²/m
Mean value of concrete tensile strength	$f_{ct.eff} = f_{ctm} =$ **2.9** N/mm²
Reinforcement ratio	$\rho_{p.eff} = A_{sr.prov} / A_{c.eff} =$ **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	$s_{r.max} = k_3 \times c_{sr} + k_1 \times k_2 \times k_4 \times \phi_{sr} / \rho_{p.eff} =$ **464** mm
Maximum crack width - exp.7.8	$w_k = s_{r.max} \times \max(\sigma_s - k_t \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_e \times \rho_{p.eff}), 0.6 \times \sigma_s) / E_s$
	$w_k =$ **0.167** mm
	$w_k / w_{max} =$ **0.557**

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force	$V =$ **17.2** kN/m
	$C_{Rd,c} = 0.18 / \gamma_C =$ **0.120**
	$k = \min(1 + \sqrt{(200\ mm / d)}, 2) =$ **2.000**
Longitudinal reinforcement ratio	$\rho_l = \min(A_{sr.prov} / d, 0.02) =$ **0.002**
	$v_{min} = 0.035\ N^{1/2}/mm \times k^{3/2} \times f_{ck}^{0.5} =$ **0.542** N/mm²
Design shear resistance - exp.6.2a & 6.2b	$V_{Rd.c} = \max(C_{Rd.c} \times k \times (100\ N^2/mm^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$
	$V_{Rd.c} =$ **92.2** kN/m
	$V / V_{Rd.c} =$ **0.186**

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)	$A_{sx.req} = \max(0.25 \times A_{sr.prov}, 0.001 \times t_{stem}) =$ **225** 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 = **300** mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 1	M = **1.8** kNm/m
Depth to tension reinforcement	$d = h - c_{bb} - \phi_{bb} / 2 =$ **219** mm
	$K = M / (d^2 \times f_{ck}) =$ **0.001**
	$K' = (2 \times \eta \times \alpha_{cc}/\gamma_C) \times (1 - \lambda \times (\delta - K_1)/(2 \times K_2)) \times (\lambda \times (\delta - K_1)/(2 \times K_2))$
	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	$A_{bb.req} = M / (f_{yd} \times z) =$ **20** 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	$\psi_2 =$ **0.6**
Serviceability bending moment	$M_{sls} =$ **1.3** kNm/m
Tensile stress in reinforcement	$\sigma_s = M_{sls} / (A_{bb.prov} \times z) =$ **11** 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	$w_k = s_{r.max} \times \max(\sigma_s - k_t \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_e \times \rho_{p.eff}), 0.6 \times \sigma_s) / E_s$
	$w_k =$ **0.019** mm
	$w_k / w_{max} =$ **0.064**

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force

$V = \mathbf{14.7}$ kN/m

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

$k = \min(1 + \sqrt{(200\ mm / d)}, 2) = \mathbf{1.956}$

Longitudinal reinforcement ratio

$\rho_l = \min(A_{bb.prov} / d, 0.02) = \mathbf{0.003}$

$v_{min} = 0.035\ N^{1/2}/mm \times k^{3/2} \times f_{ck}^{0.5} = \mathbf{0.524}$ N/mm²

Design shear resistance - exp.6.2a & 6.2b

$V_{Rd.c} = \max(C_{Rd.c} \times k \times (100\ N^2/mm^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$

$V_{Rd.c} = \mathbf{114.8}$ kN/m

$V / V_{Rd.c} = \mathbf{0.128}$

PASS - Design shear resistance exceeds design shear force

Check base design at heel

Depth of section

$h = \mathbf{300}$ mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 2

$M = \mathbf{10.2}$ kNm/m

Depth to tension reinforcement

$d = h - c_{bt} - \phi_{bt} / 2 = \mathbf{244}$ mm

$K = M / (d^2 \times f_{ck}) = \mathbf{0.006}$

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

$K' = \mathbf{0.207}$

K' > K - No compression reinforcement is required

Lever arm

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

Depth of neutral axis

$x = 2.5 \times (d - z) = \mathbf{31}$ mm

Area of tension reinforcement required

$A_{bt.req} = M / (f_{yd} \times z) = \mathbf{101}$ mm²/m

Tension reinforcement provided

12 dia.bars @ 200 c/c

Area of tension reinforcement provided

$A_{bt.prov} = \pi \times \phi_{bt}^2 / (4 \times s_{bt}) = \mathbf{565}$ mm²/m

Minimum area of reinforcement - exp.9.1N

$A_{bt.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = \mathbf{368}$ mm²/m

Maximum area of reinforcement - cl.9.2.1.1(3)

$A_{bt.max} = 0.04 \times h = \mathbf{12000}$ mm²/m

$\max(A_{bt.req}, A_{bt.min}) / A_{bt.prov} = \mathbf{0.65}$

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

$w_{max} = \mathbf{0.3}$ mm

Variable load factor - EN1990 – Table A1.1

$\psi_2 = \mathbf{0.6}$

Serviceability bending moment

$M_{sls} = \mathbf{6.2}$ kNm/m

Tensile stress in reinforcement

$\sigma_s = M_{sls} / (A_{bt.prov} \times z) = \mathbf{47}$ N/mm²

Load duration

Long term

Load duration factor

$k_t = \mathbf{0.4}$

Effective area of concrete in tension

$A_{c.eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$

$A_{c.eff} = \mathbf{89833}$ mm²/m

Mean value of concrete tensile strength

$f_{ct.eff} = f_{ctm} = \mathbf{2.9}$ N/mm²

Reinforcement ratio

$\rho_{p.eff} = A_{bt.prov} / A_{c.eff} = \mathbf{0.006}$

Modular ratio

$\alpha_e = E_s / E_{cm} = \mathbf{6.091}$

Bond property coefficient

$k_1 = \mathbf{0.8}$

Strain distribution coefficient

$k_2 = \mathbf{0.5}$

$k_3 = \mathbf{3.4}$

$k_4 = \mathbf{0.425}$

Maximum crack spacing - exp.7.11 $s_{r.max} = k_3 \times c_{bt} + k_1 \times k_2 \times k_4 \times \phi_{bt} / \rho_{p.eff}$ = **494** 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 = **0.07** mm

w_k / w_{max} = **0.232**

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force V = **9.8** kN/m

$C_{Rd,c} = 0.18 / \gamma_C$ = **0.120**

$k = \min(1 + \sqrt{}(200 \text{ mm} / d), 2)$ = **1.905**

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

$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5}$ = **0.504** N/mm²

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

$V_{Rd.c}$ = **123** kN/m

$V / V_{Rd.c}$ = **0.080**

PASS - Design shear resistance exceeds design shear force

Secondary transverse reinforcement to base - Section 9.3

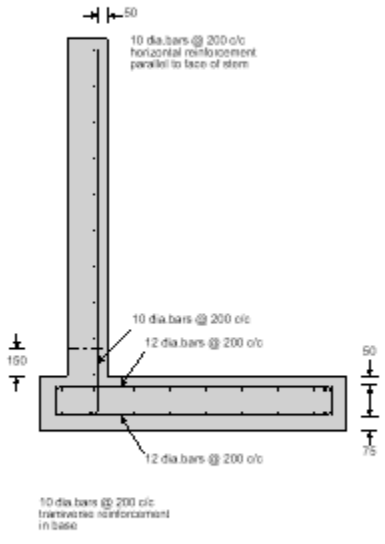
Minimum area of reinforcement – cl.9.3.1.1(2) $A_{bx.req} = 0.2 \times A_{bb.prov}$ = **113** mm²/m

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

RETAINING WALL ANALYSIS

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

Tedds calculation version 2.9.22

Analysis summary

Design summary

Overall design utilisation 0.774

Overall design status Pass

Description	Unit	Capacity	Applied	F o S	Result
Sliding stability	kN/m	32.9	25.5	1.292	PASS
Overturning stability	kNm/m	52.6	20.8	2.529	PASS
Bearing pressure	kN/m^2	92.6	64.6	1.433	PASS

Design summary

Description	Unit	Provided	Required	Utilisation	Result
Shear resistance	kN/m	114.8	11.6	0.101	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	11.6	0.101	PASS
Min. transverse stem reinf.	mm^2/m	392.7	225.0	0.573	PASS
Min. transverse base reinf.	mm^2/m	392.7	113.1	0.288	PASS

Retaining wall details

Stem type Cantilever

Stem height h_{stem} = **1650** mm

Stem thickness t_{stem} = **225** mm

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

Stem density γ_{stem} = **25** kN/m^3

Toe length l_{toe} = **150** mm

Heel length l_{heel} = **1125** mm

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

Base density γ_{base} = **25** kN/m^3

Height of retained soil h_{ret} = **1650** mm

Angle of soil surface β = **18** deg

Depth of cover d_{cover} = **0** mm

Retained soil properties

Soil type Medium dense well graded sand

Moist density γ_{mr} = **21** kN/m^3

Saturated density γ_{sr} = **23** kN/m^3

Characteristic effective shear resistance angle $\phi'_{r.k}$ = **35** deg

Characteristic wall friction angle $\delta_{r.k}$ = **17.5** deg

Base soil properties

Soil type Medium dense well graded sand

Soil density γ_b = **18** kN/m^3

Characteristic cohesion $c'_{b.k}$ = **0** kN/m^2

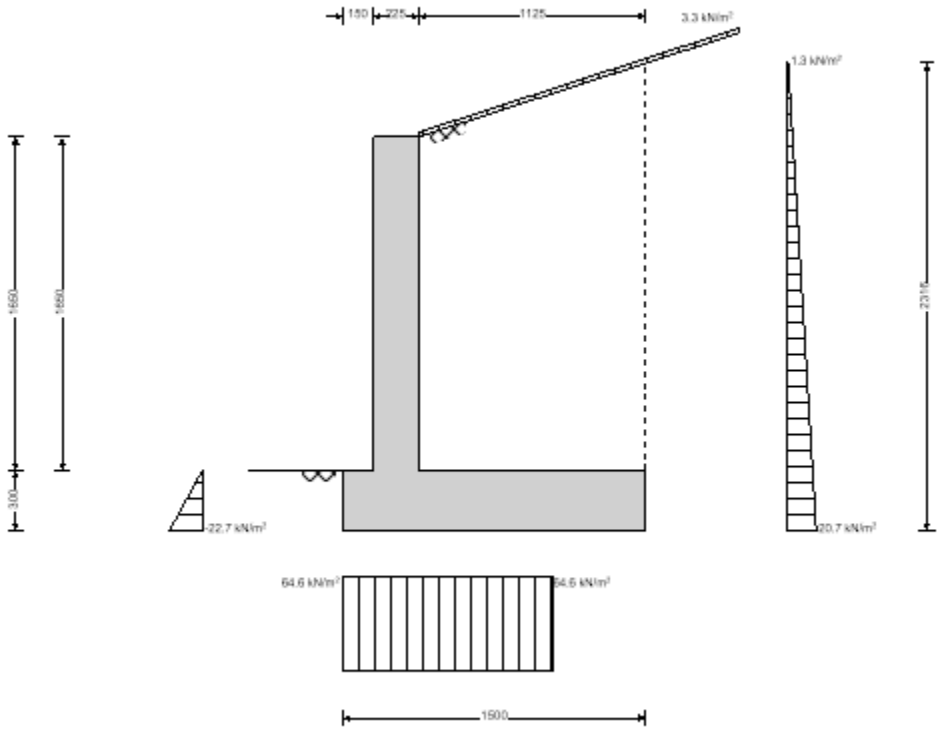
Characteristic effective shear resistance angle $\phi'_{b.k}$ = **35** deg

Characteristic wall friction angle $\delta_{b.k}$ = **15** deg

Characteristic base friction angle $\delta_{bb.k}$ = **30** deg

Loading details

Variable surcharge load — $Surcharge_Q$ = **2.5** kN/m²



General arrangement - sketch pressures relate to bearing check

Calculate retaining wall geometry

Base length	$l_{base} = l_{toe} + t_{stem} + l_{heel}$ = **1500** mm
Moist soil height	$h_{moist} = h_{soil}$ = **1650** mm
Length of surcharge load	$l_{sur} = l_{heel}$ = **1125** mm
- Distance to vertical component	$x_{sur_v} = l_{base} - l_{heel} / 2$ = **938** mm
Effective height of wall	$h_{eff} = h_{base} + d_{cover} + h_{ret} + l_{sur} \times \tan(\beta)$ = **2316** mm
- Distance to horizontal component	$x_{sur_h} = h_{eff} / 2$ = **1158** mm
Area of wall stem	$A_{stem} = h_{stem} \times t_{stem}$ = **0.371** m²
- Distance to vertical component	$x_{stem} = l_{toe} + t_{stem} / 2$ = **263** mm
Area of wall base	$A_{base} = l_{base} \times t_{base}$ = **0.45** m²
- Distance to vertical component	$x_{base} = l_{base} / 2$ = **750** mm
Area of moist soil	$A_{moist} = h_{moist} \times l_{heel} + \tan(\beta) \times l_{heel}^2 / 2$ = **2.062** m²
- Distance to vertical component	$x_{moist_v} = l_{base} - (h_{moist} \times l_{heel}^2 / 2 + \tan(\beta) \times l_{heel}^3 / 6) / A_{moist}$ = **956** mm
- Distance to horizontal component	$x_{moist_h} = h_{eff} / 3$ = **772** mm

Design approach 1

Partial factors on actions - Table A.3 - Combination 1

Partial factor set	A1
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 – Table A.4 - Combination 1

Soil parameter set	M1
Angle of shearing resistance	$\gamma_{\phi'}$ = **1.00**
Effective cohesion	$\gamma_{c'}$ = **1.00**
Weight density	γ_γ = **1.00**

Retained soil properties

Design moist density	$\gamma_{mr}' = \gamma_{mr} / \gamma_\gamma$ = **21** kN/m^3
Design saturated density	$\gamma_{sr}' = \gamma_{sr} / \gamma_\gamma$ = **23** kN/m^3
Design effective shear resistance angle	$\phi'_{r.d} = \text{atan}(\tan(\phi'_{r.k}) / \gamma_{\phi'})$ = **35** deg
Design wall friction angle	$\delta_{r.d} = \text{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'})$ = **17.5** deg

Base soil properties

Design soil density	$\gamma_b' = \gamma_b / \gamma_\gamma$ = **18** kN/m^3
Design effective shear resistance angle	$\phi'_{b.d} = \text{atan}(\tan(\phi'_{b.k}) / \gamma_{\phi'})$ = **35** deg
Design wall friction angle	$\delta_{b.d} = \text{atan}(\tan(\delta_{b.k}) / \gamma_{\phi'})$ = **15** deg
Design base friction angle	$\delta_{bb.d} = \text{atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'})$ = **30** deg
Design effective cohesion	$c'_{b.d} = c'_{b.k} / \gamma_{c'}$ = **0** kN/m^2

Using Coulomb theory

Active pressure coefficient	$K_A = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times [1 + \sqrt{[\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))]]^2})$ = **0.310**
Passive pressure coefficient	$K_P = \sin(90 - \phi'_{b.d})^2 / (\sin(90 + \delta_{b.d}) \times [1 - \sqrt{[\sin(\phi'_{b.d} + \delta_{b.d}) \times \sin(\phi'_{b.d}) / (\sin(90 + \delta_{b.d}))]]^2})$ = **6.555**

Sliding check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem}$ = **9.3** kN/m
Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base}$ = **11.3** kN/m
Moist retained soil	$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}'$ = **43.3** kN/m
Total	$F_{total_v} = F_{stem} + F_{base} + F_{moist_v}$ = **63.8** kN/m

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff}$ = **2.6** kN/m
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times h_{eff}^2 / 2$ = **22.5** kN/m
Total	$F_{total_h} = F_{sur_h} + F_{moist_h}$ = **25.1** kN/m

Check stability against sliding

Base soil resistance	$F_{exc_h} = \gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2$ = **5.1** kN/m
Base friction	$F_{friction} = F_{total_v} \times \tan(\delta_{bb.d})$ = **36.9** kN/m
Resistance to sliding	$F_{rest} = F_{exc_h} + F_{friction}$ = **42** kN/m
Factor of safety	$FoS_{sl} = F_{rest} / F_{total_h}$ = **1.675**

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem}$ = **9.3** kN/m

Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} =$ **11.3** kN/m
Moist retained soil	$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' =$ **43.3** kN/m
Total	$F_{total_v} = F_{stem} + F_{base} + F_{moist_v} =$ **63.8** kN/m

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times Surcharge_Q \times h_{eff} =$ **2.6** kN/m
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 =$ **22.5** kN/m
Base soil	$F_{exc_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 =$ **-5.1** kN/m
Total	$F_{total_h} = F_{sur_h} + F_{moist_h} + F_{exc_h} =$ **19.9** kN/m

Overturning moments on wall

Surcharge load	$M_{sur_OT} = F_{sur_h} \times x_{sur_h} =$ **3** kNm/m
Moist retained soil	$M_{moist_OT} = F_{moist_h} \times x_{moist_h} =$ **17.4** kNm/m
Total	$M_{total_OT} = M_{sur_OT} + M_{moist_OT} =$ **20.3** kNm/m

Restoring moments on wall

Wall stem	$M_{stem_R} = F_{stem} \times x_{stem} =$ **2.4** kNm/m
Wall base	$M_{base_R} = F_{base} \times x_{base} =$ **8.4** kNm/m
Moist retained soil	$M_{moist_R} = F_{moist_v} \times x_{moist_v} =$ **41.4** kNm/m
Base soil	$M_{exc_R} = -F_{exc_h} \times x_{exc_h} =$ **0.5** kNm/m
Total	$M_{total_R} = M_{stem_R} + M_{base_R} + M_{moist_R} + M_{exc_R} =$ **52.8** kNm/m

Check stability against overturning

Factor of safety $FoS_{ot} = M_{total_R} / M_{total_OT} =$ **2.596**

PASS - Maximum restoring moment is greater than overturning moment

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	$F_{base} = \gamma_G \times A_{base} \times \gamma_{base} =$ **15.2** kN/m
Surcharge load	$F_{sur_v} = \gamma_Q \times Surcharge_Q \times l_{heel} =$ **4.2** kN/m
Moist retained soil	$F_{moist_v} = \gamma_G \times A_{moist} \times \gamma_{mr}' =$ **58.5** kN/m
Total	$F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{moist_v} =$ **90.4** kN/m

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times Surcharge_Q \times h_{eff} =$ **2.6** kN/m
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 =$ **22.5** kN/m
Base soil	$F_{pass_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2 =$ **-5.1** kN/m
Total	$F_{total_h} = \max(F_{sur_h} + F_{moist_h} + F_{pass_h} - F_{total_v} \times \tan(\delta_{bb.d}), 0\ kN/m) =$ **0** kN/m

Moments on wall

Wall stem	$M_{stem} = F_{stem} \times x_{stem} =$ **3.3** kNm/m
Wall base	$M_{base} = F_{base} \times x_{base} =$ **11.4** kNm/m
Surcharge load	$M_{sur} = F_{sur_v} \times x_{sur_v} - F_{sur_h} \times x_{sur_h} =$ **1** kNm/m
Moist retained soil	$M_{moist} = F_{moist_v} \times x_{moist_v} - F_{moist_h} \times x_{moist_h} =$ **38.5** kNm/m
Base soil	$M_{pass} = -F_{pass_h} \times x_{pass_h} =$ **0.5** kNm/m
Total	$M_{total} = M_{stem} + M_{base} + M_{sur} + M_{moist} + M_{pass} =$ **54.7** kNm/m

Check bearing pressure

Distance to reaction $\bar{x} = M_{total} / F_{total_v} =$ **605** mm

Eccentricity of reaction	$e = \bar{x} - l_{base} / 2 =$ **-145** mm
Loaded length of base	$l_{load} = 2 \times \bar{x} =$ **1210** mm
Bearing pressure at toe	$q_{toe} = F_{total_v} / l_{load} =$ **74.7** kN/m²
Bearing pressure at heel	$q_{heel} =$ **0** kN/m²
Effective overburden pressure	$q = (t_{base} + d_{cover}) \times \gamma_b' =$ **5.4** kN/m²
Design effective overburden pressure	$q' = q / \gamma_\gamma =$ **5.4** kN/m²
Bearing resistance factors	$N_q = Exp(\pi \times \tan(\phi'_{b.d})) \times (\tan(45 \text{ deg} + \phi'_{b.d} / 2))^2 =$ **33.296**
	$N_c = (N_q - 1) \times \cot(\phi'_{b.d}) =$ **46.124**
	$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b.d}) =$ **45.228**
Foundation shape factors	$s_q = 1$
	$s_\gamma = 1$
	$s_c = 1$
Load inclination factors	$H = F_{sur_h} + F_{moist_h} + F_{pass_h} =$ **19.9** kN/m
	$V = F_{total_v} =$ **90.4** kN/m
	$m = 2$
	$i_q = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^m =$ **0.608**
	$i_\gamma = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^{(m+1)} =$ **0.474**
	$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b.d})) =$ **0.595**
Net ultimate bearing capacity	
	$n_f = c'_{b.d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_b' \times l_{load} \times N_\gamma \times s_\gamma \times i_\gamma =$ **342.5** kN/m²
Factor of safety	$FoS_{bp} = n_f / \max(q_{toe}, q_{heel}) =$ **4.587**
	PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

Design approach 1

Partial factors on actions - Table A.3 - Combination 2

Partial factor set	A2
Permanent unfavourable action	$\gamma_G =$ **1.000**
Permanent favourable action	$\gamma_{Gf} =$ **1.000**
Variable unfavourable action	$\gamma_Q =$ **1.300**
Variable favourable action	$\gamma_{Qf} =$ **0.000**

Partial factors for soil parameters – Table A.4 - Combination 2

Soil parameter set	M2
Angle of shearing resistance	$\gamma_{\phi'} =$ **1.25**
Effective cohesion	$\gamma_{c'} =$ **1.25**
Weight density	$\gamma_\gamma =$ **1.00**

Retained soil properties

Design moist density	$\gamma_{mr}' = \gamma_{mr} / \gamma_\gamma =$ **21** kN/m³
Design saturated density	$\gamma_{sr}' = \gamma_{sr} / \gamma_\gamma =$ **23** kN/m³
Design effective shear resistance angle	$\phi'_{r.d} = \text{atan}(\tan(\phi'_{r.k}) / \gamma_{\phi'}) =$ **29.3** deg
Design wall friction angle	$\delta_{r.d} = \text{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'}) =$ **14.2** deg

Base soil properties

Design soil density	$\gamma_b' = \gamma_b / \gamma_\gamma =$ **18** kN/m³
Design effective shear resistance angle	$\phi'_{b.d} = \text{atan}(\tan(\phi'_{b.k}) / \gamma_{\phi'}) =$ **29.3** deg
Design wall friction angle	$\delta_{b.d} = \text{atan}(\tan(\delta_{b.k}) / \gamma_{\phi'}) =$ **12.1** deg
Design base friction angle	$\delta_{bb.d} = \text{atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'}) =$ **24.8** deg

Design effective cohesion $c'_{b.d} = c'_{b.k} / \gamma_{c'} = \mathbf{0}$ kN/m²

Using Coulomb theory

Active pressure coefficient $K_A = \sin(\alpha + \phi'_{r.d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.d}) \times [1 + \sqrt{[\sin(\phi'_{r.d} + \delta_{r.d}) \times \sin(\phi'_{r.d} - \beta) / (\sin(\alpha - \delta_{r.d}) \times \sin(\alpha + \beta))]]^2}) = \mathbf{0.411}$

Passive pressure coefficient $K_P = \sin(90 - \phi'_{b.d})^2 / (\sin(90 + \delta_{b.d}) \times [1 - \sqrt{[\sin(\phi'_{b.d} + \delta_{b.d}) \times \sin(\phi'_{b.d}) / (\sin(90 + \delta_{b.d}))]]^2}) = \mathbf{4.303}$

Sliding check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = \mathbf{9.3}$ kN/m
Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = \mathbf{11.3}$ kN/m
Moist retained soil	$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' = \mathbf{43.3}$ kN/m
Total	$F_{total_v} = F_{stem} + F_{base} + F_{moist_v} = \mathbf{63.8}$ kN/m

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} = \mathbf{3}$ kN/m
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 = \mathbf{22.5}$ kN/m
Total	$F_{total_h} = F_{sur_h} + F_{moist_h} = \mathbf{25.5}$ kN/m

Check stability against sliding

Base soil resistance	$F_{exc_h} = \gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = \mathbf{3.4}$ kN/m
Base friction	$F_{friction} = F_{total_v} \times \tan(\delta_{bb.d}) = \mathbf{29.5}$ kN/m
Resistance to sliding	$F_{rest} = F_{exc_h} + F_{friction} = \mathbf{32.9}$ kN/m
Factor of safety	$FoS_{sl} = F_{rest} / F_{total_h} = \mathbf{1.292}$

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = \mathbf{9.3}$ kN/m
Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = \mathbf{11.3}$ kN/m
Moist retained soil	$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' = \mathbf{43.3}$ kN/m
Total	$F_{total_v} = F_{stem} + F_{base} + F_{moist_v} = \mathbf{63.8}$ kN/m

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} = \mathbf{3}$ kN/m
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 = \mathbf{22.5}$ kN/m
Base soil	$F_{exc_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = \mathbf{-3.4}$ kN/m
Total	$F_{total_h} = F_{sur_h} + F_{moist_h} + F_{exc_h} = \mathbf{22}$ kN/m

Overturning moments on wall

Surcharge load	$M_{sur_OT} = F_{sur_h} \times x_{sur_h} = \mathbf{3.5}$ kNm/m
Moist retained soil	$M_{moist_OT} = F_{moist_h} \times x_{moist_h} = \mathbf{17.3}$ kNm/m
Total	$M_{total_OT} = M_{sur_OT} + M_{moist_OT} = \mathbf{20.8}$ kNm/m

Restoring moments on wall

Wall stem	$M_{stem_R} = F_{stem} \times x_{stem} = \mathbf{2.4}$ kNm/m
Wall base	$M_{base_R} = F_{base} \times x_{base} = \mathbf{8.4}$ kNm/m
Moist retained soil	$M_{moist_R} = F_{moist_v} \times x_{moist_v} = \mathbf{41.4}$ kNm/m
Base soil	$M_{exc_R} = -F_{exc_h} \times x_{exc_h} = \mathbf{0.3}$ kNm/m
Total	$M_{total_R} = M_{stem_R} + M_{base_R} + M_{moist_R} + M_{exc_R} = \mathbf{52.6}$ kNm/m

Check stability against overturning

Factor of safety $FoS_{ot} = M_{total_R} / M_{total_OT} = \mathbf{2.529}$

PASS - Maximum restoring moment is greater than overturning moment

Bearing pressure check

Vertical forces on wall

Wall stem $F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem} = \mathbf{9.3}$ kN/m

Wall base $F_{base} = \gamma_G \times A_{base} \times \gamma_{base} = \mathbf{11.3}$ kN/m

Surcharge load $F_{sur_v} = \gamma_Q \times Surcharge_Q \times l_{heel} = \mathbf{3.7}$ kN/m

Moist retained soil $F_{moist_v} = \gamma_G \times A_{moist} \times \gamma_{mr}' = \mathbf{43.3}$ kN/m

Total $F_{total_v} = F_{stem} + F_{base} + F_{sur_v} + F_{moist_v} = \mathbf{67.5}$ kN/m

Horizontal forces on wall

Surcharge load $F_{sur_h} = K_A \times \cos(\delta_{r.d}) \times \gamma_Q \times Surcharge_Q \times h_{eff} = \mathbf{3}$ kN/m

Moist retained soil $F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r.d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 = \mathbf{22.5}$ kN/m

Base soil $F_{pass_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b.d}) \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2 = \mathbf{-3.4}$ kN/m

Total $F_{total_h} = \max(F_{sur_h} + F_{moist_h} + F_{pass_h} - F_{total_v} \times \tan(\delta_{bb.d}), 0\ kN/m) = \mathbf{0}$ kN/m

Moments on wall

Wall stem $M_{stem} = F_{stem} \times x_{stem} = \mathbf{2.4}$ kNm/m

Wall base $M_{base} = F_{base} \times x_{base} = \mathbf{8.4}$ kNm/m

Surcharge load $M_{sur} = F_{sur_v} \times x_{sur_v} - F_{sur_h} \times x_{sur_h} = \mathbf{0}$ kNm/m

Moist retained soil $M_{moist} = F_{moist_v} \times x_{moist_v} - F_{moist_h} \times x_{moist_h} = \mathbf{24.1}$ kNm/m

Base soil $M_{pass} = -F_{pass_h} \times x_{pass_h} = \mathbf{0.3}$ kNm/m

Total $M_{total} = M_{stem} + M_{base} + M_{sur} + M_{moist} + M_{pass} = \mathbf{35.2}$ kNm/m

Check bearing pressure

Distance to reaction $\bar{x} = M_{total} / F_{total_v} = \mathbf{522}$ mm

Eccentricity of reaction $e = \bar{x} - l_{base} / 2 = \mathbf{-228}$ mm

Loaded length of base $l_{load} = 2 \times \bar{x} = \mathbf{1044}$ mm

Bearing pressure at toe $q_{toe} = F_{total_v} / l_{load} = \mathbf{64.6}$ kN/m^2

Bearing pressure at heel $q_{heel} = \mathbf{0}$ kN/m^2

Effective overburden pressure $q = (t_{base} + d_{cover}) \times \gamma_b' = \mathbf{5.4}$ kN/m^2

Design effective overburden pressure $q' = q / \gamma_\gamma = \mathbf{5.4}$ kN/m^2

Bearing resistance factors $N_q = Exp(\pi \times \tan(\phi'_{b.d})) \times (\tan(45\ deg + \phi'_{b.d} / 2))^2 = \mathbf{16.921}$

$N_c = (N_q - 1) \times \cot(\phi'_{b.d}) = \mathbf{28.422}$

$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b.d}) = \mathbf{17.837}$

Foundation shape factors $s_q = 1$

$s_\gamma = 1$

$s_c = 1$

Load inclination factors $H = F_{sur_h} + F_{moist_h} + F_{pass_h} = \mathbf{22}$ kN/m

$V = F_{total_v} = \mathbf{67.5}$ kN/m

$m = 2$

$i_q = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^m = \mathbf{0.453}$

$i_\gamma = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^{(m+1)} = \mathbf{0.305}$

$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b.d})) = \mathbf{0.419}$

Net ultimate bearing capacity

$n_f = c'_{b.d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_b' \times l_{load} \times N_\gamma \times s_\gamma \times i_\gamma =$ **92.6** kN/m²

Factor of safety $FoS_{bp} = n_f / \max(q_{toe}, q_{heel}) =$ **1.433**

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

RETAINING WALL DESIGN

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

Tedds calculation version 2.9.22

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

Concrete strength class	C30/37
Characteristic compressive cylinder strength	f_{ck} = **30** N/mm²
Characteristic compressive cube strength	$f_{ck,cube}$ = **37** N/mm²
Mean value of compressive cylinder strength	$f_{cm} = f_{ck}$ + 8 N/mm² = **38** N/mm²
Mean value of axial tensile strength	f_{ctm} = 0.3 N/mm² × (f_{ck} / 1 N/mm²)$^{2/3}$ = **2.9** N/mm²
5% fractile of axial tensile strength	$f_{ctk,0.05} = 0.7 \times f_{ctm}$ = **2.0** N/mm²
Secant modulus of elasticity of concrete	E_{cm} = 22 kN/mm² × (f_{cm} / 10 N/mm²)$^{0.3}$ = **32837** N/mm²
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/mm²
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/mm²
Modulus of elasticity of reinforcement	E_s = **200000** N/mm²
Partial factor for reinforcing steel - Table 2.1N	γ_S = **1.15**
Design yield strength of reinforcement	$f_{yd} = f_{yk} / \gamma_S$ = **435** N/mm²

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

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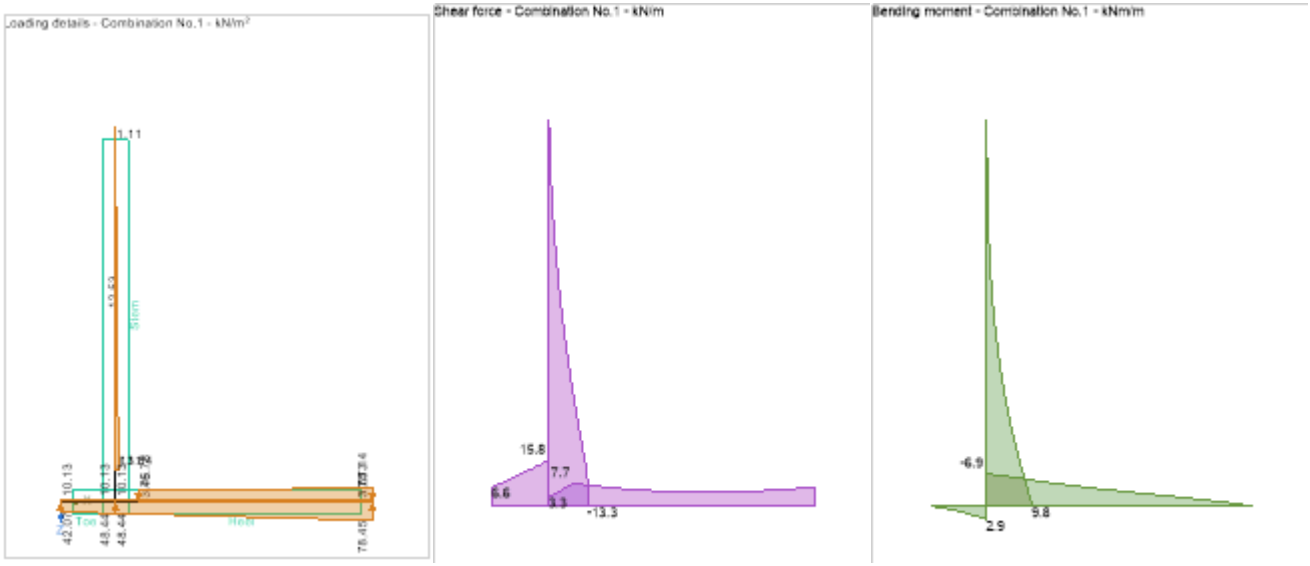
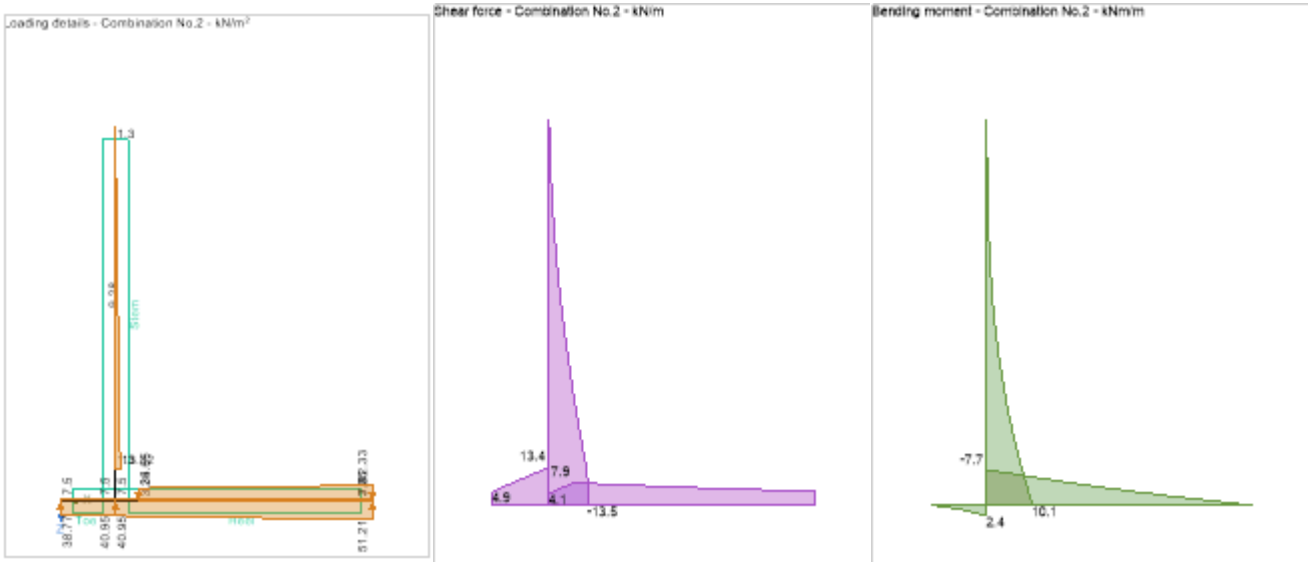
Shear Design 7 Ash Tree Court Cardiff Gate Business Park CF23 8RW	Calcs for				Start page no./Revision 9	
	Calcs by J	Calcs date 04/12/2024	Checked by	Checked date	Approved by	Approved date





Check stem design at base of stem

Depth of section — h = **225** mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 2 — M = **8** kNm/m

Depth to tension reinforcement — $d = h - c_{sr} - \phi_{sr} / 2 =$ **170** 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 — $z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_c))^{0.5}, 0.95) \times d =$ **161** mm

Depth of neutral axis — $x = 2.5 \times (d - z) =$ **21** mm

Area of tension reinforcement required — $A_{sr.req} = M / (f_{yd} \times z) =$ **114** mm²/m

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

Area of tension reinforcement provided	$A_{sr.prov} = \pi \times \phi_{sr}^2 / (4 \times s_{sr}) =$ **393** mm²/m
Minimum area of reinforcement - exp.9.1N	$A_{sr.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d =$ **256** mm²/m
Maximum area of reinforcement - cl.9.2.1.1(3)	$A_{sr.max} = 0.04 \times h =$ **9000** mm²/m
	$\max(A_{sr.req}, A_{sr.min}) / A_{sr.prov} =$ **0.652**

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	$K_b =$ **0.4**
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	$\min(K_s \times K_b \times [11 + 1.5 \times \sqrt{(f_{ck} / 1\ N/mm^2)} \times \rho_0 / \rho + 3.2 \times \sqrt{(f_{ck} / 1\ N/mm^2)} \times (\rho_0 / \rho - 1)^{3/2}], 40 \times K_b) =$ **16**
Actual span to depth ratio	$h_{stem} / d =$ **9.7**

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	$\psi_2 =$ **0.6**
Serviceability bending moment	$M_{sls} =$ **5.3** kNm/m
Tensile stress in reinforcement	$\sigma_s = M_{sls} / (A_{sr.prov} \times z) =$ **82.9** N/mm²
Load duration	Long term
Load duration factor	$k_t =$ **0.4**
Effective area of concrete in tension	$A_{c.eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$
	$A_{c.eff} =$ **67917** mm²/m
Mean value of concrete tensile strength	$f_{ct.eff} = f_{ctm} =$ **2.9** N/mm²
Reinforcement ratio	$\rho_{p.eff} = A_{sr.prov} / A_{c.eff} =$ **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	$s_{r.max} = k_3 \times c_{sr} + k_1 \times k_2 \times k_4 \times \phi_{sr} / \rho_{p.eff} =$ **464** mm
Maximum crack width - exp.7.8	$w_k = s_{r.max} \times \max(\sigma_s - k_t \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_e \times \rho_{p.eff}), 0.6 \times \sigma_s) / E_s$
	$w_k =$ **0.115** mm
	$w_k / w_{max} =$ **0.385**

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force	$V =$ **13.5** kN/m
	$C_{Rd,c} = 0.18 / \gamma_C =$ **0.120**
	$k = \min(1 + \sqrt{(200\ mm / d)}, 2) =$ **2.000**
Longitudinal reinforcement ratio	$\rho_l = \min(A_{sr.prov} / d, 0.02) =$ **0.002**
	$v_{min} = 0.035\ N^{1/2}/mm \times k^{3/2} \times f_{ck}^{0.5} =$ **0.542** N/mm²
Design shear resistance - exp.6.2a & 6.2b	$V_{Rd.c} = \max(C_{Rd.c} \times k \times (100\ N^2/mm^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$
	$V_{Rd.c} =$ **92.2** kN/m
	$V / V_{Rd.c} =$ **0.147**

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) $A_{sx.req} = \max(0.25 \times A_{sr.prov}, 0.001 \times t_{stem}) =$ **225** 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 = **300** mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 1 M = **1.4** kNm/m

Depth to tension reinforcement $d = h - c_{bb} - \phi_{bb} / 2 =$ **219** mm

$K = M / (d^2 \times f_{ck}) =$ **0.001**

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

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 $A_{bb.req} = M / (f_{yd} \times z) =$ **15** 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 $\psi_2 =$ **0.6**

Serviceability bending moment $M_{sls} =$ **1** kNm/m

Tensile stress in reinforcement $\sigma_s = M_{sls} / (A_{bb.prov} \times z) =$ **8.4** 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 $w_k = s_{r.max} \times \max(\sigma_s - k_t \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_e \times \rho_{p.eff}), 0.6 \times \sigma_s) / E_s$

$w_k =$ **0.015** mm

$w_k / w_{max} =$ **0.049**

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force

$V = \mathbf{11.6}$ kN/m

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

$k = \min(1 + \sqrt{(200\ mm / d)}, 2) = \mathbf{1.956}$

Longitudinal reinforcement ratio

$\rho_l = \min(A_{bb.prov} / d, 0.02) = \mathbf{0.003}$

$v_{min} = 0.035\ N^{1/2}/mm \times k^{3/2} \times f_{ck}^{0.5} = \mathbf{0.524}$ N/mm²

Design shear resistance - exp.6.2a & 6.2b

$V_{Rd.c} = \max(C_{Rd.c} \times k \times (100\ N^2/mm^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$

$V_{Rd.c} = \mathbf{114.8}$ kN/m

$V / V_{Rd.c} = \mathbf{0.101}$

PASS - Design shear resistance exceeds design shear force

Check base design at heel

Depth of section

$h = \mathbf{300}$ mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 2

$M = \mathbf{7}$ kNm/m

Depth to tension reinforcement

$d = h - c_{bt} - \phi_{bt} / 2 = \mathbf{244}$ mm

$K = M / (d^2 \times f_{ck}) = \mathbf{0.004}$

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

$K' = \mathbf{0.207}$

K' > K - No compression reinforcement is required

Lever arm

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

Depth of neutral axis

$x = 2.5 \times (d - z) = \mathbf{31}$ mm

Area of tension reinforcement required

$A_{bt.req} = M / (f_{yd} \times z) = \mathbf{70}$ mm²/m

Tension reinforcement provided

12 dia.bars @ 200 c/c

Area of tension reinforcement provided

$A_{bt.prov} = \pi \times \phi_{bt}^2 / (4 \times s_{bt}) = \mathbf{565}$ mm²/m

Minimum area of reinforcement - exp.9.1N

$A_{bt.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = \mathbf{368}$ mm²/m

Maximum area of reinforcement - cl.9.2.1.1(3)

$A_{bt.max} = 0.04 \times h = \mathbf{12000}$ mm²/m

$\max(A_{bt.req}, A_{bt.min}) / A_{bt.prov} = \mathbf{0.65}$

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

$w_{max} = \mathbf{0.3}$ mm

Variable load factor - EN1990 – Table A1.1

$\psi_2 = \mathbf{0.6}$

Serviceability bending moment

$M_{sls} = \mathbf{4.2}$ kNm/m

Tensile stress in reinforcement

$\sigma_s = M_{sls} / (A_{bt.prov} \times z) = \mathbf{31.7}$ N/mm²

Load duration

Long term

Load duration factor

$k_t = \mathbf{0.4}$

Effective area of concrete in tension

$A_{c.eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$

$A_{c.eff} = \mathbf{89833}$ mm²/m

Mean value of concrete tensile strength

$f_{ct.eff} = f_{ctm} = \mathbf{2.9}$ N/mm²

Reinforcement ratio

$\rho_{p.eff} = A_{bt.prov} / A_{c.eff} = \mathbf{0.006}$

Modular ratio

$\alpha_e = E_s / E_{cm} = \mathbf{6.091}$

Bond property coefficient

$k_1 = \mathbf{0.8}$

Strain distribution coefficient

$k_2 = \mathbf{0.5}$

$k_3 = \mathbf{3.4}$

$k_4 = \mathbf{0.425}$

Maximum crack spacing - exp.7.11 $s_{r.max} = k_3 \times c_{bt} + k_1 \times k_2 \times k_4 \times \phi_{bt} / \rho_{p.eff}$ = **494** 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 = **0.047** mm

w_k / w_{max} = **0.157**

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force V = **7.9** kN/m

$C_{Rd,c} = 0.18 / \gamma_C$ = **0.120**

$k = \min(1 + \sqrt{}(200 \text{ mm} / d), 2)$ = **1.905**

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

$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5}$ = **0.504** N/mm²

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

$V_{Rd.c}$ = **123** kN/m

$V / V_{Rd.c}$ = **0.064**

PASS - Design shear resistance exceeds design shear force

Secondary transverse reinforcement to base - Section 9.3

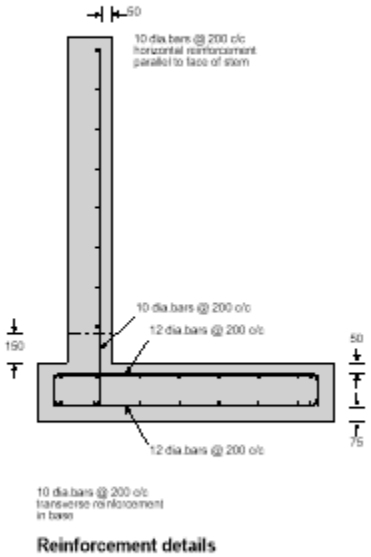
Minimum area of reinforcement – cl.9.3.1.1(2) $A_{bx.req} = 0.2 \times A_{bb.prov}$ = **113** mm²/m

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