Appendix 4: Structural Engineers Calculations

Baxter Glaysher Consulting Ltd – CALC 01 Preliminary Retaining Wall Design

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civil and structural engineers

JOB NUMBER:
222162

JOB TITLE:
20 Howitt Road. London. NW3

CLIENT:
KO Architects

CALCULATION TITLE:
Preliminary Retaining Wall Design

REFERENCE:
CALC 01

Rev	Description	Prepared by	Checked by	Date
-	Initial Issue	AO	RP	Jan-23

CALCULATION SHEET

bg consulting

Job Title:	Calculation Title:	Job No.	Calc Ref	Rev
20 Howitt Road. London. NW3	Preliminary Retaining Wall Design	222162	CALC 01	-

The attached Calculation sheets have been prepared by:

Name: Alex Ogunmola	Qualifications: HND (Structures)	Signed	AO	Date:	Jan-23

The attached calculation sheets have been approved by:

Name: Richard Price	Qualifications: IEng, AMIStructE, MICE.	Signed	RP	Date:	Jan-23

Design Risk Class: RC1

Design Check Level: 1

The design Risk Class (RC) and required Design Check Level (DCL) are identified above based on the proposed guidance within BS EN 1990
The following calculations are in respect of those structural elements to which they specifically refer.
No responsibility or liability is accepted in respect of any other element or part of the building.
Any assumed dimensions or bearing stresses must be confirmed on site to the satisfaction of the building control officer.
Weights of building materials are in accordance with BS EN 1991.
The Engineer shall check that weights of building materials not listed below but used in the following calculations are clearly referenced and are in accordance with the Manufacturers latest product data.
The Engineer shall clearly reference all specific project design data used in the following calculations provided by external sources.
The following loads are characteristic values (unless noted otherwise) Partial safety factors should be applied where necessary in accordance with appropriate standards

Calculation Design Philosophy

This structural calculation was made for a preliminary design of a retaining wall.

CALCULATION SHEET

Job Title:	Calculation Title:	Job No.	Calc Ref	Rev
20 Howitt Road. London. NW3	Preliminary Retaining Wall Design	222162	CALC 01	-
Standards and References				Date: Jan-23

Standards used in calculations:
BS 648: Schedule of Weights of Building Materials
BS 6399: Loadings for Buildings
BS 8110: Structural use of Concrete
BS 8004: Code of Practice for Foundations

References used in calculations:

CALCULATION SHEET

Job Title:	Calculation Title:	Job No.	Calc Ref	Rev
20 Howitt Road. London. NW3	Preliminary Retaining Wall Design	222162	CALC 01	-

Loading	Date: Jan-23

All loadings are SLS in kN/m^2
(Unless noted otherwise)

			Permanent	Variable	Total
Roof Loads					
Pitched tiled roof					
Roof pitch	=	30 °			
Permanent loads					
Slate Tiles	=	0.5			
Felt and Battens	=	0.15			
Rafters and Insulation	=	0.2			
Ceiling & Services	=	0.15			
Plan load	=	1.15			
Variable loads					
Imposed pitch roof load	=	0.6			
Plan Load		0.6			
			1.15	0.60	1.75

CALCULATION SHEET

Job Title:	Calculation Title:	Job No.	Calc Ref	Rev
20 Howitt Road. London. NW3	Preliminary Retaining Wall Design	222162	CALC 01	-

Loading	Date: Jan-23

All loadings are SLS in kN/m²
(Unless noted otherwise)

			Permanent	Variable	Total
Floor Loads					
Timber Floor					
Permanent loads					
Boards (19mm)	=	0.2			
Joists	=	0.2			
Ceiling	=	0.15			
Services	=	0.15			
		0.7			
Variable loads					
A1 - Residential	=	1.5			
		1.5			
			0.7	1.5	2.20

CALCULATION SHEET

Job Title:	Calculation Title:	Job No.	Calc Ref	Rev
20 Howitt Road. London. NW3	Preliminary Retaining Wall Design	222162	CALC 01	-
Loading				Date: Jan-23

All loadings are SLS in kN/m^2
(Unless noted otherwise)

			Permanent	Variable	Total
330 Wall Loads					
Solid Brickwork Construction					
Permanent loads					
330 mm brickwork	=	6.93			
1 faces plaster	=	0.2			
		7.1			
			7.13	0	7.13
225 Wall Loads					
Solid Brickwork Construction					
Permanent loads					
225 mm brickwork	=	4.73			
1 faces plaster	=	0.2			
		4.9			
			4.93	0	4.93

CALCULATION SHEET

Job Title:	Calculation Title:	Job No.	Calc Ref	Rev
20 Howitt Road. London. N	Preliminary Retaining Wall Design	222162	CALC 01	-
Specification Notes				Date: Jan-23

Cantilever Retaining Wall

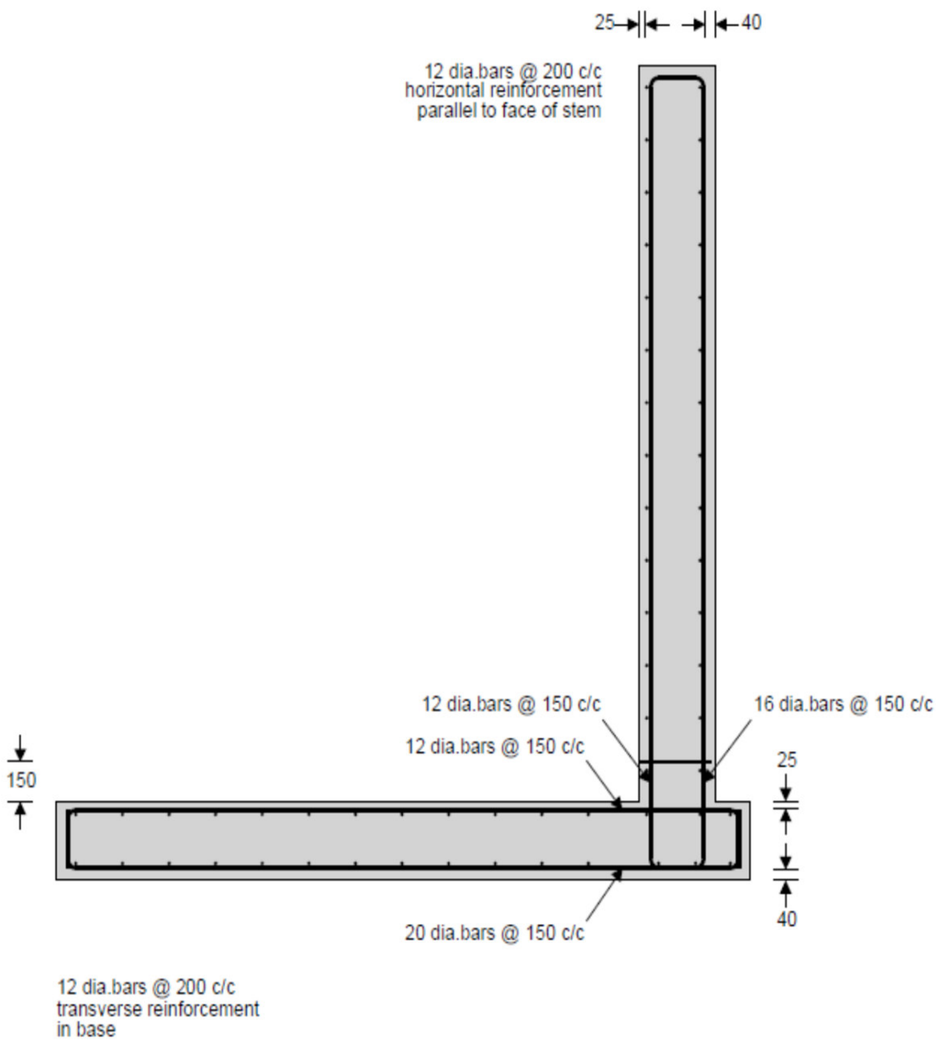
Stem: 325mm wide x 2800mm height

Base: 300mm thick

Toe: 2500mm

Heel: 150mm

Job Title:	Calculation Title:	Job No.	Calc Ref	Rev
20 Howitt Road. London. N	Preliminary Retaining Wall Design	222162	CALC 01	-
Appendices				Date: Jan-23



Reinforcement details

CALCULATION SHEET

bg consulting

Job Title	Job No.
20 HOWITT ROAD. LONDON. NW3	222162

Design Element				
RETAINING WALL PRELIMINARY DESIGN	Sheet No.	1		
	Prepared	AO	Date	JAN
	Revision		Date	

VERTICAL LOADS

		DL (kN/m)	LL (kN/m)
Pitched Roof (30°)			
1) 1.15 x 0.80	=	0.92	–
2) 0.60 x 0.80	=	–	0.48
Suspended floor			
3) 0.70 x 0.8 x 4	=	2.24	–
4) 1.50 x 0.8 x 4	=	–	4.80
Masonry (330thk)			
5 7.13 x 3.10	=	22.10	–
Masonry (225thk)			
6) 4.93 x 8.0	=	39.44	–
Point Loads on P/wall			
7) 11.08 / 6.5	=	1.70	–
8) 10.55 / 6.5	=	–	1.62
		66.40	6.90

Refer to page 2 – 14

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 2.9.12

Retaining wall details

Stem type	Cantilever
Stem height	h_{stem} = **2800** mm
Stem thickness	t_{stem} = **325** mm
Angle to rear face of stem	α = **90** deg
Stem density	γ_{stem} = **25** kN/m^3
Toe length	l_{toe} = **2500** mm
Heel length	l_{heel} = **150** mm
Base thickness	t_{base} = **300** mm
Base density	γ_{base} = **25** kN/m^3
Height of retained soil	h_{ret} = **2800** mm
Angle of soil surface	β = **0** deg
Depth of cover	d_{cover} = **0** mm
Height of water	h_{water} = **2700** mm
Water density	γ_w = **9.8** kN/m^3

Retained soil properties

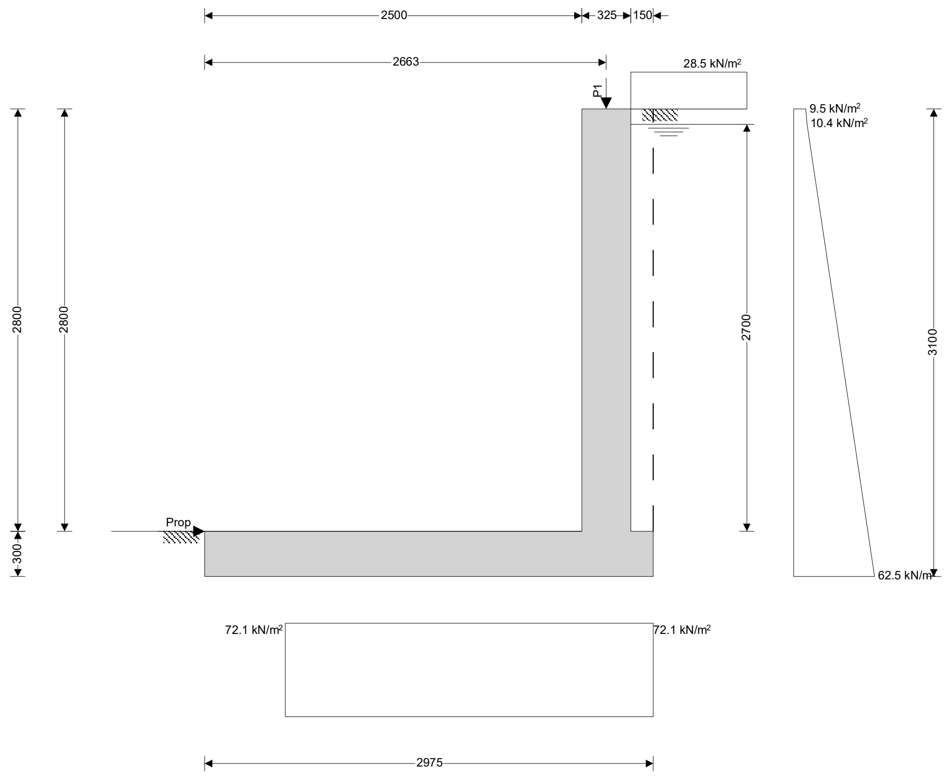
Soil type	Stiff clay
Moist density	γ_{mr} = **19** kN/m^3
Saturated density	γ_{sr} = **19** kN/m^3

Base soil properties

Soil type	Stiff clay
Soil density	γ_b = **19** kN/m^3

Loading details

Permanent surcharge load	$Surcharge_G$ = **10** kN/m^2
Variable surcharge load	$Surcharge_Q$ = **10** kN/m^2
Vertical line load at 2663 mm	P_{G1} = **66.4** kN/m
	P_{Q1} = **6.9** kN/m



General arrangement

Calculate retaining wall geometry

Base length	$l_{base} = l_{toe} + t_{stem} + l_{heel} = \mathbf{2975}$ mm
Saturated soil height	$h_{sat} = h_{water} + d_{cover} = \mathbf{2700}$ mm
Moist soil height	$h_{moist} = h_{ret} - h_{water} = \mathbf{100}$ mm
Length of surcharge load	$l_{sur} = l_{heel} = \mathbf{150}$ mm
- Distance to vertical component	$x_{sur\_v} = l_{base} - l_{heel} / 2 = \mathbf{2900}$ mm
Effective height of wall	$h_{eff} = h_{base} + d_{cover} + h_{ret} = \mathbf{3100}$ mm
- Distance to horizontal component	$x_{sur\_h} = h_{eff} / 2 = \mathbf{1550}$ mm
Area of wall stem	$A_{stem} = h_{stem} \times t_{stem} = \mathbf{0.91}$ m^2
- Distance to vertical component	$x_{stem} = l_{toe} + t_{stem} / 2 = \mathbf{2663}$ mm
Area of wall base	$A_{base} = l_{base} \times t_{base} = \mathbf{0.893}$ m^2
- Distance to vertical component	$x_{base} = l_{base} / 2 = \mathbf{1488}$ mm
Area of saturated soil	$A_{sat} = h_{sat} \times l_{heel} = \mathbf{0.405}$ m^2
- Distance to vertical component	$x_{sat\_v} = l_{base} - (h_{sat} \times l_{heel}^2 / 2) / A_{sat} = \mathbf{2900}$ mm
- Distance to horizontal component	$x_{sat\_h} = (h_{sat} + h_{base}) / 3 = \mathbf{1000}$ mm
Area of water	$A_{water} = h_{sat} \times l_{heel} = \mathbf{0.405}$ m^2
- Distance to vertical component	$x_{water\_v} = l_{base} - (h_{sat} \times l_{heel}^2 / 2) / A_{sat} = \mathbf{2900}$ mm
- Distance to horizontal component	$x_{water\_h} = (h_{sat} + h_{base}) / 3 = \mathbf{1000}$ mm
Area of moist soil	$A_{moist} = h_{moist} \times l_{heel} = \mathbf{0.015}$ m^2
- Distance to vertical component	$x_{moist\_v} = l_{base} - (h_{moist} \times l_{heel}^2 / 2) / A_{moist} = \mathbf{2900}$ mm
- Distance to horizontal component	$x_{moist\_h} = (h_{moist} \times (t_{base} + h_{sat} + h_{moist} / 3) / 2 + (h_{sat} + t_{base})^2/2) / (h_{sat} + t_{base} + h_{moist} / 2) = \mathbf{1525}$ mm

Design approach 1

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

Partial factor set	A1
Permanent unfavourable action	γ_G = **1.35**
Permanent favourable action	γ_{Gf} = **1.00**
Variable unfavourable action	γ_Q = **1.50**
Variable favourable action	γ_{Qf} = **0.00**

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**

Library item Partial factors output

Retained soil properties

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

Base soil properties

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

Soil coefficients

Coefficient of friction to back of wall	K_{fr} = **0.325**
Coefficient of friction to front of wall	K_{fb} = **0.325**
Coefficient of friction beneath base	K_{fbb} = **0.325**
Active pressure coefficient	K_A = **0.333**
Passive pressure coefficient	K_P = **4.977**

Overturning check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem}$ = **22.8** kN/m
Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base}$ = **22.3** kN/m
Line loads	$F_{P\_v} = \gamma_{Gf} \times P_{G1} + \gamma_{Qf} \times P_{Q1}$ = **66.4** kN/m
Saturated retained soil	$F_{sat\_v} = \gamma_{Gf} \times A_{sat} \times (\gamma_{sr}' - \gamma_w')$ = **3.7** kN/m
Water	$F_{water\_v} = \gamma_{Gf} \times A_{water} \times \gamma_w'$ = **4** kN/m
Water uplift	$F_{water\_u} = \gamma_{Gf} \times (h_{sat} + t_{base}) \times l_{base} / 2 \times \gamma_w'$ = **43.8** kN/m
Moist retained soil	$F_{moist\_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}'$ = **0.3** kN/m
Total	$F_{total\_v} = F_{stem} + F_{base} + F_{P\_v} + F_{sat\_v} + F_{water\_v} - F_{water\_u} + F_{moist\_v}$ = **75.7** kN/m

Horizontal forces on wall

Surcharge load	$F_{sur\_h} = K_A \times (\gamma_G \times Surcharge_G + \gamma_Q \times Surcharge_Q) \times h_{eff}$ = **29.5** kN/m
Saturated retained soil	$F_{sat\_h} = \gamma_G \times K_A \times (\gamma_{sr}' - \gamma_w') \times (h_{sat} + h_{base})^2 / 2$ = **18.6** kN/m
Water	$F_{water\_h} = \gamma_G \times \gamma_w' \times (h_{water} + d_{cover} + h_{base})^2 / 2$ = **59.6** kN/m
Moist retained soil	$F_{moist\_h} = \gamma_G \times K_A \times \gamma_{mr}' \times ((h_{eff} - h_{sat} - h_{base})^2 / 2 + (h_{eff} - h_{sat} - h_{base}) \times (h_{sat} + h_{base}))$ = **2.6** kN/m
Base soil	$F_{exc\_h} = -\gamma_{Gf} \times K_P \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2$ = **-4.3** kN/m
Total	$F_{total\_h} = F_{sur\_h} + F_{sat\_h} + F_{water\_h} + F_{moist\_h} + F_{exc\_h}$ = **106** kN/m

Overturning moments on wall

Surcharge load $M_{sur\_OT} = F_{sur\_h} \times x_{sur\_h} = \mathbf{45.6}$ kNm/m

Saturated retained soil $M_{sat\_OT} = F_{sat\_h} \times x_{sat\_h} = \mathbf{18.6}$ kNm/m

Water $M_{water\_OT} = F_{water\_h} \times x_{water\_h} + F_{water\_u} \times x_{water\_u} = \mathbf{146.4}$ kNm/m

Moist retained soil $M_{moist\_OT} = F_{moist\_h} \times x_{moist\_h} = \mathbf{4}$ kNm/m

Total $M_{total\_OT} = M_{sur\_OT} + M_{sat\_OT} + M_{water\_OT} + M_{moist\_OT} = \mathbf{214.7}$ kNm/m

Restoring moments on wall

Wall stem $M_{stem\_R} = F_{stem} \times x_{stem} = \mathbf{60.6}$ kNm/m

Wall base $M_{base\_R} = F_{base} \times x_{base} = \mathbf{33.2}$ kNm/m

Line loads $M_{P\_R} = (abs(\gamma_{Gf} \times P_{G1} + \gamma_{Qf} \times P_{Q1})) \times p_1 = \mathbf{176.8}$ kNm/m

Saturated retained soil $M_{sat\_R} = F_{sat\_v} \times x_{sat\_v} = \mathbf{10.8}$ kNm/m

Water $M_{water\_R} = F_{water\_v} \times x_{water\_v} = \mathbf{11.5}$ kNm/m

Moist retained soil $M_{moist\_R} = F_{moist\_v} \times x_{moist\_v} = \mathbf{0.8}$ kNm/m

Total $M_{total\_R} = M_{stem\_R} + M_{base\_R} + M_{P\_R} + M_{sat\_R} + M_{water\_R} + M_{moist\_R} = \mathbf{293.7}$ kNm/m

Check stability against overturning

Factor of safety $FoS_{ot} = M_{total\_R} / M_{total\_OT} = \mathbf{1.368}$

PASS - Maximum restoring moment is greater than overturning moment

Bearing pressure check

Vertical forces on wall

Wall stem $F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem} = \mathbf{30.7}$ kN/m

Wall base $F_{base} = \gamma_G \times A_{base} \times \gamma_{base} = \mathbf{30.1}$ kN/m

Surcharge load $F_{sur\_v} = (\gamma_G \times Surcharge_G + \gamma_Q \times Surcharge_Q) \times l_{heel} = \mathbf{4.3}$ kN/m

Line loads $F_{P\_v} = \gamma_G \times P_{G1} + \gamma_Q \times P_{Q1} = \mathbf{100}$ kN/m

Saturated retained soil $F_{sat\_v} = \gamma_G \times A_{sat} \times (\gamma_{sr}' - \gamma_w') = \mathbf{5}$ kN/m

Water $F_{water\_v} = \gamma_G \times A_{water} \times \gamma_w' = \mathbf{5.4}$ kN/m

Moist retained soil $F_{moist\_v} = \gamma_G \times A_{moist} \times \gamma_{mr}' = \mathbf{0.4}$ kN/m

Total $F_{total\_v} = F_{stem} + F_{base} + F_{sur\_v} + F_{P\_v} + F_{sat\_v} + F_{water\_v} + F_{moist\_v} = \mathbf{175.9}$ kN/m

Horizontal forces on wall

Surcharge load $F_{sur\_h} = K_A \times (\gamma_G \times Surcharge_G + \gamma_Q \times Surcharge_Q) \times h_{eff} = \mathbf{29.5}$ kN/m

Saturated retained soil $F_{sat\_h} = \gamma_G \times K_A \times (\gamma_{sr}' - \gamma_w') \times (h_{sat} + h_{base})^2 / 2 = \mathbf{18.6}$ kN/m

Water $F_{water\_h} = \gamma_G \times \gamma_w' \times (h_{water} + d_{cover} + h_{base})^2 / 2 = \mathbf{59.6}$ kN/m

Moist retained soil $F_{moist\_h} = \gamma_G \times K_A \times \gamma_{mr}' \times ((h_{eff} - h_{sat} - h_{base})^2 / 2 + (h_{eff} - h_{sat} - h_{base}) \times (h_{sat} + h_{base})) = \mathbf{2.6}$ kN/m

Base soil $F_{pass\_h} = -\gamma_{Gf} \times K_P \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2 = \mathbf{-4.3}$ kN/m

Total $F_{total\_h} = F_{sur\_h} + F_{sat\_h} + F_{water\_h} + F_{moist\_h} + F_{pass\_h} = \mathbf{106}$ kN/m

Moments on wall

Wall stem $M_{stem} = F_{stem} \times x_{stem} = \mathbf{81.8}$ kNm/m

Wall base $M_{base} = F_{base} \times x_{base} = \mathbf{44.8}$ kNm/m

Surcharge load $M_{sur} = F_{sur\_v} \times x_{sur\_v} - F_{sur\_h} \times x_{sur\_h} = \mathbf{-33.3}$ kNm/m

Line loads $M_P = (\gamma_G \times P_{G1} + \gamma_Q \times P_{Q1}) \times p_1 = \mathbf{266.2}$ kNm/m

Saturated retained soil $M_{sat} = F_{sat\_v} \times x_{sat\_v} - F_{sat\_h} \times x_{sat\_h} = \mathbf{-4}$ kNm/m

Water $M_{water} = F_{water\_v} \times x_{water\_v} - F_{water\_h} \times x_{water\_h} = \mathbf{-44}$ kNm/m

Moist retained soil $M_{moist} = F_{moist\_v} \times x_{moist\_v} - F_{moist\_h} \times x_{moist\_h}$ = **-2.9** kNm/m

Total $M_{total} = M_{stem} + M_{base} + M_{sur} + M_P + M_{sat} + M_{water} + M_{moist}$ = **308.6** kNm/m

Check bearing pressure

Propping force $F_{prop\_base} = F_{total\_h}$ = **106** kN/m

Distance to reaction $\bar{x} = M_{total} / F_{total\_v}$ = **1755** mm

Eccentricity of reaction $e = \bar{x} - l_{base} / 2$ = **267** mm

Loaded length of base $l_{load} = 2 \times (l_{base} - \bar{x})$ = **2441** mm

Bearing pressure at toe q_{toe} = **0** kN/m^2

Bearing pressure at heel $q_{heel} = F_{total\_v} / l_{load}$ = **72.1** kN/m^2

Factor of safety $FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel})$ = **1.735**

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 γ_G = **1.00**

Permanent favourable action γ_{Gf} = **1.00**

Variable unfavourable action γ_Q = **1.30**

Variable favourable action γ_{Qf} = **0.00**

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 γ_γ = **1.00**

Library item Partial factors output

Retained soil properties

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

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

Base soil properties

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

Soil coefficients

Coefficient of friction to back of wall K_{fr} = **0.325**

Coefficient of friction to front of wall K_{fb} = **0.325**

Coefficient of friction beneath base K_{fbb} = **0.325**

Active pressure coefficient K_A = **0.333**

Passive pressure coefficient K_P = **4.977**

Overturning check

Vertical forces on wall

Wall stem $F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem}$ = **22.8** kN/m

Wall base $F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base}$ = **22.3** kN/m

Line loads $F_{P\_v} = \gamma_{Gf} \times P_{G1} + \gamma_{Qf} \times P_{Q1}$ = **66.4** kN/m

Saturated retained soil $F_{sat\_v} = \gamma_{Gf} \times A_{sat} \times (\gamma_{sr}' - \gamma_w')$ = **3.7** kN/m

Water $F_{water\_v} = \gamma_{Gf} \times A_{water} \times \gamma_w'$ = **4** kN/m

Water uplift $F_{water\_u} = \gamma_{Gf} \times (h_{sat} + t_{base}) \times l_{base} / 2 \times \gamma_w'$ = **43.8** kN/m

Moist retained soil	$F_{moist\_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' =$ **0.3** kN/m
Total	$F_{total\_v} = F_{stem} + F_{base} + F_{P\_v} + F_{sat\_v} + F_{water\_v} - F_{water\_u} + F_{moist\_v} =$ **75.7** kN/m

Horizontal forces on wall

Surcharge load	$F_{sur\_h} = K_A \times (\gamma_G \times Surcharge_G + \gamma_Q \times Surcharge_Q) \times h_{eff} =$ **23.8** kN/m
Saturated retained soil	$F_{sat\_h} = \gamma_G \times K_A \times (\gamma_{sr}' - \gamma_w') \times (h_{sat} + h_{base})^2 / 2 =$ **13.8** kN/m
Water	$F_{water\_h} = \gamma_G \times \gamma_w' \times (h_{water} + d_{cover} + h_{base})^2 / 2 =$ **44.1** kN/m
Moist retained soil	$F_{moist\_h} = \gamma_G \times K_A \times \gamma_{mr}' \times ((h_{eff} - h_{sat} - h_{base})^2 / 2 + (h_{eff} - h_{sat} - h_{base}) \times (h_{sat} + h_{base})) =$ **1.9** kN/m
Base soil	$F_{exc\_h} = -\gamma_{Gf} \times K_P \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 =$ **-4.3** kN/m
Total	$F_{total\_h} = F_{sur\_h} + F_{sat\_h} + F_{water\_h} + F_{moist\_h} + F_{exc\_h} =$ **79.4** kN/m

Overturning moments on wall

Surcharge load	$M_{sur\_OT} = F_{sur\_h} \times x_{sur\_h} =$ **36.8** kNm/m
Saturated retained soil	$M_{sat\_OT} = F_{sat\_h} \times x_{sat\_h} =$ **13.8** kNm/m
Water	$M_{water\_OT} = F_{water\_h} \times x_{water\_h} + F_{water\_u} \times x_{water\_u} =$ **131** kNm/m
Moist retained soil	$M_{moist\_OT} = F_{moist\_h} \times x_{moist\_h} =$ **2.9** kNm/m
Total	$M_{total\_OT} = M_{sur\_OT} + M_{sat\_OT} + M_{water\_OT} + M_{moist\_OT} =$ **184.5** kNm/m

Restoring moments on wall

Wall stem	$M_{stem\_R} = F_{stem} \times x_{stem} =$ **60.6** kNm/m
Wall base	$M_{base\_R} = F_{base} \times x_{base} =$ **33.2** kNm/m
Line loads	$M_{P\_R} = (abs(\gamma_{Gf} \times P_{G1} + \gamma_{Qf} \times P_{Q1})) \times p_1 =$ **176.8** kNm/m
Saturated retained soil	$M_{sat\_R} = F_{sat\_v} \times x_{sat\_v} =$ **10.8** kNm/m
Water	$M_{water\_R} = F_{water\_v} \times x_{water\_v} =$ **11.5** kNm/m
Moist retained soil	$M_{moist\_R} = F_{moist\_v} \times x_{moist\_v} =$ **0.8** kNm/m
Total	$M_{total\_R} = M_{stem\_R} + M_{base\_R} + M_{P\_R} + M_{sat\_R} + M_{water\_R} + M_{moist\_R} =$ **293.7** kNm/m

Check stability against overturning

Factor of safety	$FoS_{ot} = M_{total\_R} / M_{total\_OT} =$ **1.591**

PASS - Maximum restoring moment is greater than overturning moment

Bearing pressure check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem} =$ **22.8** kN/m
Wall base	$F_{base} = \gamma_G \times A_{base} \times \gamma_{base} =$ **22.3** kN/m
Surcharge load	$F_{sur\_v} = (\gamma_G \times Surcharge_G + \gamma_Q \times Surcharge_Q) \times l_{heel} =$ **3.5** kN/m
Line loads	$F_{P\_v} = \gamma_G \times P_{G1} + \gamma_Q \times P_{Q1} =$ **75.4** kN/m
Saturated retained soil	$F_{sat\_v} = \gamma_G \times A_{sat} \times (\gamma_{sr}' - \gamma_w') =$ **3.7** kN/m
Water	$F_{water\_v} = \gamma_G \times A_{water} \times \gamma_w' =$ **4** kN/m
Moist retained soil	$F_{moist\_v} = \gamma_G \times A_{moist} \times \gamma_{mr}' =$ **0.3** kN/m
Total	$F_{total\_v} = F_{stem} + F_{base} + F_{sur\_v} + F_{P\_v} + F_{sat\_v} + F_{water\_v} + F_{moist\_v} =$ **131.9** kN/m

Horizontal forces on wall

Surcharge load	$F_{sur\_h} = K_A \times (\gamma_G \times Surcharge_G + \gamma_Q \times Surcharge_Q) \times h_{eff} =$ **23.8** kN/m
Saturated retained soil	$F_{sat\_h} = \gamma_G \times K_A \times (\gamma_{sr}' - \gamma_w') \times (h_{sat} + h_{base})^2 / 2 =$ **13.8** kN/m
Water	$F_{water\_h} = \gamma_G \times \gamma_w' \times (h_{water} + d_{cover} + h_{base})^2 / 2 =$ **44.1** kN/m

Moist retained soil	$F_{moist\_h} = \gamma_G \times K_A \times \gamma_{mr}' \times ((h_{eff} - h_{sat} - h_{base})^2 / 2 + (h_{eff} - h_{sat} - h_{base}) \times (h_{sat} + h_{base})) = \mathbf{1.9}$ kN/m
Base soil	$F_{pass\_h} = -\gamma_{Gf} \times K_P \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2 = \mathbf{-4.3}$ kN/m
Total	$F_{total\_h} = F_{sur\_h} + F_{sat\_h} + F_{water\_h} + F_{moist\_h} + F_{pass\_h} = \mathbf{79.4}$ kN/m

Moments on wall

Wall stem	$M_{stem} = F_{stem} \times x_{stem} = \mathbf{60.6}$ kNm/m
Wall base	$M_{base} = F_{base} \times x_{base} = \mathbf{33.2}$ kNm/m
Surcharge load	$M_{sur} = F_{sur\_v} \times x_{sur\_v} - F_{sur\_h} \times x_{sur\_h} = \mathbf{-26.8}$ kNm/m
Line loads	$M_P = (\gamma_G \times P_{G1} + \gamma_Q \times P_{Q1}) \times p_1 = \mathbf{200.7}$ kNm/m
Saturated retained soil	$M_{sat} = F_{sat\_v} \times x_{sat\_v} - F_{sat\_h} \times x_{sat\_h} = \mathbf{-3}$ kNm/m
Water	$M_{water} = F_{water\_v} \times x_{water\_v} - F_{water\_h} \times x_{water\_h} = \mathbf{-32.6}$ kNm/m
Moist retained soil	$M_{moist} = F_{moist\_v} \times x_{moist\_v} - F_{moist\_h} \times x_{moist\_h} = \mathbf{-2.1}$ kNm/m
Total	$M_{total} = M_{stem} + M_{base} + M_{sur} + M_P + M_{sat} + M_{water} + M_{moist} = \mathbf{229.9}$ kNm/m

Check bearing pressure

Propping force	$F_{prop\_base} = F_{total\_h} = \mathbf{79.4}$ kN/m
Distance to reaction	$\bar{x} = M_{total} / F_{total\_v} = \mathbf{1743}$ mm
Eccentricity of reaction	$e = \bar{x} - l_{base} / 2 = \mathbf{256}$ mm
Loaded length of base	$l_{load} = 2 \times (l_{base} - \bar{x}) = \mathbf{2464}$ mm
Bearing pressure at toe	$q_{toe} = \mathbf{0}$ kN/m^2
Bearing pressure at heel	$q_{heel} = F_{total\_v} / l_{load} = \mathbf{53.5}$ kN/m^2
Factor of safety	$FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel}) = \mathbf{2.335}$

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 2.9.12

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

Concrete strength class	C35/45
Characteristic compressive cylinder strength	$f_{ck} = \mathbf{35}$ N/mm^2
Characteristic compressive cube strength	$f_{ck,cube} = \mathbf{45}$ N/mm^2
Mean value of compressive cylinder strength	$f_{cm} = f_{ck} + 8$ N/mm^2 $= \mathbf{43}$ N/mm^2
Mean value of axial tensile strength	$f_{ctm} = 0.3$ N/mm$^2 \times (f_{ck} / 1$ N/mm$^2)^{2/3} = \mathbf{3.2}$ N/mm^2
5% fractile of axial tensile strength	$f_{ctk,0.05} = 0.7 \times f_{ctm} = \mathbf{2.2}$ N/mm^2
Secant modulus of elasticity of concrete	$E_{cm} = 22$ kN/mm$^2 \times (f_{cm} / 10$ N/mm$^2)^{0.3} = \mathbf{34077}$ N/mm^2
Partial factor for concrete - Table 2.1N	$\gamma_C = \mathbf{1.50}$
Compressive strength coefficient - cl.3.1.6(1)	$\alpha_{cc} = \mathbf{0.85}$
Design compressive concrete strength - exp.3.15	$f_{cd} = \alpha_{cc} \times f_{ck} / \gamma_C = \mathbf{19.8}$ N/mm^2
Maximum aggregate size	$h_{agg} = \mathbf{20}$ mm
Ultimate strain - Table 3.1	$\varepsilon_{cu2} = \mathbf{0.0035}$
Shortening strain - Table 3.1	$\varepsilon_{cu3} = \mathbf{0.0035}$
Effective compression zone height factor	$\lambda = \mathbf{0.80}$
Effective strength factor	$\eta = \mathbf{1.00}$
Bending coefficient k_1	$K_1 = \mathbf{0.40}$
Bending coefficient k_2	$K_2 = 1.00 \times (0.6 + 0.0014/\varepsilon_{cu2}) = \mathbf{1.00}$
Bending coefficient k_3	$K_3 = \mathbf{0.40}$

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

Reinforcement details

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

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

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

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

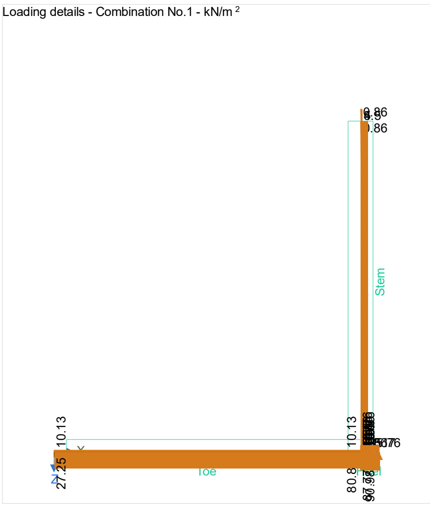
Cover to reinforcement

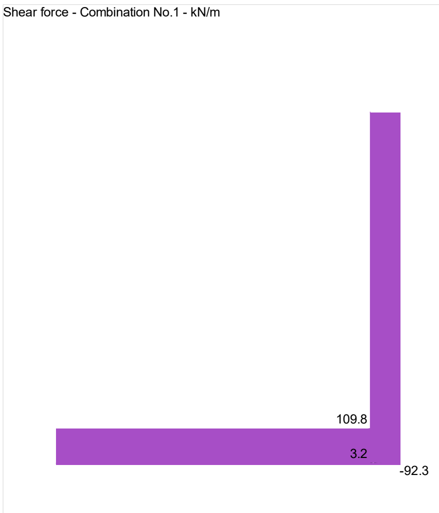
Front face of stem c_{sf} = **25** mm

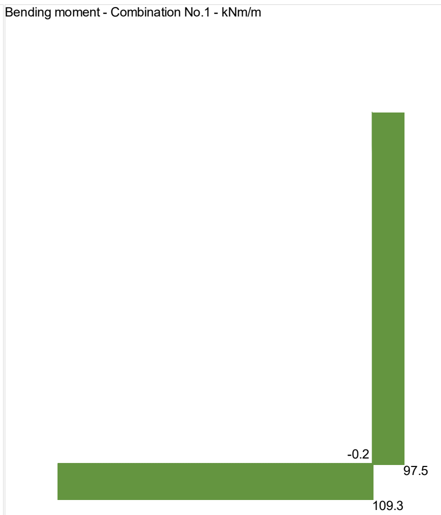
Rear face of stem c_{sr} = **40** mm

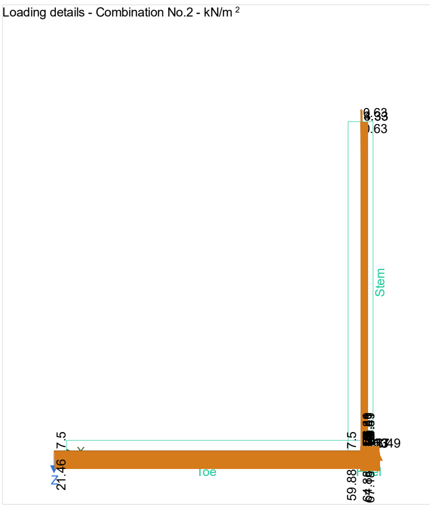
Top face of base c_{bt} = **25** mm

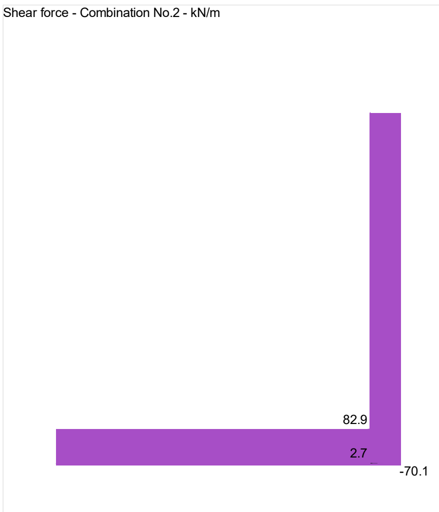
Bottom face of base c_{bb} = **40** mm

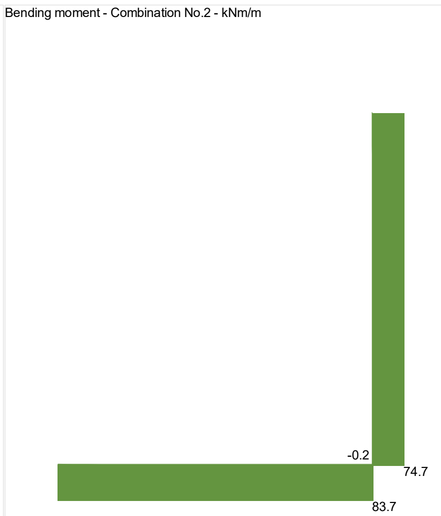












Check stem design at base of stem

Depth of section h = **325** mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 1 — $M = \mathbf{97.5}$ kNm/m

Depth to tension reinforcement — $d = h - c_{sr} - \phi_{sr} / 2 = \mathbf{277}$ mm

$K = M / (d^2 \times f_{ck}) = \mathbf{0.036}$

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

$K' = \mathbf{0.207}$

K' > K - No compression reinforcement is required

Lever arm — $z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_C))^{0.5}, 0.95) \times d = \mathbf{263}$ mm

Depth of neutral axis — $x = 2.5 \times (d – z) = \mathbf{35}$ mm

Area of tension reinforcement required — $A_{sr.req} = M / (f_{yd} \times z) = \mathbf{852}$ mm²/m

Tension reinforcement provided — 16 dia.bars @ 150 c/c

Area of tension reinforcement provided — $A_{sr.prov} = \pi \times \phi_{sr}^2 / (4 \times s_{sr}) = \mathbf{1340}$ mm²/m

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

Maximum area of reinforcement - cl.9.2.1.1(3) — $A_{sr.max} = 0.04 \times h = \mathbf{13000}$ mm²/m

$\max(A_{sr.req}, A_{sr.min}) / A_{sr.prov} = \mathbf{0.636}$

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

Required tension reinforcement ratio — $\rho = A_{sr.req} / d = \mathbf{0.003}$

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

Structural system factor - Table 7.4N — $K_b = \mathbf{0.4}$

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

Limiting span to depth ratio - exp.7.16.a — $\min(K_s \times K_b \times [11 + 1.5 \times \sqrt{(f_{ck} / 1 \text{ N/mm}^2)} \times \rho_0 / \rho + 3.2 \times \sqrt{(f_{ck} / 1 \text{ N/mm}^2)} \times (\rho_0 / \rho - 1)^{3/2}], 40 \times K_b) = \mathbf{16}$

Actual span to depth ratio — $h_{stem} / d = \mathbf{10.1}$

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

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 — $M_{sls} = \mathbf{65.5}$ kNm/m

Tensile stress in reinforcement — $\sigma_s = M_{sls} / (A_{sr.prov} \times z) = \mathbf{185.8}$ N/mm²

Load duration — Long term

Load duration factor — $k_t = \mathbf{0.4}$

Effective area of concrete in tension — $A_{c.eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$

$A_{c.eff} = \mathbf{96792}$ mm²/m

Mean value of concrete tensile strength — $f_{ct.eff} = f_{ctm} = \mathbf{3.2}$ N/mm²

Reinforcement ratio — $\rho_{p.eff} = A_{sr.prov} / A_{c.eff} = \mathbf{0.014}$

Modular ratio — $\alpha_e = E_s / E_{cm} = \mathbf{5.869}$

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 — $s_{r.max} = k_3 \times c_{sr} + k_1 \times k_2 \times k_4 \times \phi_{sr} / \rho_{p.eff} = \mathbf{332}$ mm

Maximum crack width - exp.7.8 — $w_k = s_{r.max} \times \max(\sigma_s – k_t \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_e \times \rho_{p.eff}), 0.6 \times \sigma_s) / E_s$

$w_k = \mathbf{0.185}$ mm

w_k / w_{max} = **0.618**

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force — V = **92.3** kN/m

$C_{Rd,c}$ = 0.18 / γ_C = **0.120**

k = min(1 + √(200 mm / d), 2) = **1.850**

Longitudinal reinforcement ratio — ρ_l = min($A_{sr.prov}$ / d, 0.02) = **0.005**

v_{min} = 0.035 $N^{1/2}$/mm × $k^{3/2}$ × $f_{ck}^{0.5}$ = **0.521** N/mm²

Design shear resistance - exp.6.2a & 6.2b — $V_{Rd.c}$ = max($C_{Rd.c}$ × k × (100 N²/mm⁴ × ρ_l × f_{ck})$^{1/3}$, v_{min}) × d

$V_{Rd.c}$ = **157.9** kN/m

V / $V_{Rd.c}$ = **0.585**

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 × $A_{sr.prov}$, 0.001 × t_{stem}) = **335** mm²/m

Maximum spacing of reinforcement – cl.9.6.3(2) — s_{sx_max} = **400** mm

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

Area of transverse reinforcement provided — $A_{sx.prov}$ = π × ϕ_{sx}^2 / (4 × s_{sx}) = **565** 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 = **109.3** kNm/m

Depth to tension reinforcement — d = h - c_{bb} - ϕ_{bb} / 2 = **250** mm

K = M / (d² × f_{ck}) = **0.050**

K' = (2 × η × α_{cc}/γ_C)×(1 - λ × (δ - K_1)/(2 × K_2))×(λ × (δ - K_1)/(2 × K_2))

K' = **0.207**

K' > K - No compression reinforcement is required

Lever arm — z = min(0.5 + 0.5 × (1 - 2 × K / (η × α_{cc} / γ_C))$^{0.5}$, 0.95) × d = **237** mm

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

Area of tension reinforcement required — $A_{bb.req}$ = M / (f_{yd} × z) = **1059** mm²/m

Tension reinforcement provided — 20 dia.bars @ 150 c/c

Area of tension reinforcement provided — $A_{bb.prov}$ = π × ϕ_{bb}^2 / (4 × s_{bb}) = **2094** mm²/m

Minimum area of reinforcement - exp.9.1N — $A_{bb.min}$ = max(0.26 × f_{ctm} / f_{yk}, 0.0013) × d = **417** mm²/m

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

max($A_{bb.req}$, $A_{bb.min}$) / $A_{bb.prov}$ = **0.505**

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} = **79.4** kNm/m

Tensile stress in reinforcement — σ_s = M_{sls} / ($A_{bb.prov}$ × z) = **159.6** 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 × (h - d), (h - x) / 3, h / 2)

$A_{c.eff}$ = **89583** mm²/m

Mean value of concrete tensile strength $f_{ct.eff} = f_{ctm} = \mathbf{3.2}$ N/mm^2

Reinforcement ratio $\rho_{p.eff} = A_{bb.prov} / A_{c.eff} = \mathbf{0.023}$

Modular ratio $\alpha_e = E_s / E_{cm} = \mathbf{5.869}$

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 $s_{r.max} = k_3 \times c_{bb} + k_1 \times k_2 \times k_4 \times \phi_{bb} / \rho_{p.eff} = \mathbf{281}$ mm

Maximum crack width - exp.7.8 $w_k = s_{r.max} \times \max(\sigma_s - k_t \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_e \times \rho_{p.eff}), 0.6 \times \sigma_s) / E_s$

$w_k = \mathbf{0.137}$ mm

$w_k / w_{max} = \mathbf{0.456}$

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force $V = \mathbf{109.8}$ kN/m

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

$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2) = \mathbf{1.894}$

Longitudinal reinforcement ratio $\rho_l = \min(A_{bb.prov} / d, 0.02) = \mathbf{0.008}$

$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5} = \mathbf{0.540}$ N/mm^2

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

$V_{Rd.c} = \mathbf{175.3}$ kN/m

$V / V_{Rd.c} = \mathbf{0.626}$

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 1 $M = \mathbf{0.2}$ kNm/m

Depth to tension reinforcement $d = h - c_{bt} - \phi_{bt} / 2 = \mathbf{269}$ mm

$K = M / (d^2 \times f_{ck}) = \mathbf{0.000}$

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

$K' = \mathbf{0.207}$

K' > K - No compression reinforcement is required

Lever arm $z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_C))^{0.5}, 0.95) \times d = \mathbf{256}$ mm

Depth of neutral axis $x = 2.5 \times (d - z) = \mathbf{34}$ mm

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

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

Area of tension reinforcement provided $A_{bt.prov} = \pi \times \phi_{bt}^2 / (4 \times s_{bt}) = \mathbf{754}$ mm^2/m

Minimum area of reinforcement - exp.9.1N $A_{bt.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d = \mathbf{449}$ mm^2/m

Maximum area of reinforcement - cl.9.2.1.1(3) $A_{bt.max} = 0.04 \times h = \mathbf{12000}$ mm^2/m

$\max(A_{bt.req}, A_{bt.min}) / A_{bt.prov} = \mathbf{0.596}$

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 $M_{sls} = \mathbf{0.1}$ kNm/m

Tensile stress in reinforcement $\sigma_s = M_{sls} / (A_{bt.prov} \times z) = \mathbf{0.6}$ N/mm^2

Load duration	Long term
Load duration factor	k_t = **0.4**
Effective area of concrete in tension	$A_{c.eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$
	$A_{c.eff}$ = **77500** mm^2/m
Mean value of concrete tensile strength	$f_{ct.eff} = f_{ctm}$ = **3.2** N/mm^2
Reinforcement ratio	$\rho_{p.eff} = A_{bt.prov} / A_{c.eff}$ = **0.010**
Modular ratio	$\alpha_e = E_s / E_{cm}$ = **5.869**
Bond property coefficient	k_1 = **0.8**
Strain distribution coefficient	k_2 = **0.5**
	k_3 = **3.4**
	k_4 = **0.425**
Maximum crack spacing - exp.7.11	$s_{r.max} = k_3 \times c_{bt} + k_1 \times k_2 \times k_4 \times \phi_{bt} / \rho_{p.eff}$ = **295** 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 = **0.001** mm
	w_k / w_{max} = **0.002**

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

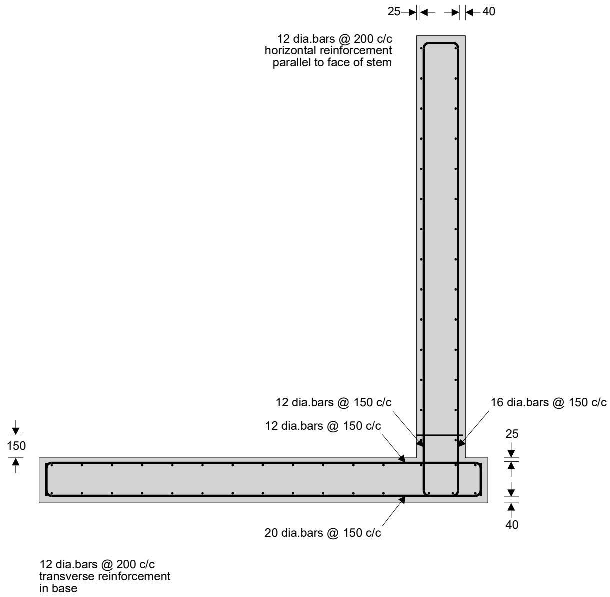
Design shear force	V = **3.2** kN/m
	$C_{Rd,c} = 0.18 / \gamma_C$ = **0.120**
	$k = \min(1 + \sqrt{(200 \text{ mm} / d)}, 2)$ = **1.862**
Longitudinal reinforcement ratio	$\rho_l = \min(A_{bt.prov} / d, 0.02)$ = **0.003**
	$v_{min} = 0.035 \text{ N}^{1/2}/\text{mm} \times k^{3/2} \times f_{ck}^{0.5}$ = **0.526** N/mm^2
Design shear resistance - exp.6.2a & 6.2b	$V_{Rd.c} = \max(C_{Rd.c} \times k \times (100 \text{ N}^2/\text{mm}^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$
	$V_{Rd.c}$ = **141.6** kN/m
	$V / V_{Rd.c}$ = **0.022**

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)	$A_{bx.req} = 0.2 \times A_{bb.prov}$ = **419** mm^2/m
Maximum spacing of reinforcement – cl.9.3.1.1(3)	s_{bx_max} = **450** mm
Transverse reinforcement provided	12 dia.bars @ 200 c/c
Area of transverse reinforcement provided	$A_{bx.prov} = \pi \times \phi_{bx}^2 / (4 \times s_{bx})$ = **565** mm^2/m

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



Reinforcement details