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 2.9.14

Retaining wall details

Stem type	Cantilever with stepped rear face
Stem height	h_{stem} = **3300** mm
Number of steps	N_{steps} = **4**
Height of step 1	h_{s1} = **1600** mm
Thickness of step 1	t_{s1} = **2500** mm
Height of step 2	h_{s2} = **700** mm
Thickness of step 2	t_{s2} = **2000** mm
Height of step 3	h_{s3} = **700** mm
Thickness of step 3	t_{s3} = **1300** mm
Height of step 4	h_{s4} = **300** mm
Thickness of step 4	t_{s4} = **500** mm
Angle to rear face of stem	α = **90** deg
Stem density	γ_{stem} = **25** kN/m^3
Base thickness	t_{base} = **0** mm
Base density	γ_{base} = **25** kN/m^3
Height of retained soil	h_{ret} = **2500** mm
Angle of soil surface	β = **0** deg
Depth of cover	d_{cover} = **800** mm

Retained soil properties

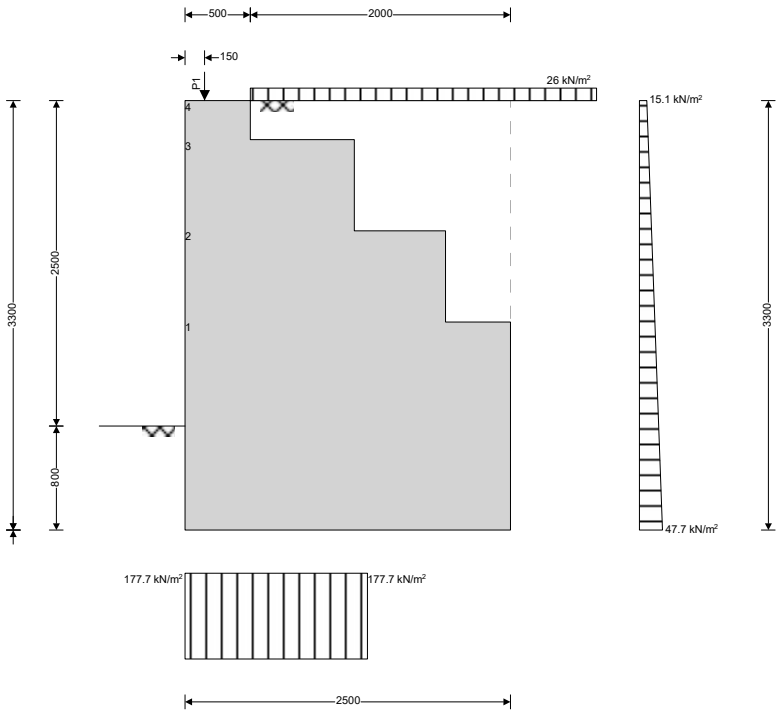
Soil type	Medium dense gravel
Moist density	γ_{mr} = **17** kN/m^3
Saturated density	γ_{sr} = **20.5** kN/m^3
Characteristic effective shear resistance angle	$\phi'_{r.k}$ = **30** deg
Characteristic wall friction angle	$\delta_{r.k}$ = **15** deg

Base soil properties

Soil type	Dense rock fill
Soil density	γ_b = **18** kN/m^3
Characteristic cohesion	$c'_{b.k}$ = **0** kN/m^2
Characteristic effective shear resistance angle	$\phi'_{b.k}$ = **40** deg
Characteristic wall friction angle	$\delta_{b.k}$ = **20** deg
Characteristic base friction angle	$\delta_{bb.k}$ = **30** deg

Loading details

Variable surcharge load	$Surcharge_Q$ = **20** kN/m^2
Vertical line load at 150 mm	P_{G1} = **5** kN/m



General arrangement

Calculate retaining wall geometry

Base length	$l_{base} = t_{s1} =$ **2500** mm
Moist soil height	$h_{moist} = h_{soil} =$ **3300** mm
Length of surcharge load	$l_{sur} = (l_{heel} + t_{s1} - t_{s4}) =$ **2000** mm
- Distance to vertical component	$x_{sur\_v} = l_{base} - (l_{heel} + t_{s1} - t_{s4}) / 2 =$ **1500** mm
Effective height of wall	$h_{eff} = h_{base} + d_{cover} + h_{ret} =$ **3300** mm
- Distance to horizontal component	$x_{sur\_h} = h_{eff} / 2 =$ **1650** mm
Area of wall stem	$A_{stem} = h_{s1} \times t_{s1} + h_{s2} \times t_{s2} + h_{s3} \times t_{s3} + h_{s4} \times t_{s4} =$ **6.46** m^2
- Distance to vertical component	$x_{stem} = l_{base} - (h_{s1} \times t_{s1} \times (l_{heel} + t_{s1} - t_{s1} / 2) + h_{s2} \times t_{s2} \times (l_{heel} + t_{s1} - t_{s2} / 2) + h_{s3} \times t_{s3} \times (l_{heel} + t_{s1} - t_{s3} / 2) + h_{s4} \times t_{s4} \times (l_{heel} + t_{s1} - t_{s4} / 2)) / A_{stem} =$ **1088** mm
Area of wall base	$A_{base} = l_{base} \times t_{base} =$ **0** m^2
- Distance to vertical component	$x_{base} = l_{base} / 2 =$ **1250** mm
Area of moist soil	$A_{moist} = l_{heel} \times h_{s1} + (l_{heel} + t_{s1} - t_{s2}) \times h_{s2} + (l_{heel} + t_{s1} - t_{s3}) \times h_{s3} + (l_{heel} + t_{s1} - t_{s4}) \times h_{s4} =$ **1.79** m^2
- Distance to vertical component	$x_{moist\_v} = l_{base} - (l_{heel} \times h_{s1} \times l_{heel} / 2 + (l_{heel} + t_{s1} - t_{s2}) \times h_{s2} \times (l_{heel} + t_{s1} - t_{s2}) / 2 + (l_{heel} + t_{s1} - t_{s3}) \times h_{s3} \times (l_{heel} + t_{s1} - t_{s3}) / 2 + (l_{heel} + t_{s1} - t_{s4}) \times h_{s4} \times (l_{heel} + t_{s1} - t_{s4}) / 2) / A_{moist} =$ **1834** mm
- Distance to horizontal component	$x_{moist\_h} = h_{eff} / 3 =$ **1100** 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	$\gamma_{mr}' = \gamma_{mr} / \gamma_\gamma$ = **17** kN/m^3
Design saturated density	$\gamma_{sr}' = \gamma_{sr} / \gamma_\gamma$ = **20.5** kN/m^3
Design effective shear resistance angle	$\phi'_{r.d} = \text{atan}(\tan(\phi'_{r.k}) / \gamma_{\phi'})$ = **30** deg
Design wall friction angle	$\delta_{r.d} = \text{atan}(\tan(\delta_{r.k}) / \gamma_{\phi'})$ = **15** deg

Base soil properties

Design soil density	$\gamma_b' = \gamma_b / \gamma_\gamma$ = **18** kN/m^3
Design effective shear resistance angle	$\phi'_{b.d} = \text{atan}(\tan(\phi'_{b.k}) / \gamma_{\phi'})$ = **40** deg
Design wall friction angle	$\delta_{b.d} = \text{atan}(\tan(\delta_{b.k}) / \gamma_{\phi'})$ = **20** 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 Rankine theory

At rest pressure coefficient	$K_0 = 1 - \sin(\phi'_{r.d})$ = **0.500**
Passive pressure coefficient	$K_P = (1 + \sin(\phi'_{b.d})) / (1 - \sin(\phi'_{b.d}))$ = **4.599**

Sliding check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem}$ = **161.5** kN/m
Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base}$ = **0** kN/m
Line loads	$F_{P\_v} = \gamma_{Gf} \times P_{G1}$ = **5** kN/m
Moist retained soil	$F_{moist\_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}'$ = **30.4** kN/m
Total	$F_{total\_v} = F_{stem} + F_{base} + F_{P\_v} + F_{moist\_v}$ = **196.9** kN/m

Horizontal forces on wall

Surcharge load	$F_{sur\_h} = K_0 \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff}$ = **49.5** kN/m
Moist retained soil	$F_{moist\_h} = \gamma_G \times K_0 \times \gamma_{mr}' \times h_{eff}^2 / 2$ = **62.5** kN/m
Total	$F_{total\_h} = F_{sur\_h} + F_{moist\_h}$ = **112** kN/m

Check stability against sliding

Base soil resistance	$F_{exc\_h} = \gamma_{Gf} \times K_P \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2$ = **26.5** kN/m
Base friction	$F_{friction} = F_{total\_v} \times \tan(\delta_{bb.d})$ = **113.7** kN/m
Resistance to sliding	$F_{rest} = F_{exc\_h} + F_{friction}$ = **140.2** kN/m
Factor of safety	$FoS_{sl} = F_{rest} / F_{total\_h}$ = **1.252**

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem}$ = **161.5** kN/m

Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} =$ **0** kN/m
Line loads	$F_{P\_v} = \gamma_{Gf} \times P_{G1} =$ **5** kN/m
Moist retained soil	$F_{moist\_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' =$ **30.4** kN/m
Total	$F_{total\_v} = F_{stem} + F_{base} + F_{P\_v} + F_{moist\_v} =$ **196.9** kN/m
Horizontal forces on wall	
Surcharge load	$F_{sur\_h} = K_0 \times \gamma_Q \times Surcharge_Q \times h_{eff} =$ **49.5** kN/m
Moist retained soil	$F_{moist\_h} = \gamma_G \times K_0 \times \gamma_{mr}' \times h_{eff}^2 / 2 =$ **62.5** kN/m
Base soil	$F_{exc\_h} = -\gamma_{Gf} \times K_P \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 =$ **-26.5** kN/m
Total	$F_{total\_h} = F_{sur\_h} + F_{moist\_h} + F_{exc\_h} =$ **85.5** kN/m
Overturning moments on wall	
Surcharge load	$M_{sur\_OT} = F_{sur\_h} \times x_{sur\_h} =$ **81.7** kNm/m
Moist retained soil	$M_{moist\_OT} = F_{moist\_h} \times x_{moist\_h} =$ **68.7** kNm/m
Total	$M_{total\_OT} = M_{sur\_OT} + M_{moist\_OT} =$ **150.4** kNm/m
Restoring moments on wall	
Wall stem	$M_{stem\_R} = F_{stem} \times x_{stem} =$ **175.7** kNm/m
Wall base	$M_{base\_R} = F_{base} \times x_{base} =$ **0** kNm/m
Line loads	$M_{P\_R} = abs(\gamma_{Gf} \times P_{G1}) \times p_1 =$ **0.8** kNm/m
Moist retained soil	$M_{moist\_R} = F_{moist\_v} \times x_{moist\_v} =$ **55.8** kNm/m
Base soil	$M_{exc\_R} = -F_{exc\_h} \times x_{exc\_h} =$ **7.1** kNm/m
Total	$M_{total\_R} = M_{stem\_R} + M_{base\_R} + M_{P\_R} + M_{moist\_R} + M_{exc\_R} =$ **239.4** 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	$F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem} =$ **218** kN/m
Wall base	$F_{base} = \gamma_G \times A_{base} \times \gamma_{base} =$ **0** kN/m
Surcharge load	$F_{sur\_v} = \gamma_Q \times Surcharge_Q \times (l_{heel} + t_{s1} - t_{s4}) =$ **60** kN/m
Line loads	$F_{P\_v} = \gamma_G \times P_{G1} =$ **6.8** kN/m
Moist retained soil	$F_{moist\_v} = \gamma_G \times A_{moist} \times \gamma_{mr}' =$ **41.1** kN/m
Total	$F_{total\_v} = F_{stem} + F_{base} + F_{sur\_v} + F_{P\_v} + F_{moist\_v} =$ **325.9** kN/m
Horizontal forces on wall	
Surcharge load	$F_{sur\_h} = K_0 \times \gamma_Q \times Surcharge_Q \times h_{eff} =$ **49.5** kN/m
Moist retained soil	$F_{moist\_h} = \gamma_G \times K_0 \times \gamma_{mr}' \times h_{eff}^2 / 2 =$ **62.5** kN/m
Base soil	$F_{pass\_h} = -\gamma_{Gf} \times K_P \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2 =$ **-26.5** 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	$M_{stem} = F_{stem} \times x_{stem} =$ **237.2** kNm/m
Wall base	$M_{base} = F_{base} \times x_{base} =$ **0** kNm/m
Surcharge load	$M_{sur} = F_{sur\_v} \times x_{sur\_v} - F_{sur\_h} \times x_{sur\_h} =$ **8.3** kNm/m
Line loads	$M_P = \gamma_G \times P_{G1} \times p_1 =$ **1** kNm/m
Moist retained soil	$M_{moist} = F_{moist\_v} \times x_{moist\_v} - F_{moist\_h} \times x_{moist\_h} =$ **6.6** kNm/m
Base soil	$M_{pass} = -F_{pass\_h} \times x_{pass\_h} =$ **7.1** kNm/m

Total	$M_{total} = M_{stem} + M_{base} + M_{sur} + M_P + M_{moist} + M_{pass} =$ **260.3** kNm/m
Check bearing pressure	
Distance to reaction	$\bar{x} = M_{total} / F_{total\_v} =$ **799** mm
Eccentricity of reaction	$e = \bar{x} - l_{base} / 2 =$ **-451** mm
Loaded length of base	$l_{load} = 2 \times \bar{x} =$ **1597** mm
Bearing pressure at toe	$q_{toe} = F_{total\_v} / l_{load} =$ **204** kN/m^2
Bearing pressure at heel	$q_{heel} =$ **0** kN/m^2
Effective overburden pressure	$q = (t_{base} + d_{cover}) \times \gamma_b' =$ **14.4** kN/m^2
Design effective overburden pressure	$q' = q / \gamma_\gamma =$ **14.4** kN/m^2
Bearing resistance factors	$N_q = Exp(\pi \times \tan(\phi'_{b.d})) \times (\tan(45 \text{ deg} + \phi'_{b.d} / 2))^2 =$ **64.195**
	$N_c = (N_q - 1) \times \cot(\phi'_{b.d}) =$ **75.313**
	$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b.d}) =$ **106.054**
Foundation shape factors	$s_q = 1$
	$s_\gamma = 1$
	$s_c = 1$
Load inclination factors	$H = F_{sur\_h} + F_{moist\_h} + F_{pass\_h} =$ **85.5** kN/m
	$V = F_{total\_v} =$ **325.9** kN/m
	$m = 2$
	$i_q = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^m =$ **0.544**
	$i_\gamma = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^{(m+1)} =$ **0.401**
	$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b.d})) =$ **0.537**
Net ultimate bearing capacity	
	$n_f = c'_{b.d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_b' \times l_{load} \times N_\gamma \times s_\gamma \times i_\gamma =$ **1115** kN/m^2
Factor of safety	$FoS_{bp} = n_f / \max(q_{toe}, q_{heel}) =$ **5.466**
	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	$\gamma_G =$ **1.00**
Permanent favourable action	$\gamma_{Gf} =$ **1.00**
Variable unfavourable action	$\gamma_Q =$ **1.30**
Variable favourable action	$\gamma_{Qf} =$ **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	$\gamma_\gamma =$ **1.00**
	Library item Partial factors output
Retained soil properties	
Design moist density	$\gamma_{mr}' = \gamma_{mr} / \gamma_\gamma =$ **17** kN/m^3
Design saturated density	$\gamma_{sr}' = \gamma_{sr} / \gamma_\gamma =$ **20.5** kN/m^3
Design effective shear resistance angle	$\phi'_{r.d} = atan(\tan(\phi'_{r.k}) / \gamma_{\phi'}) =$ **24.8** deg
Design wall friction angle	$\delta_{r.d} = atan(\tan(\delta_{r.k}) / \gamma_{\phi'}) =$ **12.1** deg
Base soil properties	
Design soil density	$\gamma_b' = \gamma_b / \gamma_\gamma =$ **18** kN/m^3

Design effective shear resistance angle	$\phi'_{b.d} = \text{atan}(\tan(\phi'_{b.k}) / \gamma_{\phi'}) =$ **33.9** deg
Design wall friction angle	$\delta_{b.d} = \text{atan}(\tan(\delta_{b.k}) / \gamma_{\phi'}) =$ **16.2** deg
Design base friction angle	$\delta_{bb.d} = \text{atan}(\tan(\delta_{bb.k}) / \gamma_{\phi'}) =$ **24.8** deg
Design effective cohesion	$c'_{b.d} = c'_{b.k} / \gamma_{c'} =$ **0** kN/m^2
Using Rankine theory	
At rest pressure coefficient	$K_0 = 1 - \sin(\phi'_{r.d}) =$ **0.581**
Passive pressure coefficient	$K_P = (1 + \sin(\phi'_{b.d})) / (1 - \sin(\phi'_{b.d})) =$ **3.518**
Sliding check	
Vertical forces on wall	
Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} =$ **161.5** kN/m
Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} =$ **0** kN/m
Line loads	$F_{P\_v} = \gamma_{Gf} \times P_{G1} =$ **5** kN/m
Moist retained soil	$F_{moist\_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' =$ **30.4** kN/m
Total	$F_{total\_v} = F_{stem} + F_{base} + F_{P\_v} + F_{moist\_v} =$ **196.9** kN/m
Horizontal forces on wall	
Surcharge load	$F_{sur\_h} = K_0 \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} =$ **49.8** kN/m
Moist retained soil	$F_{moist\_h} = \gamma_G \times K_0 \times \gamma_{mr}' \times h_{eff}^2 / 2 =$ **53.8** kN/m
Total	$F_{total\_h} = F_{sur\_h} + F_{moist\_h} =$ **103.6** kN/m
Check stability against sliding	
Base soil resistance	$F_{exc\_h} = \gamma_{Gf} \times K_P \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 =$ **20.3** kN/m
Base friction	$F_{friction} = F_{total\_v} \times \tan(\delta_{bb.d}) =$ **91** kN/m
Resistance to sliding	$F_{rest} = F_{exc\_h} + F_{friction} =$ **111.2** kN/m
Factor of safety	$FoS_{sl} = F_{rest} / F_{total\_h} =$ **1.074**
	PASS - Resistance to sliding is greater than sliding force
Overturning check	
Vertical forces on wall	
Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} =$ **161.5** kN/m
Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} =$ **0** kN/m
Line loads	$F_{P\_v} = \gamma_{Gf} \times P_{G1} =$ **5** kN/m
Moist retained soil	$F_{moist\_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' =$ **30.4** kN/m
Total	$F_{total\_v} = F_{stem} + F_{base} + F_{P\_v} + F_{moist\_v} =$ **196.9** kN/m
Horizontal forces on wall	
Surcharge load	$F_{sur\_h} = K_0 \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} =$ **49.8** kN/m
Moist retained soil	$F_{moist\_h} = \gamma_G \times K_0 \times \gamma_{mr}' \times h_{eff}^2 / 2 =$ **53.8** kN/m
Base soil	$F_{exc\_h} = -\gamma_{Gf} \times K_P \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 =$ **-20.3** kN/m
Total	$F_{total\_h} = F_{sur\_h} + F_{moist\_h} + F_{exc\_h} =$ **83.3** kN/m
Overturning moments on wall	
Surcharge load	$M_{sur\_OT} = F_{sur\_h} \times x_{sur\_h} =$ **82.2** kNm/m
Moist retained soil	$M_{moist\_OT} = F_{moist\_h} \times x_{moist\_h} =$ **59.1** kNm/m
Total	$M_{total\_OT} = M_{sur\_OT} + M_{moist\_OT} =$ **141.3** kNm/m
Restoring moments on wall	
Wall stem	$M_{stem\_R} = F_{stem} \times x_{stem} =$ **175.7** kNm/m
Wall base	$M_{base\_R} = F_{base} \times x_{base} =$ **0** kNm/m
Line loads	$M_{P\_R} = \text{abs}(\gamma_{Gf} \times P_{G1}) \times p_1 =$ **0.8** kNm/m

Moist retained soil	$M_{moist\_R} = F_{moist\_v} \times x_{moist\_v}$ = **55.8** kNm/m
Base soil	$M_{exc\_R} = -F_{exc\_h} \times x_{exc\_h}$ = **5.4** kNm/m
Total	$M_{total\_R} = M_{stem\_R} + M_{base\_R} + M_{P\_R} + M_{moist\_R} + M_{exc\_R}$ = **237.7** kNm/m

Check stability against overturning

Factor of safety	$FoS_{ot} = M_{total\_R} / M_{total\_OT}$ = **1.682**
	PASS - Maximum restoring moment is greater than overturning moment

Bearing pressure check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem}$ = **161.5** kN/m
Wall base	$F_{base} = \gamma_G \times A_{base} \times \gamma_{base}$ = **0** kN/m
Surcharge load	$F_{sur\_v} = \gamma_Q \times Surcharge_Q \times (l_{heel} + t_{s1} - t_{s4})$ = **52** kN/m
Line loads	$F_{P\_v} = \gamma_G \times P_{G1}$ = **5** kN/m
Moist retained soil	$F_{moist\_v} = \gamma_G \times A_{moist} \times \gamma_{mr}'$ = **30.4** kN/m
Total	$F_{total\_v} = F_{stem} + F_{base} + F_{sur\_v} + F_{P\_v} + F_{moist\_v}$ = **248.9** kN/m

Horizontal forces on wall

Surcharge load	$F_{sur\_h} = K_0 \times \gamma_Q \times Surcharge_Q \times h_{eff}$ = **49.8** kN/m
Moist retained soil	$F_{moist\_h} = \gamma_G \times K_0 \times \gamma_{mr}' \times h_{eff}^2 / 2$ = **53.8** kN/m
Base soil	$F_{pass\_h} = -\gamma_{Gf} \times K_P \times \gamma_b' \times (d_{cover} + h_{base})^2 / 2$ = **-20.3** 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	$M_{stem} = F_{stem} \times x_{stem}$ = **175.7** kNm/m
Wall base	$M_{base} = F_{base} \times x_{base}$ = **0** kNm/m
Surcharge load	$M_{sur} = F_{sur\_v} \times x_{sur\_v} - F_{sur\_h} \times x_{sur\_h}$ = **-4.2** kNm/m
Line loads	$M_P = \gamma_G \times P_{G1} \times p_1$ = **0.8** kNm/m
Moist retained soil	$M_{moist} = F_{moist\_v} \times x_{moist\_v} - F_{moist\_h} \times x_{moist\_h}$ = **-3.3** kNm/m
Base soil	$M_{pass} = -F_{pass\_h} \times x_{pass\_h}$ = **5.4** kNm/m
Total	$M_{total} = M_{stem} + M_{base} + M_{sur} + M_P + M_{moist} + M_{pass}$ = **174.4** kNm/m

Check bearing pressure

Distance to reaction	$\bar{x} = M_{total} / F_{total\_v}$ = **700** mm
Eccentricity of reaction	$e = \bar{x} - l_{base} / 2$ = **-550** mm
Loaded length of base	$l_{load} = 2 \times \bar{x}$ = **1401** mm
Bearing pressure at toe	$q_{toe} = F_{total\_v} / l_{load}$ = **177.7** kN/m^2
Bearing pressure at heel	q_{heel} = **0** kN/m^2
Effective overburden pressure	$q = (t_{base} + d_{cover}) \times \gamma_b'$ = **14.4** kN/m^2
Design effective overburden pressure	$q' = q / \gamma_\gamma$ = **14.4** kN/m^2
Bearing resistance factors	$N_q = Exp(\pi \times \tan(\phi'_{b.d})) \times (\tan(45\ deg + \phi'_{b.d} / 2))^2$ = **28.987**
	$N_c = (N_q - 1) \times \cot(\phi'_{b.d})$ = **41.692**
	$N_\gamma = 2 \times (N_q - 1) \times \tan(\phi'_{b.d})$ = **37.574**
Foundation shape factors	$s_q = 1$
	$s_\gamma = 1$
	$s_c = 1$
Load inclination factors	$H = F_{sur\_h} + F_{moist\_h} + F_{pass\_h}$ = **83.3** kN/m
	$V = F_{total\_v}$ = **248.9** kN/m
	$m = 2$

$i_q = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^m$ = **0.443**

$i_\gamma = [1 - H / (V + l_{load} \times c'_{b.d} \times \cot(\phi'_{b.d}))]^{(m + 1)}$ = **0.295**

$i_c = i_q - (1 - i_q) / (N_c \times \tan(\phi'_{b.d}))$ = **0.423**

Net ultimate bearing capacity

$n_f = c'_{b.d} \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma_b' \times l_{load} \times N_\gamma \times s_\gamma \times i_\gamma$ = **324.3** kN/m^2

Factor of safety

$FoS_{bp} = n_f / \max(q_{toe}, q_{heel})$ = **1.825**

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure