



Vale Consultancy
CONSULTING CIVIL & STRUCTURAL ENGINEERS

Title: Structural Calculations for retaining wall
Project: 20 Daphne Road, SA10 8DP
Client: Craig Gorman

Document No: 001
Project No: N2599
Prepared By: NL
Checked By: MJ

Revision: -

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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

Analysis summary

Description	Unit	Capacity	Applied	F o S	Result
Sliding stability	kN/m	12.8	11.3	1.130	PASS
Overturning stability	kNm/m	9.9	6.1	1.629	PASS
Bearing pressure	kN/m ²	100	20.2	4.959	PASS

Retaining wall details

Stem type	Cantilever with stepped rear face
Stem height	$h_{\text{stem}} = 1100 \text{ mm}$
Number of steps	$N_{\text{steps}} = 1$
Height of step 1	$h_{s1} = 1100 \text{ mm}$
Thickness of step 1	$t_{s1} = 315 \text{ mm}$
Angle to rear face of stem	$\alpha = 90 \text{ deg}$
Stem density	$\gamma_{\text{stem}} = 25 \text{ kN/m}^3$
Toe length	$l_{\text{toe}} = 485 \text{ mm}$
Heel length	$l_{\text{heel}} = 50 \text{ mm}$
Base thickness	$t_{\text{base}} = 250 \text{ mm}$
Base density	$\gamma_{\text{base}} = 25 \text{ kN/m}^3$
Height of retained soil	$h_{\text{ret}} = 600 \text{ mm}$
Angle of soil surface	$\beta = 0 \text{ deg}$
Depth of cover	$d_{\text{cover}} = 200 \text{ mm}$
Height of water	$h_{\text{water}} = 100 \text{ mm}$
Water density	$\gamma_w = 9.8 \text{ kN/m}^3$

Retained soil properties

Soil type	Medium dense well graded sand
Moist density	$\gamma_{\text{mr}} = 21 \text{ kN/m}^3$
Saturated density	$\gamma_{\text{sr}} = 23 \text{ kN/m}^3$
Characteristic effective shear resistance angle	$\phi'_{r,k} = 30 \text{ deg}$
Characteristic wall friction angle	$\delta_{r,k} = 0 \text{ deg}$

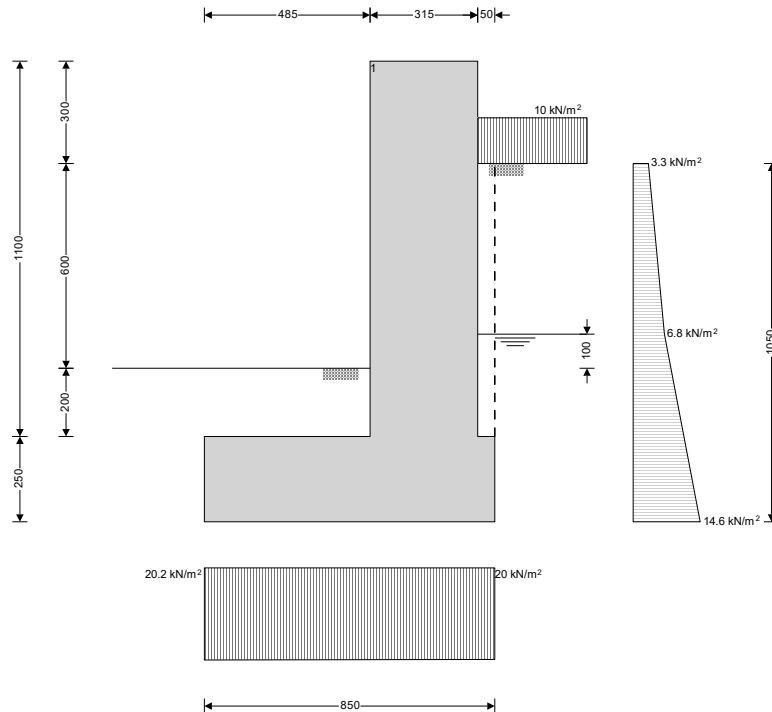
Base soil properties

Soil type	Medium dense well graded sand
Soil density	$\gamma_b = 18 \text{ kN/m}^3$
Characteristic effective shear resistance angle	$\phi'_{b,k} = 30 \text{ deg}$
Characteristic wall friction angle	$\delta_{b,k} = 15 \text{ deg}$
Characteristic base friction angle	$\delta_{bb,k} = 30 \text{ deg}$
Presumed bearing capacity	$P_{\text{bearing}} = 100 \text{ kN/m}^2$

Loading details

Variable surcharge load	Surcharge _Q = 10 kN/m ²
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General arrangement

Calculate retaining wall geometry

Base length

$$l_{base} = l_{toe} + t_{s1} + l_{heel} = \mathbf{850 \text{ mm}}$$

Saturated soil height

$$h_{sat} = h_{water} + d_{cover} = \mathbf{300 \text{ mm}}$$

Moist soil height

$$h_{moist} = h_{ret} - h_{water} = \mathbf{500 \text{ mm}}$$

Length of surcharge load

$$l_{sur} = (l_{heel} + t_{s1} - t_{s1}) = \mathbf{50 \text{ mm}}$$

- Distance to vertical component

$$x_{sur_v} = l_{base} - (l_{heel} + t_{s1} - t_{s1}) / 2 = \mathbf{825 \text{ mm}}$$

Effective height of wall

$$h_{eff} = h_{base} + d_{cover} + h_{ret} = \mathbf{1050 \text{ mm}}$$

- Distance to horizontal component

$$x_{sur_h} = h_{eff} / 2 = \mathbf{525 \text{ mm}}$$

Area of wall stem

$$A_{stem} = h_{s1} \times t_{s1} = \mathbf{0.347 \text{ m}^2}$$

- Distance to vertical component

$$x_{stem} = l_{base} - (h_{s1} \times t_{s1} \times (l_{heel} + t_{s1} - t_{s1} / 2)) / A_{stem} = \mathbf{643 \text{ mm}}$$

Area of wall base

$$A_{base} = l_{base} \times t_{base} = \mathbf{0.213 \text{ m}^2}$$

- Distance to vertical component

$$x_{base} = l_{base} / 2 = \mathbf{425 \text{ mm}}$$

Area of saturated soil

$$A_{sat} = l_{heel} \times h_{sat} = \mathbf{0.015 \text{ m}^2}$$

- Distance to vertical component

$$x_{sat_v} = l_{base} - (l_{heel} \times h_{sat} \times l_{heel} / 2) / A_{sat} = \mathbf{825 \text{ mm}}$$

- Distance to horizontal component

$$x_{sat_h} = (h_{sat} + h_{base}) / 3 = \mathbf{183 \text{ mm}}$$

Area of water

$$A_{water} = l_{heel} \times h_{sat} = \mathbf{0.015 \text{ m}^2}$$

- Distance to vertical component

$$x_{water_v} = l_{base} - (l_{heel} \times h_{sat} \times l_{heel} / 2) / A_{sat} = \mathbf{825 \text{ mm}}$$

- Distance to uplift component

$$x_{water_u} = 2 \times l_{base} / 3 = \mathbf{567 \text{ mm}}$$

- Distance to horizontal component

$$x_{water_h} = (h_{sat} + h_{base}) / 3 = \mathbf{183 \text{ mm}}$$

Area of moist soil

$$A_{moist} = l_{heel} \times (h_{soil} - h_{sat}) = \mathbf{0.025 \text{ m}^2}$$

- Distance to vertical component

$$x_{moist_v} = l_{base} - (l_{heel} \times (h_{soil} - h_{sat}) \times l_{heel} / 2) / A_{moist} = \mathbf{825 \text{ mm}}$$

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- Distance to horizontal component

$$x_{\text{moist}_h} = (h_{\text{moist}} \times (t_{\text{base}} + h_{\text{sat}} + h_{\text{moist}} / 3) / 2 + (h_{\text{sat}} + t_{\text{base}})^2 / 2) / (h_{\text{sat}} + t_{\text{base}} + h_{\text{moist}} / 2) = \mathbf{413 \text{ mm}}$$

Area of base soil

$$A_{\text{pass}} = d_{\text{cover}} \times l_{\text{toe}} = \mathbf{0.097 \text{ m}^2}$$

- Distance to vertical component

$$x_{\text{pass}_v} = l_{\text{base}} - (d_{\text{cover}} \times l_{\text{toe}} \times (l_{\text{base}} - l_{\text{toe}} / 2)) / A_{\text{pass}} = \mathbf{242 \text{ mm}}$$

- Distance to horizontal component

$$x_{\text{pass}_h} = (d_{\text{cover}} + h_{\text{base}}) / 3 = \mathbf{150 \text{ mm}}$$

Area of excavated base soil

$$A_{\text{exc}} = h_{\text{pass}} \times l_{\text{toe}} = \mathbf{0.097 \text{ m}^2}$$

- Distance to vertical component

$$x_{\text{exc}_v} = l_{\text{base}} - (h_{\text{pass}} \times l_{\text{toe}} \times (l_{\text{base}} - l_{\text{toe}} / 2)) / A_{\text{exc}} = \mathbf{242 \text{ mm}}$$

- Distance to horizontal component

$$x_{\text{exc}_h} = (h_{\text{pass}} + h_{\text{base}}) / 3 = \mathbf{150 \text{ mm}}$$

Using Coulomb theory

Active pressure coefficient

$$K_A = \sin(\alpha + \phi'_{r,k})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,k}) \times [1 + \sqrt{[\sin(\phi'_{r,k} + \delta_{r,k}) \times \sin(\phi'_{r,k} - \beta) / (\sin(\alpha - \delta_{r,k}) \times \sin(\alpha + \beta))]}]) = \mathbf{0.333}$$

Passive pressure coefficient

$$K_P = \sin(90 - \phi'_{b,k})^2 / (\sin(90 + \delta_{b,k}) \times [1 - \sqrt{[\sin(\phi'_{b,k} + \delta_{b,k}) \times \sin(\phi'_{b,k}) / (\sin(90 + \delta_{b,k}))]}]) = \mathbf{4.977}$$

Bearing pressure check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = A_{\text{stem}} \times \gamma_{\text{stem}} = \mathbf{8.7 \text{ kN/m}}$$

Wall base

$$F_{\text{base}} = A_{\text{base}} \times \gamma_{\text{base}} = \mathbf{5.3 \text{ kN/m}}$$

Surcharge load

$$F_{\text{sur}_v} = \text{Surcharge}_Q \times (l_{\text{heel}} + t_{s1} - t_{s1}) = \mathbf{0.5 \text{ kN/m}}$$

Saturated retained soil

$$F_{\text{sat}_v} = A_{\text{sat}} \times (\gamma_{\text{sr}} - \gamma_w) = \mathbf{0.2 \text{ kN/m}}$$

Water

$$F_{\text{water}_v} = A_{\text{water}} \times \gamma_w = \mathbf{0.1 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_v} = A_{\text{moist}} \times \gamma_{\text{mr}} = \mathbf{0.5 \text{ kN/m}}$$

Base soil

$$F_{\text{pass}_v} = A_{\text{pass}} \times \gamma_b = \mathbf{1.7 \text{ kN/m}}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{sur}_v} + F_{\text{sat}_v} + F_{\text{water}_v} + F_{\text{moist}_v} + F_{\text{pass}_v} = \mathbf{17.1 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_A \times \text{Surcharge}_Q \times h_{\text{eff}} = \mathbf{3.5 \text{ kN/m}}$$

Saturated retained soil

$$F_{\text{sat}_h} = K_A \times (\gamma_{\text{sr}} - \gamma_w) \times (h_{\text{sat}} + h_{\text{base}})^2 / 2 = \mathbf{0.7 \text{ kN/m}}$$

Water

$$F_{\text{water}_h} = \gamma_w \times (h_{\text{water}} + d_{\text{cover}} + h_{\text{base}})^2 / 2 = \mathbf{1.5 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_h} = K_A \times \gamma_{\text{mr}} \times ((h_{\text{eff}} - h_{\text{sat}} - h_{\text{base}})^2 / 2 + (h_{\text{eff}} - h_{\text{sat}} - h_{\text{base}}) \times (h_{\text{sat}} + h_{\text{base}})) = \mathbf{2.8 \text{ kN/m}}$$

Base soil

$$F_{\text{pass}_h} = \max(-K_P \times \cos(\delta_{b,k}) \times \gamma_b \times (d_{\text{cover}} + h_{\text{base}})^2 / 2, -(F_{\text{sat}_h} + F_{\text{moist}_h} + F_{\text{water}_h} + F_{\text{sur}_h})) = \mathbf{-8.4 \text{ kN/m}}$$

Total

$$F_{\text{total}_h} = \max(F_{\text{sur}_h} + F_{\text{sat}_h} + F_{\text{water}_h} + F_{\text{moist}_h} + F_{\text{pass}_h} - F_{\text{total}_v} \times \tan(\delta_{bb,k}), 0 \text{ kN/m}) = \mathbf{0 \text{ kN/m}}$$

Moments on wall

Wall stem

$$M_{\text{stem}} = F_{\text{stem}} \times x_{\text{stem}} = \mathbf{5.6 \text{ kNm/m}}$$

Wall base

$$M_{\text{base}} = F_{\text{base}} \times x_{\text{base}} = \mathbf{2.3 \text{ kNm/m}}$$

Surcharge load

$$M_{\text{sur}} = F_{\text{sur}_v} \times x_{\text{sur}_v} - F_{\text{sur}_h} \times x_{\text{sur}_h} = \mathbf{-1.4 \text{ kNm/m}}$$

Saturated retained soil

$$M_{\text{sat}} = F_{\text{sat}_v} \times x_{\text{sat}_v} - F_{\text{sat}_h} \times x_{\text{sat}_h} = \mathbf{0 \text{ kNm/m}}$$

Water

$$M_{\text{water}} = F_{\text{water}_v} \times x_{\text{water}_v} - F_{\text{water}_h} \times x_{\text{water}_h} = \mathbf{-0.2 \text{ kNm/m}}$$

Moist retained soil

$$M_{\text{moist}} = F_{\text{moist}_v} \times x_{\text{moist}_v} - F_{\text{moist}_h} \times x_{\text{moist}_h} = \mathbf{-0.7 \text{ kNm/m}}$$

Base soil

$$M_{\text{pass}} = F_{\text{pass}_v} \times x_{\text{pass}_v} - F_{\text{pass}_h} \times x_{\text{pass}_h} = \mathbf{1.7 \text{ kNm/m}}$$

Total

$$M_{\text{total}} = M_{\text{stem}} + M_{\text{base}} + M_{\text{sur}} + M_{\text{sat}} + M_{\text{water}} + M_{\text{moist}} + M_{\text{pass}} = \mathbf{7.3 \text{ kNm/m}}$$

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Check bearing pressure

Distance to reaction

$$\bar{x} = M_{\text{total}} / F_{\text{total}_v} = \mathbf{425 \text{ mm}}$$

Eccentricity of reaction

$$e = \bar{x} - l_{\text{base}} / 2 = \mathbf{-0 \text{ mm}}$$

Loaded length of base

$$l_{\text{load}} = l_{\text{base}} = \mathbf{850 \text{ mm}}$$

Bearing pressure at toe

$$q_{\text{toe}} = F_{\text{total}_v} / l_{\text{base}} \times (1 - 6 \times e / l_{\text{base}}) = \mathbf{20.2 \text{ kN/m}^2}$$

Bearing pressure at heel

$$q_{\text{heel}} = F_{\text{total}_v} / l_{\text{base}} \times (1 + 6 \times e / l_{\text{base}}) = \mathbf{20 \text{ kN/m}^2}$$

Factor of safety

$$FoS_{bp} = P_{\text{bearing}} / \max(q_{\text{toe}}, q_{\text{heel}}) = \mathbf{4.959}$$

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

Design approach 1

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

Partial factor set

A1

Permanent unfavourable action

$$\gamma_G = \mathbf{1.35}$$

Permanent favourable action

$$\gamma_{Gf} = \mathbf{1.00}$$

Variable unfavourable action

$$\gamma_Q = \mathbf{1.50}$$

Variable favourable action

$$\gamma_{Qf} = \mathbf{0.00}$$

Partial factors for soil parameters – Table A.4 - Combination 1

Soil parameter set

M1

Angle of shearing resistance

$$\gamma_{\phi'} = \mathbf{1.00}$$

Effective cohesion

$$\gamma_{c'} = \mathbf{1.00}$$

Weight density

$$\gamma_{\gamma} = \mathbf{1.00}$$

Library item Partial factors output

Water properties

Design water density

$$\gamma_w' = \gamma_w / \gamma_{\gamma} = \mathbf{9.8 \text{ kN/m}^3}$$

Retained soil properties

Design moist density

$$\gamma_{mr}' = \gamma_{mr} / \gamma_{\gamma} = \mathbf{21 \text{ kN/m}^3}$$

Design saturated density

$$\gamma_{sr}' = \gamma_{sr} / \gamma_{\gamma} = \mathbf{23 \text{ kN/m}^3}$$

Design effective shear resistance angle

$$\phi'_{r,d} = \text{atan}(\tan(\phi'_{r,k}) / \gamma_{\phi'}) = \mathbf{30 \text{ deg}}$$

Design wall friction angle

$$\delta_{r,d} = \text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}) = \mathbf{0 \text{ deg}}$$

Base soil properties

Design soil density

$$\gamma_b' = \gamma_b / \gamma_{\gamma} = \mathbf{18 \text{ kN/m}^3}$$

Design effective shear resistance angle

$$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_{\phi'}) = \mathbf{30 \text{ deg}}$$

Design wall friction angle

$$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_{\phi'}) = \mathbf{15 \text{ deg}}$$

Design base friction angle

$$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_{\phi'}) = \mathbf{30 \text{ deg}}$$

Design effective cohesion

$$c'_{b,d} = c'_{b,k} / \gamma_{c'} = \mathbf{0 \text{ kN/m}^2}$$

Using Coulomb theory

Active pressure coefficient

$$K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times [1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))}]^2) = \mathbf{0.333}$$

Passive pressure coefficient

$$K_P = \sin(90 - \phi'_{b,d})^2 / (\sin(90 + \delta_{b,d}) \times [1 - \sqrt{(\sin(\phi'_{b,d} + \delta_{b,d}) \times \sin(\phi'_{b,d}) / (\sin(90 + \delta_{b,d}))}]^2) = \mathbf{4.977}$$

Sliding check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = \gamma_{Gf} \times A_{\text{stem}} \times \gamma_{\text{stem}} = \mathbf{8.7 \text{ kN/m}}$$

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Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = 5.3 \text{ kN/m}$
Saturated retained soil	$F_{sat_v} = \gamma_{Gf} \times A_{sat} \times (\gamma_{sr}' - \gamma_w') = 0.2 \text{ kN/m}$
Water	$F_{water_v} = \gamma_{Gf} \times A_{water} \times \gamma_w' = 0.1 \text{ kN/m}$
Water uplift	$F_{water_u} = \gamma_{Gf} \times (h_{sat} + t_{base}) \times l_{base} / 2 \times \gamma_w' = 2.3 \text{ kN/m}$
Moist retained soil	$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' = 0.5 \text{ kN/m}$
Base soil	$F_{exc_v} = \gamma_{Gf} \times A_{exc} \times \gamma_b' = 1.7 \text{ kN/m}$
Total	$F_{total_v} = F_{stem} + F_{base} + F_{sat_v} + F_{water_v} - F_{water_u} + F_{moist_v} + F_{exc_v} = 14.3 \text{ kN/m}$

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} = 5.3 \text{ kN/m}$
Saturated retained soil	$F_{sat_h} = \gamma_G \times K_A \times (\gamma_{sr}' - \gamma_w') \times (h_{sat} + h_{base})^2 / 2 = 0.9 \text{ kN/m}$
Water	$F_{water_h} = \gamma_G \times \gamma_w' \times (h_{water} + d_{cover} + h_{base})^2 / 2 = 2 \text{ kN/m}$
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \gamma_{mr}' \times ((h_{eff} - h_{sat} - h_{base})^2 / 2 + (h_{eff} - h_{sat} - h_{base}) \times (h_{sat} + h_{base})) = 3.8 \text{ kN/m}$
Total	$F_{total_h} = F_{sur_h} + F_{sat_h} + F_{water_h} + F_{moist_h} = 11.9 \text{ kN/m}$

Check stability against sliding

Base soil resistance	$F_{exc_h} = \gamma_{Gf} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = 8.8 \text{ kN/m}$
Base friction	$F_{friction} = F_{total_v} \times \tan(\delta_{bb,d}) = 8.3 \text{ kN/m}$
Resistance to sliding	$F_{rest} = F_{exc_h} + F_{friction} = 17 \text{ kN/m}$
Factor of safety	$FoS_{sl} = F_{rest} / F_{total_h} = 1.426$

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = 8.7 \text{ kN/m}$
Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = 5.3 \text{ kN/m}$
Saturated retained soil	$F_{sat_v} = \gamma_{Gf} \times A_{sat} \times (\gamma_{sr}' - \gamma_w') = 0.2 \text{ kN/m}$
Water	$F_{water_v} = \gamma_{Gf} \times A_{water} \times \gamma_w' = 0.1 \text{ kN/m}$
Water uplift	$F_{water_u} = \gamma_{Gf} \times (h_{sat} + t_{base}) \times l_{base} / 2 \times \gamma_w' = 2.3 \text{ kN/m}$
Moist retained soil	$F_{moist_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}' = 0.5 \text{ kN/m}$
Base soil	$F_{exc_v} = \gamma_{Gf} \times A_{exc} \times \gamma_b' = 1.7 \text{ kN/m}$
Total	$F_{total_v} = F_{stem} + F_{base} + F_{sat_v} + F_{water_v} - F_{water_u} + F_{moist_v} + F_{exc_v} = 14.3 \text{ kN/m}$

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} = 5.3 \text{ kN/m}$
Saturated retained soil	$F_{sat_h} = \gamma_G \times K_A \times (\gamma_{sr}' - \gamma_w') \times (h_{sat} + h_{base})^2 / 2 = 0.9 \text{ kN/m}$
Water	$F_{water_h} = \gamma_G \times \gamma_w' \times (h_{water} + d_{cover} + h_{base})^2 / 2 = 2 \text{ kN/m}$
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \gamma_{mr}' \times ((h_{eff} - h_{sat} - h_{base})^2 / 2 + (h_{eff} - h_{sat} - h_{base}) \times (h_{sat} + h_{base})) = 3.8 \text{ kN/m}$
Base soil	$F_{exc_h} = -\gamma_{Gf} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = -8.8 \text{ kN/m}$
Total	$F_{total_h} = F_{sur_h} + F_{sat_h} + F_{water_h} + F_{moist_h} + F_{exc_h} = 3.2 \text{ kN/m}$

Overturning moments on wall

Surcharge load	$M_{sur_OT} = F_{sur_h} \times X_{sur_h} = 2.8 \text{ kNm/m}$
Saturated retained soil	$M_{sat_OT} = F_{sat_h} \times X_{sat_h} = 0.2 \text{ kNm/m}$
Water	$M_{water_OT} = F_{water_h} \times X_{water_h} + F_{water_u} \times X_{water_u} = 1.7 \text{ kNm/m}$

Moist retained soil

$$M_{\text{moist_OT}} = F_{\text{moist_h}} \times X_{\text{moist_h}} = \mathbf{1.6 \text{ kNm/m}}$$

Total

$$M_{\text{total_OT}} = M_{\text{sur_OT}} + M_{\text{sat_OT}} + M_{\text{water_OT}} + M_{\text{moist_OT}} = \mathbf{6.1 \text{ kNm/m}}$$

Restoring moments on wall

Wall stem

$$M_{\text{stem_R}} = F_{\text{stem}} \times X_{\text{stem}} = \mathbf{5.6 \text{ kNm/m}}$$

Wall base

$$M_{\text{base_R}} = F_{\text{base}} \times X_{\text{base}} = \mathbf{2.3 \text{ kNm/m}}$$

Saturated retained soil

$$M_{\text{sat_R}} = F_{\text{sat_v}} \times X_{\text{sat_v}} = \mathbf{0.2 \text{ kNm/m}}$$

Water

$$M_{\text{water_R}} = F_{\text{water_v}} \times X_{\text{water_v}} = \mathbf{0.1 \text{ kNm/m}}$$

Moist retained soil

$$M_{\text{moist_R}} = F_{\text{moist_v}} \times X_{\text{moist_v}} = \mathbf{0.4 \text{ kNm/m}}$$

Base soil

$$M_{\text{exc_R}} = F_{\text{exc_v}} \times X_{\text{exc_v}} - F_{\text{exc_h}} \times X_{\text{exc_h}} = \mathbf{1.7 \text{ kNm/m}}$$

Total

$$M_{\text{total_R}} = M_{\text{stem_R}} + M_{\text{base_R}} + M_{\text{sat_R}} + M_{\text{water_R}} + M_{\text{moist_R}} + M_{\text{exc_R}} = \mathbf{10.3 \text{ kNm/m}}$$

Check stability against overturning

Factor of safety

$$FoS_{\text{ot}} = M_{\text{total_R}} / M_{\text{total_OT}} = \mathbf{1.672}$$

PASS - Maximum restoring moment is greater than overturning moment

Design approach 1

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

Partial factor set

A2

Permanent unfavourable action

$$\gamma_G = \mathbf{1.00}$$

Permanent favourable action

$$\gamma_{Gf} = \mathbf{1.00}$$

Variable unfavourable action

$$\gamma_Q = \mathbf{1.30}$$

Variable favourable action

$$\gamma_{Qf} = \mathbf{0.00}$$

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

Soil parameter set

M2

Angle of shearing resistance

$$\gamma_{\phi'} = \mathbf{1.25}$$

Effective cohesion

$$\gamma_{c'} = \mathbf{1.25}$$

Weight density

$$\gamma_{\gamma} = \mathbf{1.00}$$

Library item Partial factors output

Water properties

Design water density

$$\gamma_w' = \gamma_w / \gamma_{\gamma} = \mathbf{9.8 \text{ kN/m}^3}$$

Retained soil properties

Design moist density

$$\gamma_{mr}' = \gamma_{mr} / \gamma_{\gamma} = \mathbf{21 \text{ kN/m}^3}$$

Design saturated density

$$\gamma_{sr}' = \gamma_{sr} / \gamma_{\gamma} = \mathbf{23 \text{ kN/m}^3}$$

Design effective shear resistance angle

$$\phi'_{r,d} = \text{atan}(\tan(\phi'_{r,k}) / \gamma_{\phi'}) = \mathbf{24.8 \text{ deg}}$$

Design wall friction angle

$$\delta_{r,d} = \text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}) = \mathbf{0 \text{ deg}}$$

Base soil properties

Design soil density

$$\gamma_b' = \gamma_b / \gamma_{\gamma} = \mathbf{18 \text{ kN/m}^3}$$

Design effective shear resistance angle

$$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_{\phi'}) = \mathbf{24.8 \text{ deg}}$$

Design wall friction angle

$$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_{\phi'}) = \mathbf{12.1 \text{ deg}}$$

Design base friction angle

$$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_{\phi'}) = \mathbf{24.8 \text{ deg}}$$

Design effective cohesion

$$c'_{b,d} = c'_{b,k} / \gamma_{c'} = \mathbf{0 \text{ kN/m}^2}$$

Using Coulomb theory

Active pressure coefficient

$$K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times [1 + \sqrt{(\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))}]^2) = \mathbf{0.409}$$

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Passive pressure coefficient

$$K_P = \sin(90 - \phi'_{b,d})^2 / (\sin(90 + \delta_{b,d}) \times [1 - \sqrt{(\sin(\phi'_{b,d} + \delta_{b,d}) \times \sin(\phi'_{b,d}) / (\sin(90 + \delta_{b,d}))}]^2) = \mathbf{3.473}$$

Sliding check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = \gamma_{\text{Gf}} \times A_{\text{stem}} \times \gamma_{\text{stem}} = \mathbf{8.7 \text{ kN/m}}$$

Wall base

$$F_{\text{base}} = \gamma_{\text{Gf}} \times A_{\text{base}} \times \gamma_{\text{base}} = \mathbf{5.3 \text{ kN/m}}$$

Saturated retained soil

$$F_{\text{sat}_v} = \gamma_{\text{Gf}} \times A_{\text{sat}} \times (\gamma_{\text{sr}}' - \gamma_w') = \mathbf{0.2 \text{ kN/m}}$$

Water

$$F_{\text{water}_v} = \gamma_{\text{Gf}} \times A_{\text{water}} \times \gamma_w' = \mathbf{0.1 \text{ kN/m}}$$

Water uplift

$$F_{\text{water}_u} = \gamma_{\text{Gf}} \times (h_{\text{sat}} + t_{\text{base}}) \times l_{\text{base}} / 2 \times \gamma_w' = \mathbf{2.3 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_v} = \gamma_{\text{Gf}} \times A_{\text{moist}} \times \gamma_{\text{mr}}' = \mathbf{0.5 \text{ kN/m}}$$

Base soil

$$F_{\text{exc}_v} = \gamma_{\text{Gf}} \times A_{\text{exc}} \times \gamma_b' = \mathbf{1.7 \text{ kN/m}}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{sat}_v} + F_{\text{water}_v} - F_{\text{water}_u} + F_{\text{moist}_v} + F_{\text{exc}_v} = \mathbf{14.3 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{\text{eff}} = \mathbf{5.6 \text{ kN/m}}$$

Saturated retained soil

$$F_{\text{sat}_h} = \gamma_G \times K_A \times (\gamma_{\text{sr}}' - \gamma_w') \times (h_{\text{sat}} + h_{\text{base}})^2 / 2 = \mathbf{0.8 \text{ kN/m}}$$

Water

$$F_{\text{water}_h} = \gamma_G \times \gamma_w' \times (h_{\text{water}} + d_{\text{cover}} + h_{\text{base}})^2 / 2 = \mathbf{1.5 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_h} = \gamma_G \times K_A \times \gamma_{\text{mr}}' \times ((h_{\text{eff}} - h_{\text{sat}} - h_{\text{base}})^2 / 2 + (h_{\text{eff}} - h_{\text{sat}} - h_{\text{base}}) \times (h_{\text{sat}} + h_{\text{base}})) = \mathbf{3.4 \text{ kN/m}}$$

Total

$$F_{\text{total}_h} = F_{\text{sur}_h} + F_{\text{sat}_h} + F_{\text{water}_h} + F_{\text{moist}_h} = \mathbf{11.3 \text{ kN/m}}$$

Check stability against sliding

Base soil resistance

$$F_{\text{exc}_h} = \gamma_{\text{Gf}} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (h_{\text{pass}} + h_{\text{base}})^2 / 2 = \mathbf{6.2 \text{ kN/m}}$$

Base friction

$$F_{\text{friction}} = F_{\text{total}_v} \times \tan(\delta_{bb,d}) = \mathbf{6.6 \text{ kN/m}}$$

Resistance to sliding

$$F_{\text{rest}} = F_{\text{exc}_h} + F_{\text{friction}} = \mathbf{12.8 \text{ kN/m}}$$

Factor of safety

$$FoS_{\text{sl}} = F_{\text{rest}} / F_{\text{total}_h} = \mathbf{1.13}$$

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = \gamma_{\text{Gf}} \times A_{\text{stem}} \times \gamma_{\text{stem}} = \mathbf{8.7 \text{ kN/m}}$$

Wall base

$$F_{\text{base}} = \gamma_{\text{Gf}} \times A_{\text{base}} \times \gamma_{\text{base}} = \mathbf{5.3 \text{ kN/m}}$$

Saturated retained soil

$$F_{\text{sat}_v} = \gamma_{\text{Gf}} \times A_{\text{sat}} \times (\gamma_{\text{sr}}' - \gamma_w') = \mathbf{0.2 \text{ kN/m}}$$

Water

$$F_{\text{water}_v} = \gamma_{\text{Gf}} \times A_{\text{water}} \times \gamma_w' = \mathbf{0.1 \text{ kN/m}}$$

Water uplift

$$F_{\text{water}_u} = \gamma_{\text{Gf}} \times (h_{\text{sat}} + t_{\text{base}}) \times l_{\text{base}} / 2 \times \gamma_w' = \mathbf{2.3 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_v} = \gamma_{\text{Gf}} \times A_{\text{moist}} \times \gamma_{\text{mr}}' = \mathbf{0.5 \text{ kN/m}}$$

Base soil

$$F_{\text{exc}_v} = \gamma_{\text{Gf}} \times A_{\text{exc}} \times \gamma_b' = \mathbf{1.7 \text{ kN/m}}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{sat}_v} + F_{\text{water}_v} - F_{\text{water}_u} + F_{\text{moist}_v} + F_{\text{exc}_v} = \mathbf{14.3 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_A \times \gamma_Q \times \text{Surcharge}_Q \times h_{\text{eff}} = \mathbf{5.6 \text{ kN/m}}$$

Saturated retained soil

$$F_{\text{sat}_h} = \gamma_G \times K_A \times (\gamma_{\text{sr}}' - \gamma_w') \times (h_{\text{sat}} + h_{\text{base}})^2 / 2 = \mathbf{0.8 \text{ kN/m}}$$

Water

$$F_{\text{water}_h} = \gamma_G \times \gamma_w' \times (h_{\text{water}} + d_{\text{cover}} + h_{\text{base}})^2 / 2 = \mathbf{1.5 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_h} = \gamma_G \times K_A \times \gamma_{\text{mr}}' \times ((h_{\text{eff}} - h_{\text{sat}} - h_{\text{base}})^2 / 2 + (h_{\text{eff}} - h_{\text{sat}} - h_{\text{base}}) \times (h_{\text{sat}} + h_{\text{base}})) = \mathbf{3.4 \text{ kN/m}}$$

Base soil

$$F_{\text{exc}_h} = -\gamma_{\text{Gf}} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (h_{\text{pass}} + h_{\text{base}})^2 / 2 = \mathbf{-6.2 \text{ kN/m}}$$

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Total $F_{total_h} = F_{sur_h} + F_{sat_h} + F_{water_h} + F_{moist_h} + F_{exc_h} = 5.1 \text{ kN/m}$

Overturning moments on wall

Surcharge load $M_{sur_OT} = F_{sur_h} \times X_{sur_h} = 2.9 \text{ kNm/m}$

Saturated retained soil $M_{sat_OT} = F_{sat_h} \times X_{sat_h} = 0.1 \text{ kNm/m}$

Water $M_{water_OT} = F_{water_h} \times X_{water_h} + F_{water_u} \times X_{water_u} = 1.6 \text{ kNm/m}$

Moist retained soil $M_{moist_OT} = F_{moist_h} \times X_{moist_h} = 1.4 \text{ kNm/m}$

Total $M_{total_OT} = M_{sur_OT} + M_{sat_OT} + M_{water_OT} + M_{moist_OT} = 6.1 \text{ kNm/m}$

Restoring moments on wall

Wall stem $M_{stem_R} = F_{stem} \times X_{stem} = 5.6 \text{ kNm/m}$

Wall base $M_{base_R} = F_{base} \times X_{base} = 2.3 \text{ kNm/m}$

Saturated retained soil $M_{sat_R} = F_{sat_v} \times X_{sat_v} = 0.2 \text{ kNm/m}$

Water $M_{water_R} = F_{water_v} \times X_{water_v} = 0.1 \text{ kNm/m}$

Moist retained soil $M_{moist_R} = F_{moist_v} \times X_{moist_v} = 0.4 \text{ kNm/m}$

Base soil $M_{exc_R} = F_{exc_v} \times X_{exc_v} - F_{exc_h} \times X_{exc_h} = 1.4 \text{ kNm/m}$

Total $M_{total_R} = M_{stem_R} + M_{base_R} + M_{sat_R} + M_{water_R} + M_{moist_R} + M_{exc_R} = 9.9 \text{ kNm/m}$

Check stability against overturning

Factor of safety $FoS_{ot} = M_{total_R} / M_{total_OT} = 1.629$

PASS - Maximum restoring moment is greater than overturning moment