

Project BDW Yorkshire West - Owl Lane, Chidswell				Job no. 1048/151	
Calcs for Highway retaining wall 0.5m				Start page no./Revision 1	
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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 2.9.16

Retaining wall details

Stem type	Cantilever
Stem height	$h_{\text{stem}} = 700$ mm
Stem thickness	$t_{\text{stem}} = 400$ mm
Angle to rear face of stem	$\alpha = 90$ deg
Stem density	$\gamma_{\text{stem}} = 25$ kN/m ³
Toe length	$l_{\text{toe}} = 300$ mm
Base thickness	$t_{\text{base}} = 300$ mm
Base density	$\gamma_{\text{base}} = 25$ kN/m ³
Height of retained soil	$h_{\text{ret}} = 500$ mm
Angle of soil surface	$\beta = 0$ deg
Depth of cover	$d_{\text{cover}} = 200$ mm
Depth of excavation	$d_{\text{exc}} = 150$ mm

Retained soil properties

Soil type	Very dense well graded sand and gravel
Moist density	$\gamma_{\text{mr}} = 21$ kN/m ³
Saturated density	$\gamma_{\text{sr}} = 23$ kN/m ³
Characteristic effective shear resistance angle	$\phi'_{\text{r,k}} = 42$ deg
Characteristic wall friction angle	$\delta_{\text{r,k}} = 21$ deg

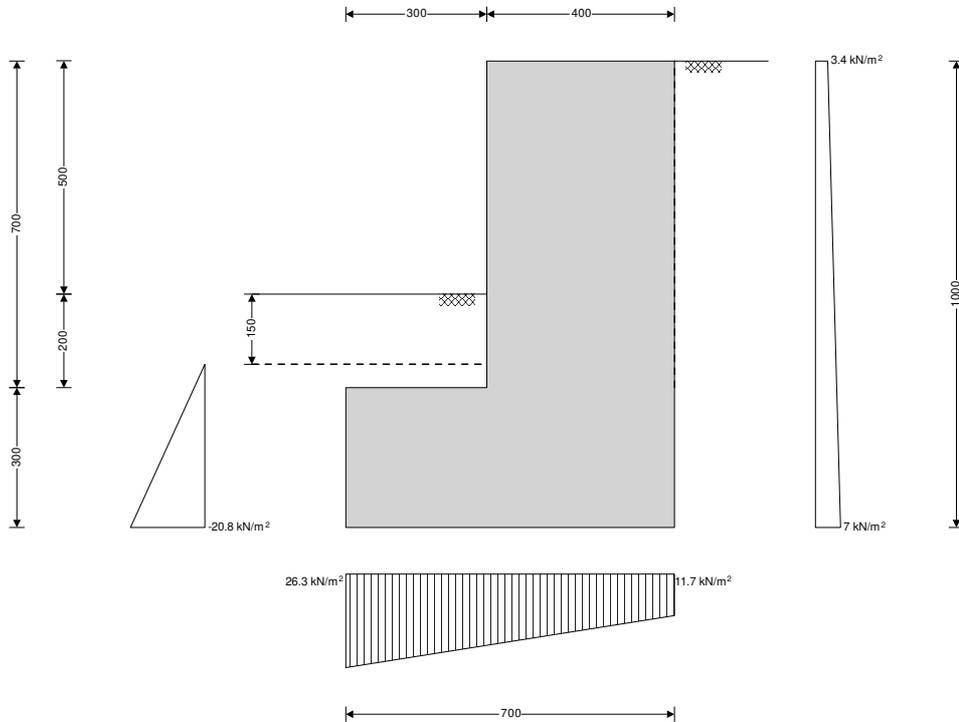
Base soil properties

Soil type	Dense gravel
Soil density	$\gamma_{\text{b}} = 17.5$ kN/m ³
Characteristic effective shear resistance angle	$\phi'_{\text{b,k}} = 36$ deg
Characteristic wall friction angle	$\delta_{\text{b,k}} = 18$ deg
Characteristic base friction angle	$\delta_{\text{bb,k}} = 24$ deg
Presumed bearing capacity	$P_{\text{bearing}} = 100$ kN/m ²

Loading details

Variable surcharge load	Surcharge _Q = 20 kN/m ²
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General arrangement - sketch pressures relate to bearing check

Calculate retaining wall geometry

- Base length
- Moist soil height
- Length of surcharge load
 - Distance to vertical component
- Effective height of wall
 - Distance to horizontal component
- Area of wall stem
 - Distance to vertical component
- Area of wall base
 - Distance to vertical component
- Area of base soil
 - Distance to vertical component
 - Distance to horizontal component
- Area of excavated base soil
 - Distance to vertical component
 - Distance to horizontal component

$$l_{base} = l_{toe} + t_{stem} = 700 \text{ mm}$$

$$h_{moist} = h_{soil} = 700 \text{ mm}$$

$$l_{sur} = l_{heel} = 0 \text{ mm}$$

$$x_{sur_v} = l_{base} - l_{heel} / 2 = 700 \text{ mm}$$

$$h_{eff} = h_{base} + d_{cover} + h_{ret} = 1000 \text{ mm}$$

$$x_{sur_h} = h_{eff} / 2 = 500 \text{ mm}$$

$$A_{stem} = h_{stem} \times t_{stem} = 0.28 \text{ m}^2$$

$$x_{stem} = l_{toe} + t_{stem} / 2 = 500 \text{ mm}$$

$$A_{base} = l_{base} \times t_{base} = 0.21 \text{ m}^2$$

$$x_{base} = l_{base} / 2 = 350 \text{ mm}$$

$$A_{pass} = d_{cover} \times l_{toe} = 0.06 \text{ m}^2$$

$$x_{pass_v} = l_{base} - (d_{cover} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{pass} = 150 \text{ mm}$$

$$x_{pass_h} = (d_{cover} + h_{base}) / 3 = 167 \text{ mm}$$

$$A_{exc} = h_{pass} \times l_{toe} = 0.015 \text{ m}^2$$

$$x_{exc_v} = l_{base} - (h_{pass} \times l_{toe} \times (l_{base} - l_{toe} / 2)) / A_{exc} = 150 \text{ mm}$$

$$x_{exc_h} = (h_{pass} + h_{base}) / 3 = 117 \text{ mm}$$

Using Coulomb theory

Active pressure coefficient

$$K_A = \frac{\sin(\alpha + \phi'_{r,k})^2}{(\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,k}) \times [1 + \sqrt{(\sin(\phi'_{r,k} + \delta_{r,k}) \times \sin(\phi'_{r,k} - \beta) / (\sin(\alpha - \delta_{r,k}) \times \sin(\alpha + \beta))}]^2)} = 0.183$$

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Passive pressure coefficient

$$K_P = \sin(90 - \phi'_{b,k})^2 / (\sin(90 + \delta_{b,k}) \times [1 - \sqrt{[\sin(\phi'_{b,k} + \delta_{b,k}) \times \sin(\phi'_{b,k}) / (\sin(90 + \delta_{b,k}))]}])^2 = \mathbf{8.022}$$

Bearing pressure check

Vertical forces on wall

Wall stem

$$F_{\text{stem}} = A_{\text{stem}} \times \gamma_{\text{stem}} = \mathbf{7 \text{ kN/m}}$$

Wall base

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

Base soil

$$F_{\text{pass}_v} = A_{\text{pass}} \times \gamma_b = \mathbf{1.1 \text{ kN/m}}$$

Total

$$F_{\text{total}_v} = F_{\text{stem}} + F_{\text{base}} + F_{\text{pass}_v} = \mathbf{13.3 \text{ kN/m}}$$

Horizontal forces on wall

Surcharge load

$$F_{\text{sur}_h} = K_A \times \cos(\delta_{r,k}) \times \text{Surcharge}_Q \times h_{\text{eff}} = \mathbf{3.4 \text{ kN/m}}$$

Moist retained soil

$$F_{\text{moist}_h} = K_A \times \cos(\delta_{r,k}) \times \gamma_{\text{mr}} \times h_{\text{eff}}^2 / 2 = \mathbf{1.8 \text{ kN/m}}$$

Base soil

$$F_{\text{pass}_h} = \max(-K_P \times \cos(\delta_{b,k}) \times \gamma_b \times (d_{\text{cover}} + h_{\text{base}})^2 / 2, -(F_{\text{moist}_h} + F_{\text{sur}_h})) = \mathbf{-5.2 \text{ kN/m}}$$

Total

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

Moments on wall

Wall stem

$$M_{\text{stem}} = F_{\text{stem}} \times X_{\text{stem}} = \mathbf{3.5 \text{ kNm/m}}$$

Wall base

$$M_{\text{base}} = F_{\text{base}} \times X_{\text{base}} = \mathbf{1.8 \text{ kNm/m}}$$

Surcharge load

$$M_{\text{sur}} = -F_{\text{sur}_h} \times X_{\text{sur}_h} = \mathbf{-1.7 \text{ kNm/m}}$$

Moist retained soil

$$M_{\text{moist}} = -F_{\text{moist}_h} \times X_{\text{moist}_h} = \mathbf{-0.6 \text{ kNm/m}}$$

Base soil

$$M_{\text{pass}} = F_{\text{pass}_v} \times X_{\text{pass}_v} - F_{\text{pass}_h} \times X_{\text{pass}_h} = \mathbf{1 \text{ kNm/m}}$$

Total

$$M_{\text{total}} = M_{\text{stem}} + M_{\text{base}} + M_{\text{sur}} + M_{\text{moist}} + M_{\text{pass}} = \mathbf{4.1 \text{ kNm/m}}$$

Check bearing pressure

Distance to reaction

$$\bar{x} = M_{\text{total}} / F_{\text{total}_v} = \mathbf{305 \text{ mm}}$$

Eccentricity of reaction

$$e = \bar{x} - l_{\text{base}} / 2 = \mathbf{-45 \text{ mm}}$$

Loaded length of base

$$l_{\text{load}} = l_{\text{base}} = \mathbf{700 \text{ mm}}$$

Bearing pressure at toe

$$q_{\text{toe}} = F_{\text{total}_v} / l_{\text{base}} \times (1 - 6 \times e / l_{\text{base}}) = \mathbf{26.3 \text{ kN/m}^2}$$

Bearing pressure at heel

$$q_{\text{heel}} = F_{\text{total}_v} / l_{\text{base}} \times (1 + 6 \times e / l_{\text{base}}) = \mathbf{11.7 \text{ kN/m}^2}$$

Factor of safety

$$FoS_{\text{bp}} = P_{\text{bearing}} / \max(q_{\text{toe}}, q_{\text{heel}}) = \mathbf{3.803}$$

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

$\gamma_G = \mathbf{1.350}$

Permanent favourable action

$\gamma_{Gf} = \mathbf{1.000}$

Variable unfavourable action

$\gamma_Q = \mathbf{1.500}$

Variable favourable action

$\gamma_{Qf} = \mathbf{0.000}$

Partial factors for soil parameters – 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

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

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Retained soil properties

Design moist density	$\gamma_{mr}' = \gamma_{mr} / \gamma_r = 21 \text{ kN/m}^3$
Design saturated density	$\gamma_{sr}' = \gamma_{sr} / \gamma_r = 23 \text{ kN/m}^3$
Design effective shear resistance angle	$\phi'_{r,d} = \text{atan}(\tan(\phi'_{r,k}) / \gamma_\phi) = 42 \text{ deg}$
Design wall friction angle	$\delta_{r,d} = \text{atan}(\tan(\delta_{r,k}) / \gamma_\phi) = 21 \text{ deg}$

Base soil properties

Design soil density	$\gamma_b' = \gamma_b / \gamma_r = 17.5 \text{ kN/m}^3$
Design effective shear resistance angle	$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_\phi) = 36 \text{ deg}$
Design wall friction angle	$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_\phi) = 18 \text{ deg}$
Design base friction angle	$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_\phi) = 24 \text{ deg}$
Design effective cohesion	$c'_{b,d} = c'_{b,k} / \gamma_c = 0 \text{ kN/m}^2$

Using Coulomb theory

Active pressure coefficient	$K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times [1 + \sqrt{[\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))]}]^2) = 0.183$
Passive pressure coefficient	$K_P = \sin(90 - \phi'_{b,d})^2 / (\sin(90 + \delta_{b,d}) \times [1 - \sqrt{[\sin(\phi'_{b,d} + \delta_{b,d}) \times \sin(\phi'_{b,d}) / (\sin(90 + \delta_{b,d}))]}]^2) = 8.022$

Sliding check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = 7 \text{ kN/m}$
Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = 5.3 \text{ kN/m}$
Base soil	$F_{exc_v} = \gamma_{Gf} \times A_{exc} \times \gamma_b' = 0.3 \text{ kN/m}$
Total	$F_{total_v} = F_{stem} + F_{base} + F_{exc_v} = 12.5 \text{ kN/m}$

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \cos(\delta_{r,d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} = 5.1 \text{ kN/m}$
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 = 2.4 \text{ kN/m}$
Total	$F_{total_h} = F_{sur_h} + F_{moist_h} = 7.5 \text{ kN/m}$

Check stability against sliding

Base soil resistance	$F_{exc_h} = \gamma_{Gf} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = 8.2 \text{ kN/m}$
Base friction	$F_{friction} = F_{total_v} \times \tan(\delta_{bb,d}) = 5.6 \text{ kN/m}$
Resistance to sliding	$F_{rest} = F_{exc_h} + F_{friction} = 13.7 \text{ kN/m}$
Factor of safety	$FoS_{sl} = F_{rest} / F_{total_h} = 1.824$

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = 7 \text{ kN/m}$
Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = 5.3 \text{ kN/m}$
Base soil	$F_{exc_v} = \gamma_{Gf} \times A_{exc} \times \gamma_b' = 0.3 \text{ kN/m}$
Total	$F_{total_v} = F_{stem} + F_{base} + F_{exc_v} = 12.5 \text{ kN/m}$

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \cos(\delta_{r,d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} = 5.1 \text{ kN/m}$
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 = 2.4 \text{ kN/m}$
Base soil	$F_{exc_h} = \max(-\gamma_{Gf} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2, -(F_{moist_h} + F_{sur_h})) = -7.5 \text{ kN/m}$

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Total $F_{total_h} = F_{sur_h} + F_{moist_h} + F_{exc_h} = 0 \text{ kN/m}$

Overtuning moments on wall

Surcharge load $M_{sur_OT} = F_{sur_h} \times X_{sur_h} = 2.6 \text{ kNm/m}$

Moist retained soil $M_{moist_OT} = F_{moist_h} \times X_{moist_h} = 0.8 \text{ kNm/m}$

Total $M_{total_OT} = M_{sur_OT} + M_{moist_OT} = 3.4 \text{ kNm/m}$

Restoring moments on wall

Wall stem $M_{stem_R} = F_{stem} \times X_{stem} = 3.5 \text{ kNm/m}$

Wall base $M_{base_R} = F_{base} \times X_{base} = 1.8 \text{ kNm/m}$

Base soil $M_{exc_R} = F_{exc_v} \times X_{exc_v} - F_{exc_h} \times X_{exc_h} = 0.9 \text{ kNm/m}$

Total $M_{total_R} = M_{stem_R} + M_{base_R} + M_{exc_R} = 6.3 \text{ kNm/m}$

Check stability against overturning

Factor of safety $FoS_{ot} = M_{total_R} / M_{total_OT} = 1.859$

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	$\gamma_G = 1.000$
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	$\gamma_{mr} = \gamma_{mr} / \gamma_{\gamma} = 21 \text{ kN/m}^3$
Design saturated density	$\gamma_{sr} = \gamma_{sr} / \gamma_{\gamma} = 23 \text{ kN/m}^3$
Design effective shear resistance angle	$\phi'_{r,d} = \text{atan}(\tan(\phi'_{r,k}) / \gamma_{\phi'}) = 35.8 \text{ deg}$
Design wall friction angle	$\delta_{r,d} = \text{atan}(\tan(\delta_{r,k}) / \gamma_{\phi'}) = 17.1 \text{ deg}$

Base soil properties

Design soil density	$\gamma_b = \gamma_b / \gamma_{\gamma} = 17.5 \text{ kN/m}^3$
Design effective shear resistance angle	$\phi'_{b,d} = \text{atan}(\tan(\phi'_{b,k}) / \gamma_{\phi'}) = 30.2 \text{ deg}$
Design wall friction angle	$\delta_{b,d} = \text{atan}(\tan(\delta_{b,k}) / \gamma_{\phi'}) = 14.6 \text{ deg}$
Design base friction angle	$\delta_{bb,d} = \text{atan}(\tan(\delta_{bb,k}) / \gamma_{\phi'}) = 19.6 \text{ deg}$
Design effective cohesion	$c'_{b,d} = c'_{b,k} / \gamma_{c'} = 0 \text{ kN/m}^2$

Using Coulomb theory

Active pressure coefficient	$K_A = \sin(\alpha + \phi'_{r,d})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r,d}) \times [1 + \sqrt{[\sin(\phi'_{r,d} + \delta_{r,d}) \times \sin(\phi'_{r,d} - \beta) / (\sin(\alpha - \delta_{r,d}) \times \sin(\alpha + \beta))]}]^2) = 0.239$
Passive pressure coefficient	$K_P = \sin(90 - \phi'_{b,d})^2 / (\sin(90 + \delta_{b,d}) \times [1 - \sqrt{[\sin(\phi'_{b,d} + \delta_{b,d}) \times \sin(\phi'_{b,d}) / (\sin(90 + \delta_{b,d}))]}]^2) = 4.938$

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Sliding check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = 7 \text{ kN/m}$
Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = 5.3 \text{ kN/m}$
Base soil	$F_{exc_v} = \gamma_{Gf} \times A_{exc} \times \gamma_b' = 0.3 \text{ kN/m}$
Total	$F_{total_v} = F_{stem} + F_{base} + F_{exc_v} = 12.5 \text{ kN/m}$

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \cos(\delta_{r,d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} = 5.9 \text{ kN/m}$
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 = 2.4 \text{ kN/m}$
Total	$F_{total_h} = F_{sur_h} + F_{moist_h} = 8.3 \text{ kN/m}$

Check stability against sliding

Base soil resistance	$F_{exc_h} = \gamma_{Gf} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2 = 5.1 \text{ kN/m}$
Base friction	$F_{friction} = F_{total_v} \times \tan(\delta_{bb,d}) = 4.5 \text{ kN/m}$
Resistance to sliding	$F_{rest} = F_{exc_h} + F_{friction} = 9.6 \text{ kN/m}$
Factor of safety	$FoS_{sl} = F_{rest} / F_{total_h} = 1.149$

PASS - Resistance to sliding is greater than sliding force

Overturning check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem} = 7 \text{ kN/m}$
Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base} = 5.3 \text{ kN/m}$
Base soil	$F_{exc_v} = \gamma_{Gf} \times A_{exc} \times \gamma_b' = 0.3 \text{ kN/m}$
Total	$F_{total_v} = F_{stem} + F_{base} + F_{exc_v} = 12.5 \text{ kN/m}$

Horizontal forces on wall

Surcharge load	$F_{sur_h} = K_A \times \cos(\delta_{r,d}) \times \gamma_Q \times \text{Surcharge}_Q \times h_{eff} = 5.9 \text{ kN/m}$
Moist retained soil	$F_{moist_h} = \gamma_G \times K_A \times \cos(\delta_{r,d}) \times \gamma_{mr}' \times h_{eff}^2 / 2 = 2.4 \text{ kN/m}$
Base soil	$F_{exc_h} = \max(-\gamma_{Gf} \times K_P \times \cos(\delta_{b,d}) \times \gamma_b' \times (h_{pass} + h_{base})^2 / 2, -(F_{moist_h} + F_{sur_h})) = -5.1 \text{ kN/m}$
Total	$F_{total_h} = F_{sur_h} + F_{moist_h} + F_{exc_h} = 3.2 \text{ kN/m}$

Overturning moments on wall

Surcharge load	$M_{sur_OT} = F_{sur_h} \times X_{sur_h} = 3 \text{ kNm/m}$
Moist retained soil	$M_{moist_OT} = F_{moist_h} \times X_{moist_h} = 0.8 \text{ kNm/m}$
Total	$M_{total_OT} = M_{sur_OT} + M_{moist_OT} = 3.8 \text{ kNm/m}$

Restoring moments on wall

Wall stem	$M_{stem_R} = F_{stem} \times X_{stem} = 3.5 \text{ kNm/m}$
Wall base	$M_{base_R} = F_{base} \times X_{base} = 1.8 \text{ kNm/m}$
Base soil	$M_{exc_R} = F_{exc_v} \times X_{exc_v} - F_{exc_h} \times X_{exc_h} = 0.6 \text{ kNm/m}$
Total	$M_{total_R} = M_{stem_R} + M_{base_R} + M_{exc_R} = 6 \text{ kNm/m}$

Check stability against overturning

Factor of safety	$FoS_{ot} = M_{total_R} / M_{total_OT} = 1.586$
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PASS - Maximum restoring moment is greater than overturning moment