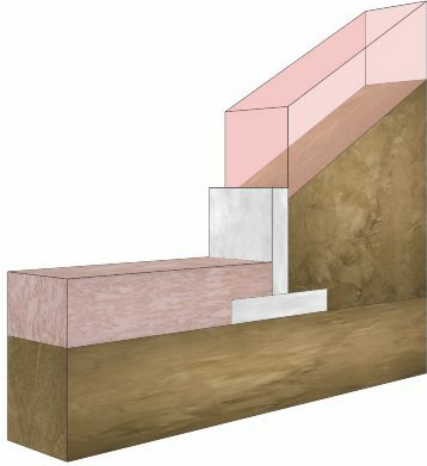


Retaining Wall Calculations - Detailed Report

REFERENCES	CALCULATIONS	RESULTS																																																																																										
	<p>INPUTS:</p> <div style="text-align: center;">  </div> <p>Stem:</p> <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>Layer</th> <th>Height</th> <th>Base width</th> <th>Top width</th> <th>Front offset</th> <th>Back offset</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>1.156</td> <td>0.254</td> <td>0.254</td> <td>0.000</td> <td>0.000</td> </tr> </tbody> </table> <p style="text-align: center;">Stem total height: $H_{stem} = 1.155701$ m</p> <p>Footing:</p> <p style="text-align: center;">Base thickness: $H_{base} = 0.25399$ m Toe width: $W_{toe} = 0.6096$ m Heel width: $W_{heel} = 0.6604$ m</p> <p>Soil:</p> <p>Substructure:</p> <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>Layer</th> <th>Height</th> <th>Unit weight</th> <th>Friction angle</th> <th>Cohesion</th> <th>Allowable pressure</th> <th>Soil-concrete friction</th> <th>Name</th> </tr> <tr> <td></td> <td>m</td> <td>kN/m³</td> <td>°</td> <td>kPa</td> <td>kPa</td> <td></td> <td></td> </tr> </thead> <tbody> <tr> <td>1</td> <td>1.000</td> <td>19.000</td> <td>20.000</td> <td>40.000</td> <td>100.000</td> <td>0.550</td> <td>Loam</td> </tr> </tbody> </table> <p style="text-align: center;">Total sub soil height: $H_{soil, sub} = 1$ m</p> <p>Active:</p> <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>Layer</th> <th>Height</th> <th>Unit weight</th> <th>Friction angle</th> <th>Cohesion</th> <th>Inclination</th> <th>Name</th> </tr> <tr> <td></td> <td>m</td> <td>kN/m³</td> <td>°</td> <td>kPa</td> <td>°</td> <td></td> </tr> </thead> <tbody> <tr> <td>1</td> <td>1.791</td> <td>18.000</td> <td>30.000</td> <td>-</td> <td>30.000</td> <td>Medium Clay</td> </tr> </tbody> </table> <p style="text-align: center;">Total active soil height: $H_{soil, active} = 1.790979$ m</p> <p>Passive:</p> <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>Layer</th> <th>Height</th> <th>Unit weight</th> <th>Friction angle</th> <th>Cohesion</th> <th>Name</th> </tr> <tr> <td></td> <td>m</td> <td>kN/m³</td> <td>°</td> <td>kPa</td> <td></td> </tr> </thead> <tbody> <tr> <td>1</td> <td>0.610</td> <td>18.000</td> <td>25.000</td> <td>-</td> <td>Sand</td> </tr> </tbody> </table> <p style="text-align: center;">Total passive soil height: $H_{soil, passive} = 0.6096$ m</p> <p>Loads:</p> <p>Active:</p> <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>Load Id</th> <th>Type</th> <th>Magnitude</th> <th>Length</th> <th>Start pos.</th> </tr> <tr> <td></td> <td></td> <td>kN</td> <td>m</td> <td>m</td> </tr> </thead> <tbody> <tr> <td>1</td> <td>Uniform</td> <td>1.680</td> <td>0.763</td> <td>0.000</td> </tr> </tbody> </table>	Layer	Height	Base width	Top width	Front offset	Back offset	1	1.156	0.254	0.254	0.000	0.000	Layer	Height	Unit weight	Friction angle	Cohesion	Allowable pressure	Soil-concrete friction	Name		m	kN/m ³	°	kPa	kPa			1	1.000	19.000	20.000	40.000	100.000	0.550	Loam	Layer	Height	Unit weight	Friction angle	Cohesion	Inclination	Name		m	kN/m ³	°	kPa	°		1	1.791	18.000	30.000	-	30.000	Medium Clay	Layer	Height	Unit weight	Friction angle	Cohesion	Name		m	kN/m ³	°	kPa		1	0.610	18.000	25.000	-	Sand	Load Id	Type	Magnitude	Length	Start pos.			kN	m	m	1	Uniform	1.680	0.763	0.000	
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Notes:

- All the calculated forces, pressures, distributed loads and design results are for a unitary (1 m) strip of the wall.

SOIL PROPERTIES:**Active soil:**

Principles of Foundation Engineering, Braja Das, 7th Ed. - Eqn. 7.19

Rankine active earth pressure coefficient *Simplified for the case of Inclined Granular Backfill with Vertical Back Face* $K_{a,1}$

$$K_{a,1} = \cos(\alpha_{soil \text{ active}}) \cdot \frac{\cos(\alpha_{soil \text{ active}}) - \sqrt{\cos^2(\alpha_{soil \text{ active}}) - \cos^2(\phi_{soil \text{ active}, 1})}}{\cos(\alpha_{soil \text{ active}}) + \sqrt{\cos^2(\alpha_{soil \text{ active}}) - \cos^2(\phi_{soil \text{ active}, 1})}}$$

$$K_{a,1} = \cos(30^\circ) \cdot \frac{\cos(30^\circ) - \sqrt{\cos^2(30^\circ) - \cos^2(30^\circ)}}{\cos(30^\circ) + \sqrt{\cos^2(30^\circ) - \cos^2(30^\circ)}} = 0.86603$$

Equivalent Rankine active earth pressure coefficient *Equivalent Rankine earth pressure coefficient for all the layers* \bar{K}_{a*}

$$\bar{K}_{a*} = \frac{\sum K_{a,i} \cdot h_i}{H_{soil, \text{ active}}}$$

$$\bar{K}_{a*} = \frac{1.551 \text{ m}}{1.791 \text{ m}} = 0.86603$$

Passive soil:

Principles of Foundation Engineering, Braja Das, 7th Ed. - Eqn. 7.61

Rankine passive earth pressure coefficient $K_{p,1}$

$$K_{p,1} = \tan^2\left(45^\circ + \frac{\phi_{soil \text{ passive}, 1}}{2}\right)$$

$$K_{p,1} = \tan^2\left(45^\circ + \frac{25^\circ}{2}\right) = 2.4639$$

ACTING FORCES:**Vertical forces:****Self-weight of the structure:**

$$\text{Stem wall weight: } P = \gamma_{concrete, \text{ stem}} \cdot V_{stem} = 23.58 \text{ kN/m}^3 \cdot 0.29354 \text{ m}^3 = 6.9217 \text{ kN}$$

$$\text{Base weight: } P = \gamma_{concrete, \text{ footing}} \cdot V_{base} = 23.58 \text{ kN/m}^3 \cdot 0.38708 \text{ m}^3 = 9.1274 \text{ kN}$$

Self-weight of the soil:

$$P_{active, 1} = \gamma_{soil \text{ active}, 1} \cdot V_{soil \text{ active}, 1} = 18 \text{ kN/m}^3 \cdot 0.84717 \text{ m}^3 = 15.249 \text{ kN}$$

$$\text{Total active soil weight: } P_{active} = 15.249011 \text{ kN}$$

$$P_{passive, 1} = \gamma_{soil \text{ passive}, 1} \cdot V_{soil \text{ passive}, 1} = 18 \text{ kN/m}^3 \cdot 0.21678 \text{ m}^3 = 3.902 \text{ kN}$$

$$\text{Total passive soil weight: } P_{passive} = 3.902039 \text{ kN}$$

Vertical component of the pressure from retained soil:

$$P_1 = P_{0, 1 \text{ (vert)}} \cdot H_{soil \text{ active}, 1} + \frac{1}{2} \cdot \gamma_{soil \text{ active}, 1} \cdot H_{soil \text{ active}, 1}^2 \cdot 1 \text{ m} \cdot K_{a,1} \cdot \sin(\alpha_{soil \text{ active}})$$

$$P_1 = 0 \text{ kN/m}^1 \cdot 1.791 \text{ m} + \frac{1}{2} \cdot 18 \text{ kN/m}^3 \cdot 1.791 \text{ m}^2 \cdot 1 \text{ m} \cdot 0.86603 \cdot \sin(30^\circ) = 12.5 \text{ kN}$$

$$\text{Total vertical active pressure: } P_{a, \text{ retained (vertical)}} = 12.500404 \text{ kN}$$

Superimposed loads resultants:

$$\text{Surcharge resultant (uniform): } P_1 = q_{active, 1} \cdot L_{active, 1} = 1.68 \text{ kN/m}^1 \cdot 0.76258 \text{ m} = 1.2811 \text{ kN}$$

Vertical soil pressure due to superimposed loads:

$$\text{Surcharge pressure (vertical): } P_{uniform, \text{ vertical}, 1} = q_{active, 1} \cdot H_{soil, \text{ active}} \cdot K_{a*} \cdot \sin(\alpha_{soil \text{ active}})$$

$$P_{uniform, \text{ vertical}, 1} = 1.68 \text{ kN/m}^1 \cdot 1.791 \text{ m} \cdot 0.86603 \cdot \sin(30^\circ) = 1.3029 \text{ kN}$$

$$\text{Total vertical force downwards: } \sum P_{vertical} = 50.284533 \text{ kN}$$

Horizontal forces:**Rankine active force**

Rankine Active horizontal resultant force per unit length, due to retained earth

$$P_{a, \text{ retained, horizontal}, 1} = P_{0, 1} \cdot H_{soil \text{ active}, 1} + \frac{1}{2} \cdot \gamma_{soil \text{ active}, 1} \cdot H_{soil \text{ active}, 1}^2 \cdot 1 \text{ m} \cdot K_{a,1} \cdot \cos(\alpha_{soil \text{ active}})$$

$$P_{a, \text{ retained, horizontal}, 1} = 0 \text{ kN/m}^1 \cdot 1.791 \text{ m} + \frac{1}{2} \cdot 18 \text{ kN/m}^3 \cdot 1.791 \text{ m}^2 \cdot 1 \text{ m} \cdot 0.86603 \cdot \cos(30^\circ) = 21.651 \text{ kN}$$

$$\text{Total horizontal force (active soil): } P_{a, \text{ retained, horizontal}} = 21.651335 \text{ kN}$$

The Reinforced Concrete Design Handbook, ACI SP-17(14), Vol. 2

Rankine active force

Rankine Active horizontal resultant force per unit length, due to superimposed loads

$$P_{a, \text{uniform, horizontal}, 1} = q_{\text{active}, 1} \cdot H_{\text{soil, active}} \cdot K_{a*} \cdot \cos(\alpha_{\text{soil active}})$$

$$P_{a, \text{uniform, horizontal}, 1} = 1.68 \text{ kN/m}^2 \cdot 1.791 \text{ m} \cdot 0.86603 \cdot \cos(30^\circ) = 2.2566 \text{ kN}$$

$$\text{Total horizontal force leftwards: } \sum P_{\text{horizontal leftwards}} = 23.907968 \text{ kN}$$

Rankine passive force

Horizontal Rankine passive resultant force per unit length

$$P_{p,1} = P_{0,1} \cdot H_{\text{soil passive}, 1} + \frac{1}{2} \cdot \gamma_{\text{soil passive}, 1} \cdot H_{\text{soil passive}, 1}^2 \cdot 1 \text{ m} \cdot K_{p,1}$$

$$P_{p,1} = 0 \text{ kN/m}^2 \cdot 0.6096 \text{ m} + \frac{1}{2} \cdot 18 \text{ kN/m}^3 \cdot 0.6096 \text{ m}^2 \cdot 1 \text{ m} \cdot 2.4639 = 8.2406 \text{ kN}$$

$$\text{Total horizontal force (passive soil): } P_p = 8.24058 \text{ kN}$$

$$\text{Total horizontal force rightwards: } \sum P_{\text{horizontal rightwards}} = 8.24058 \text{ kN}$$

STABILITY CHECKS:**Overturning:****Restoring moment**

The self-weight of the retaining wall and the soil, the distributed load above the heel, the passive soil weight and its associated horizontal pressure, if considered, tend to counteract the overturning moment. Moments taken about the front edge of base (toe):

$$M = P \cdot d_{\text{lever}}$$

Moment	Force, P /kN, 1 ^{NaN}	Lever, d m	Moment, M kN · m
Stem wall	6.922	0.737	5.099
Base	9.127	0.762	6.955
Active soil weight (layer 1)	15.249	1.216	18.537
Passive soil weight (layer 1)	3.902	0.305	1.189
Surcharge (load 1)	1.281	1.194	1.529
Vertical active soil pressure (all layers)	12.500	1.524	19.051
Vertical surcharge soil pressure (load 1)	1.303	1.524	1.986
Passive pressure (layer 1)	8.241	0.203	1.674

$$\text{Total restoring moment: } \sum M_R = 56.019805 \text{ kN} \cdot \text{m}$$

Overturning moment

The horizontal components of the active soil lateral pressure tend to overturn the retaining wall about the front edge of the base (toe):

$$M = P \cdot d_{\text{lever}}$$

Moment	Force, P /kN, 1 ^{NaN}	Lever, d m	Moment, M kN · m
Active pressure (layer 1)	21.651	0.597	12.926
Surcharge earth pressure	2.257	0.895	2.021

$$\text{Total overturning moment: } M_{OTM} = 14.946486 \text{ kN} \cdot \text{m}$$

Stability requirement against overturning

Factor of safety FS

$$FS = \frac{\sum M_R}{M_{OTM}}$$

$$FS = \frac{56.02 \text{ kNm}}{14.946 \text{ kNm}} = 3.748 \geq 2$$

**OVERTURNING:
PASS
FS: 3.75**

Bearing:**Soil Pressure Resultant Distance**

To calculate soil pressure, the location of the vertical resultant force must be determined.

Soil pressure resultant distance a

$$a = \frac{\sum M_R - M_{OTM}}{\sum P_{\text{vertical}}}$$

$$a = \frac{56.02 \text{ kNm} - 14.946 \text{ kNm}}{50.285 \text{ kN}} = 0.81682 \text{ m}$$

Soil pressure resultant eccentricity e

$$e = \left| \frac{W_{base}}{2} - a \right|$$

$$e = \left| \frac{1.524 \text{ m}}{2} - 0.81682 \text{ m} \right| = 0.054818 \text{ m}$$

Uplift check

Check if the resultant falls within the middle third of the base.

$$\frac{W_{base}}{6} = \frac{1.5240 \text{ m}}{6} = 0.254 \text{ m} > e = 0.055 \text{ m}$$

UPLIFT CHECK 1:
PASS
Ratio: 0.216

Applied soil pressure distribution

Minimum soil pressure q_{min}

$$q_{min} = \frac{\sum P_{vertical}}{W_{base} \cdot 1 \text{ m}} \cdot \left(1 - \frac{6 \cdot e}{W_{base}} \right)$$

$$q_{min} = \frac{50.285 \text{ kN}}{1.524 \text{ m} \cdot 1 \text{ m}} \cdot \left(1 - \frac{6 \cdot 0.054818 \text{ m}}{1.524 \text{ m}} \right) = 25.874 \text{ kPa} > 0 \text{ kPa}$$

UPLIFT CHECK 2:
PASS
Value: 25.87 > 0

Maximum soil pressure q_{max}

$$q_{max} = \frac{\sum P_{vertical}}{W_{base} \cdot 1 \text{ m}} \cdot \left(1 + \frac{6 \cdot e}{W_{base}} \right)$$

$$q_{max} = \frac{50.285 \text{ kN}}{1.524 \text{ m} \cdot 1 \text{ m}} \cdot \left(1 + \frac{6 \cdot 0.054818 \text{ m}}{1.524 \text{ m}} \right) = 40.116 \text{ kPa}$$

Stability requirement against bearing capacity failure

Factor of safety FS

$$FS = \frac{q_{soil \text{ sub, } 1}}{q_{max}}$$

$$FS = \frac{100 \text{ kPa}}{40.116 \text{ kPa}} = 2.4928 \geq 2$$

BEARING: PASS
FS: 2.49

Sliding:

Horizontal frictional resisting force

Horizontal frictional resisting force considering passive contribution $\mu \sum P + P_p$

$$\mu \sum P + P_p = \mu_{soil-concrete \text{ sub, } 1} \cdot \sum P_{vertical} + P_p$$

$$\mu \sum P + P_p = 0.55 \cdot 50.285 \text{ kN} + 8.2406 \text{ kN} = 35.897 \text{ kN}$$

Total horizontal acting force

$$\sum P_{horizontal \text{ leftwards}} = 23.907968 \text{ kN}$$

Stability requirement against sliding

Factor of safety FS

$$FS = \frac{\mu \sum P + P_p}{\sum P_{horizontal \text{ leftwards}}}$$

$$FS = \frac{35.897 \text{ kN}}{23.908 \text{ kN}} = 1.5015 \geq 1.5$$

SLIDING: PASS
FS: 1.50