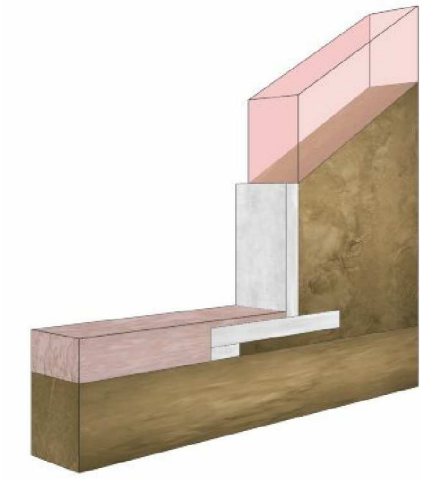
REFERENCES	CALCULATIONS	RESULTS

INPUTS:



Stem:

Layer	Height	Base width	Top width	Front offset	Back offset
1	1.862	0.254	0.254	0.000	0.000

Stem total height: $H_{stem} = 1.862$ m

Footing:

Base thickness: $H_{base} = 0.254$ m
Toe width: $W_{toe} = 1.41$ m
Heel width: $W_{heel} = 0.914$ m
Key width: $W_{key} = 0.51$ m
Key height: $H_{key} = 0.17$ m
Key offset: $\text{Offset}_{key} = 0$ m

Soil:

Substructure:

Layer	Height	Unit weight	Friction angle	Allowable pressure	Soil-concrete friction	Name
	m	kN/m³	°	kPa		
1	1.000	19.000	33.000	100.000	0.550	Loam

Active:

Layer	Height	Unit weight	Friction angle	Cohesion	Inclination	Name
	m	kN/m³	°	kPa	°	
1	2.814	19.000	33.000	-	30.000	Medium Clay

Total active soil height: $H_{soil,\ active} = 2.813698$ m

Passive:

Layer	Height	Unit weight	Friction angle	Cohesion	Name
	m	kN/m³	°	kPa	
1	0.506	19.000	33.000	-	Sand

Total passive soil height: $H_{soil,\ passive} = 0.506$ m

Loads:

Active:

Development Review File No: D07-12-21-0021
Plan # 18575
1994 St. Joseph Blvd., Ottawa, Ontario

Load Id	Type	Magnitude kN	Length m	Start pos. m
1	Uniform	1.920	1.055	0.000

Notes:

1. 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* $K_{a,1}$

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

$$K_{a,1} = \cos(30\ ^\circ) \cdot \frac{\cos(30\ ^\circ) - \sqrt{\cos^2(30\ ^\circ) - \cos^2(33\ ^\circ)}}{\cos(30\ ^\circ) + \sqrt{\cos^2(30\ ^\circ) - \cos^2(33\ ^\circ)}} = 0.52034$$

Equivalent Rankine active earth pressure coefficient *Equivalent Rankine earth pressure coefficient for all the layers* K_{a*}

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

$$K_{a*} = \frac{1.4641\ \text{m}}{2.8137\ \text{m}} = 0.52034$$

Note: User must validate that wall rotation is sufficient to justify K_a < 1.0.

Passive soil:

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

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

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

$$K_{p,1} = \tan^2\left(45\ ^\circ + \frac{33\ ^\circ}{2}\right) = 3.3921$$

Note: User must validate that wall rotation is sufficient to justify K_p > 1.0.

ACTING FORCES:

Vertical forces:

Self-weight of the structure:

Stem wall weight: $P = \gamma_{concrete,\ stem} \cdot V_{stem} = 23.58\ \text{kN/m}^3 \cdot 0.47295\ \text{m}^3 = 11.152\ \text{kN}$

Base weight: $P = \gamma_{concrete,\ footing} \cdot V_{base} = 23.58\ \text{kN/m}^3 \cdot 0.65481\ \text{m}^3 = 15.44\ \text{kN}$

Key weight: $P = \gamma_{concrete,\ footing} \cdot V_{key} = 23.58\ \text{kN/m}^3 \cdot 0.0867\ \text{m}^3 = 2.0444\ \text{kN}$

Self-weight of the soil:

$$P_{active,\ 1} = \gamma_{soil\ active,\ 1} \cdot V_{soil\ active,\ 1} = 19\ \text{kN/m}^3 \cdot 1.943\ \text{m}^3 = 36.917\ \text{kN}$$

Total active soil weight: $P_{active} = 36.917495\ \text{kN}$

$$P_{passive,\ 1} = \gamma_{soil\ passive,\ 1} \cdot V_{soil\ passive,\ 1} = 19\ \text{kN/m}^3 \cdot 0.11562\ \text{m}^3 = 2.1968\ \text{kN}$$

Total passive soil weight: $P_{passive} = 2.19678\ \text{kN}$

Vertical component of the pressure from retained soil:

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

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

$$P_1 = 0\ \text{kN/m}^1 \cdot 2.8137\ \text{m} + \frac{1}{2} \cdot 19\ \text{kN/m}^3 \cdot 2.8137\ \text{m}^2 \cdot 1\ \text{m} \cdot 0.52034 \cdot \sin(30\ ^\circ) = 19.567\ \text{kN}$$

Total vertical active pressure: $P_{a,\ retained\ (vertical)} = 19.567365\ \text{kN}$

Superimposed loads resultants:

Surcharge resultant (uniform): $P_1 = q_{active,\ 1} \cdot L_{active,\ 1} = 1.92\ \text{kN/m}^1 \cdot 1.0554\ \text{m} = 2.0264\ \text{kN}$

Vertical soil pressure due to superimposed loads:

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

$P_{uniform,\ vertical,1} = 1.92\ \text{kN/m}^1 \cdot 2.8137\ \text{m} \cdot 0.52034 \cdot \sin(30\ ^\circ) = 1.4055\ \text{kN}$

Total vertical force downwards: $\sum P_{vertical} = 90.750473\ \text{kN}$

Horizontal forces:

Rankine active force

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

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

$P_{a,\ retained,\ horizontal,1} = 0\ \text{kN/m}^1 \cdot 2.8137\ \text{m} + \frac{1}{2} \cdot 19\ \text{kN/m}^3 \cdot (2.8137\ \text{m})^2 \cdot 1\ \text{m} \cdot 0.52034 \cdot \cos(30\ ^\circ) = 33.892\ \text{kN}$

Total horizontal force (active soil): $P_{a,\ retained,\ horizontal} = 33.89167\ \text{kN}$

Rankine active force

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

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

$P_{a,\ uniform,\ horizontal,1} = 1.92\ \text{kN/m}^1 \cdot 2.8137\ \text{m} \cdot 0.52034 \cdot \cos(30\ ^\circ) = 2.4344\ \text{kN}$

Total horizontal force leftwards: $\sum P_{horizontal\ leftwards} = 36.326076\ \text{kN}$

Rankine passive force

Horizontal Rankine passive resultant force per unit length

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

$P_{p,1} = 0\ \text{kN/m}^1 \cdot 0.506\ \text{m} + \frac{1}{2} \cdot 19\ \text{kN/m}^3 \cdot (0.506\ \text{m})^2 \cdot 1\ \text{m} \cdot 3.3921 = 8.2508\ \text{kN}$

Total horizontal force (passive soil): $P_p = 8.250796\ \text{kN}$

Total horizontal force rightwards: $\sum P_{horizontal\ rightwards} = 8.250796\ \text{kN}$

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):

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

Moment	Force, P /kN,1^{NaN}	Lever, d m	Moment, M kN · m
Stem wall	11.152	1.537	17.141
Base	15.440	1.289	19.903
Key	2.044	0.255	0.521
Active soil weight (layer 1)	36.917	2.140	79.000
Passive soil weight (layer 1)	2.197	0.705	1.549
Surcharge (load 1)	2.026	2.121	4.298
Vertical active soil pressure (all layers)	19.567	2.578	50.445
Vertical surcharge soil pressure (load 1)	1.406	2.578	3.623
Passive pressure (layer 1)	8.251	-0.001	-0.011

Total restoring moment: $\sum M_R = 176.468577\ \text{kN} * \text{m}$

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):

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

Moment	Force, P /kN,1^{NaN}	Lever, d m	Moment, M kN · m
Active pressure (layer 1)	33.892	0.768	26.025
Surcharge earth pressure	2.434	1.237	3.011

Total overturning moment: $M_{OTM} = 29.036386\ \text{kN} * \text{m}$

Stability requirement against overturning

Factor of safety FS

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

$$FS = \frac{176.47\ \text{kNm}}{29.036\ \text{kNm}} = 6.0775 \geq 2$$

OVERTURNING:
PASS
FS: 6.08

Bearing:

Soil Pressure Resultant Distance

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

Soil pressure resultant distance a

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

$$a = \frac{176.47\ \text{kNm} - 29.036\ \text{kNm}}{90.75\ \text{kN}} = 1.6246\ \text{m}$$

Soil pressure resultant eccentricity e

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

$$e = \left| \frac{2.578\ \text{m}}{2} - 1.6246\ \text{m} \right| = 0.33559\ \text{m}$$

Uplift check

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

$$\frac{W_{base}}{6} = \frac{2.5780\ m}{6} = 0.43\ m\ > e = 0.336\ m$$

UPLIFT CHECK 1: PASS
Ratio: 0.781

Applied soil pressure distribution

Minimum soil pressure q_{toe}

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

$$q_{toe} = \frac{90.75\ \text{kN}}{2.578\ \text{m} \cdot 1\ \text{m}} \cdot \left(1 - \frac{6 \cdot 0.33559\ \text{m}}{2.578\ \text{m}}\right) = 7.7077\ \text{kPa}$$

UPLIFT CHECK 2: PASS
Value: 7.71 > 0

Maximum soil pressure q_{heel}

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

$$q_{heel} = \frac{90.75\ \text{kN}}{2.578\ \text{m} \cdot 1\ \text{m}} \cdot \left(1 + \frac{6 \cdot 0.33559\ \text{m}}{2.578\ \text{m}}\right) = 62.696\ \text{kPa}$$

Stability requirement against bearing capacity failure

Factor of safety FS

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

$$FS = \frac{100\ \text{kPa}}{62.696\ \text{kPa}} = 1.595 \geq 1.5$$

BEARING: PASS
FS: 1.59

Sliding:

Horizontal frictional resisting force

Soil-soil friction coefficient $\mu_{soil-soil,\ passive}$

$$\mu_{soil-soil,\ passive} = \tan(\phi_{soil\ passive,\ 1})$$

$$\mu_{soil-soil,\ passive} = \tan(33\ ^\circ) = 0.64941$$

Soil-soil friction coefficient $\mu_{soil-soil,\ sub}$

$$\mu_{soil-soil,\ sub} = \tan(\phi_{soil\ sub,\ 1})$$

$$\mu_{soil-soil,\ sub} = \tan(33\ ^\circ) = 0.64941$$

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

Vertical soil pressure at key start $q_{key,\ start}$

$$q_{key,\ start} = q_{toe} + \frac{q_{heel} - q_{toe}}{W_{base}} \cdot (W_{base} - \text{Offset}_{key})$$

$$q_{key,\ start} = 7.7077\ \text{kPa} + \frac{62.696\ \text{kPa} - 7.7077\ \text{kPa}}{2.578\ \text{m}} \cdot (2.578\ \text{m} - 0\ \text{m}) = 62.696\ \text{kPa}$$

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

Vertical soil pressure at key end $q_{key,\ end}$

$$q_{key,\ end} = q_{toe} + \frac{q_{heel} - q_{toe}}{W_{base}} \cdot (W_{base} - \text{Offset}_{key} - W_{key})$$

$$q_{key,\ end} = 7.7077\ \text{kPa} + \frac{62.696\ \text{kPa} - 7.7077\ \text{kPa}}{2.578\ \text{m}} \cdot (2.578\ \text{m} - 0\ \text{m} - 0.51\ \text{m}) = 51.818\ \text{kPa}$$

Vertical soil pressure resultant before key $P_{vertical,\ passive}$

$$P_{vertical,\ passive} = \frac{q_{heel} + q_{key,\ start}}{2} \cdot \text{Offset}_{key}$$

$$P_{vertical,\ passive} = \frac{62.696\ \text{kPa} + 62.696\ \text{kPa}}{2} \cdot 0\ \text{m} = 0\ \text{kN/m}^1$$

Vertical soil pressure resultant on key $P_{vertical,\ key}$

$$P_{vertical,\ key} = \frac{q_{key,\ start} + q_{key,\ end}}{2} \cdot W_{key}$$

$$P_{vertical,\ key} = \frac{62.696\ \text{kPa} + 51.818\ \text{kPa}}{2} \cdot 0.51\ \text{m} = 29.201\ \text{kN/m}^1$$

Vertical soil pressure resultant after key $P_{vertical,\ active}$

$$P_{vertical,\ active} = \frac{q_{key,\ end} + q_{toe}}{2} \cdot (W_{base} - \text{Offset}_{key} - W_{key})$$

$$P_{vertical,\ active} = \frac{51.818\ \text{kPa} + 7.7077\ \text{kPa}}{2} \cdot (2.578\ \text{m} - 0\ \text{m} - 0.51\ \text{m}) = 61.549\ \text{kN/m}^1$$

Horizontal frictional resisting force considering passive contribution with shear key present $\sum \mu P + P_p$

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

$$\sum \mu P + P_p = 0.55 \cdot 29.201\ \text{kN/m}^1 + 0.64941 \cdot 0\ \text{kN/m}^1 + 0.5 \cdot 61.549\ \text{kN/m}^1 + 8.2508\ \text{kN} = 55.086\ \text{kN}$$

Total horizontal acting force

$$\sum P_{horizontal\ leftwards} = 36.326076\ \text{kN}$$

Stability requirement against sliding

Factor of safety FS

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

$$FS = \frac{55.086\ \text{kN}}{36.326\ \text{kN}} = 1.5164 \geq 1.5$$

SLIDING: PASS
FS: 1.52

DAIDO GROUP INC.
STRUCTURAL ENGINEERS
TEL: 613-302-8972
DAIDOGROUP@GMAIL.COM

Development Review File No: D07-12-21-0021
Plan # 18575
1994 St. Joseph Blv., Ottawa, Ontario