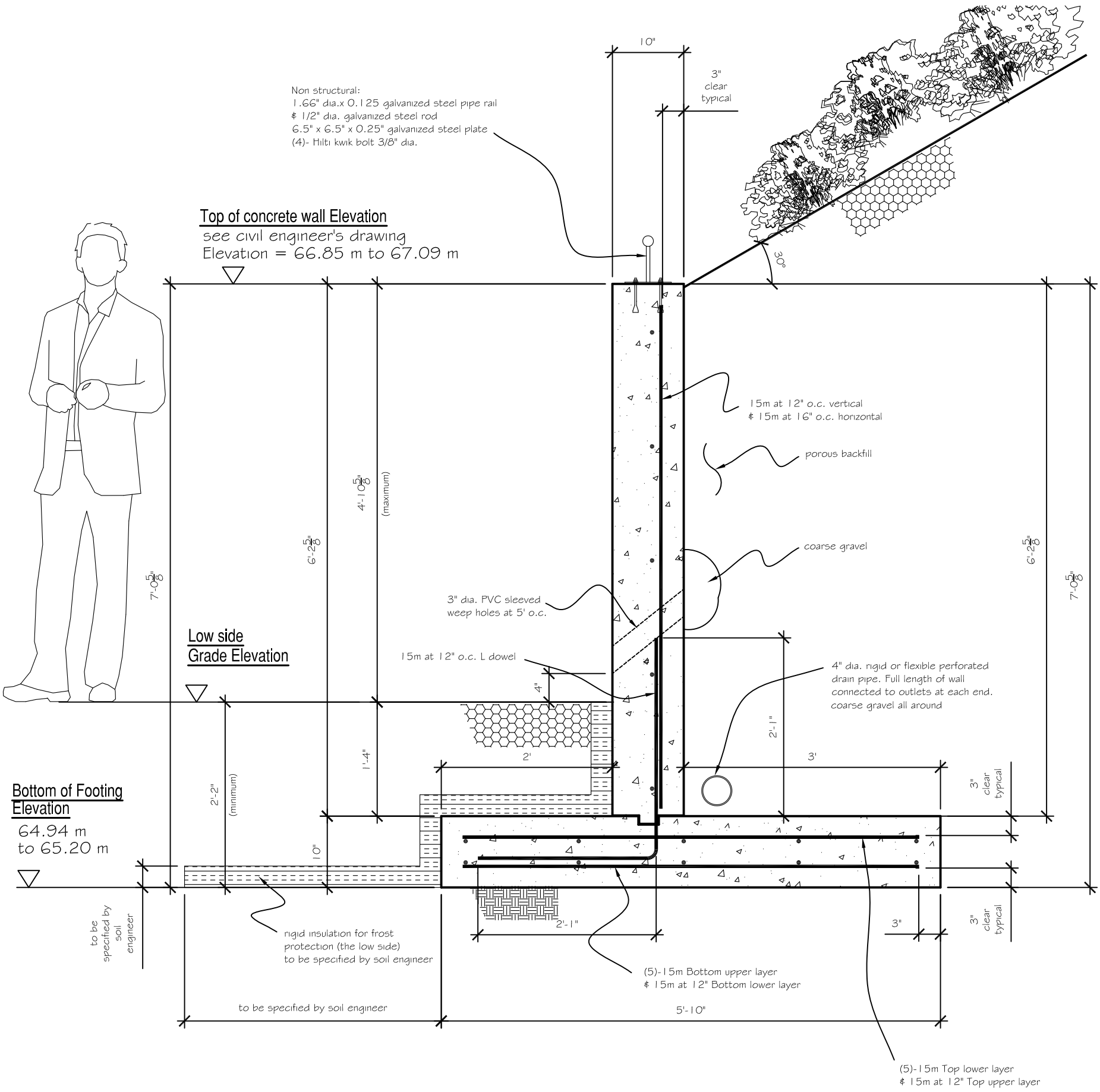

SECTION THRU. TYPICAL RETAINING WALL AREA (SOUTH)

Notes:

~ Bearing capacity assumed to be 100 kPa (SLS) for clay material, to be confirmed by soil engineer
~ Concrete to be 25 mPa at 28 days, with 5% air (+/-1%)
~ Rebar 400 mPa
~ Provide Rigid insulation to protect the frost penetration since one side of the retaining wall is above the frost cover, details to be specified by soil engineer
~ Lap 42 x bar diameter, which is 25" for 15m bar
~ concrete cover 3" typical

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LICENSED PROFESSIONAL ENGINEER
T. T-Y. TAI
August 11, 2023
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Structural
PROVINCE OF ONTARIO

PROJECT
Orleans Physio
1994 St. Joseph Blvd.,
Ottawa, Ontario

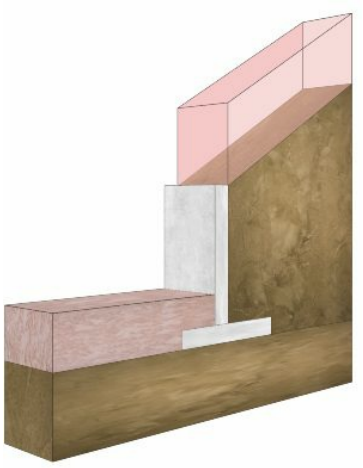
TITLE
RETAINING WALL SECTIONS
TYPICAL RETAINING WALL (SOUTH)

DRAWN	DATE	
TRENCH TAI	August 11, 2023	S9b
PAPER SIZE	SCALE	
11" x 17"	3/4" = 1'-0"	

Retaining Wall Calculations - Detailed Report

REFERENCES	CALCULATIONS	RESULTS

INPUTS:



Stem:

Layer	Height	Base width	Top width	Front offset	Back offset
1	1.890	0.254	0.254	0.000	0.000

Stem total height: $H_{stem} = 1.88976 \text{ m}$

Footing:

Base thickness: $H_{base} = 0.25399 \text{ m}$
Toe width: $W_{toe} = 0.6096 \text{ m}$
Heel width: $W_{heel} = 0.904342 \text{ m}$

Soil:

Substructure:

Layer	Height	Unit weight	Friction angle	Cohesion	Allowable pressure	Soil-concrete friction	Name
	m	kN/m^3	°	kPa	kPa		
1	1.000	19.000	30.000	40.000	100.000	0.700	Loam

Total sub soil height: $H_{soil,\ sub} = 1 \text{ m}$

Active:

Layer	Height	Unit weight	Friction angle	Cohesion	Inclination	Name
	m	kN/m^3	°	kPa	°	
1	2.666	18.000	30.000	-	30.000	Medium Clay

Total active soil height: $H_{soil,\ active} = 2.665872 \text{ m}$

Passive:

Layer	Height	Unit weight	Friction angle	Cohesion	Name
	m	kN/m^3	°	kPa	
1	0.671	18.000	30.000	-	Sand

Total passive soil height: $H_{soil,\ passive} = 0.67056 \text{ m}$

Loads:

Active:

Load Id	Type	Magnitude	Length	Start pos.
		kN	m	m
1	Uniform	1.680	1.044	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* $K_{a,1}$

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

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

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

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

$$K_{a*} = \frac{2.3087\ \text{m}}{2.6659\ \text{m}} = 0.86603$$

Passive soil:

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

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

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

$$K_{p,1} = \tan^2\left(45\ ^\circ + \frac{30\ ^\circ}{2}\right) = 3$$

ACTING FORCES:

Vertical forces:

Self-weight of the structure:

Stem wall weight: $P = \gamma_{concrete,\ stem} \cdot V_{stem} = 23.58\ \text{kN/m}^3 \cdot 0.47981\ \text{m}^3 = 11.314\ \text{kN}$

Base weight: $P = \gamma_{concrete,\ footing} \cdot V_{base} = 23.58\ \text{kN/m}^3 \cdot 0.44901\ \text{m}^3 = 10.588\ \text{kN}$

Self-weight of the soil:

$$P_{active,\ 1} = \gamma_{soil\ active,\ 1} \cdot V_{soil\ active,\ 1} = 18\ \text{kN/m}^3 \cdot 1.9405\ \text{m}^3 = 34.929\ \text{kN}$$

Total active soil weight: $P_{active} = 34.928773\ \text{kN}$

$$P_{passive,\ 1} = \gamma_{soil\ passive,\ 1} \cdot V_{soil\ passive,\ 1} = 18\ \text{kN/m}^3 \cdot 0.25394\ \text{m}^3 = 4.5709\ \text{kN}$$

Total passive soil weight: $P_{passive} = 4.570941\ \text{kN}$

Vertical component of the pressure from retained soil:

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

$$P_1 = P_{0,\ 1\ (vert)} \cdot H_{soil\ active,\ 1} + \tfrac{1}{2} \cdot \gamma_{soil\ active,\ 1} \cdot H^2_{soil\ active,\ 1} \cdot 1\ \text{m} \cdot K_{a,1} \cdot \sin(\alpha_{soil\ active})$$
$$P_1 = 0\ \text{kN/m}^1 \cdot 2.6659\ \text{m} + \tfrac{1}{2} \cdot 18\ \text{kN/m}^3 \cdot 2.6659\ \text{m}^2 \cdot 1\ \text{m} \cdot 0.86603 \cdot \sin(30\ ^\circ) = 27.696\ \text{kN}$$

Total vertical active pressure: $P_{a,\ retained\ (vertical)} = 27.696292\ \text{kN}$

Superimposed loads resultants:

Surcharge resultant (uniform): $P_1 = q_{active,\ 1} \cdot L_{active,\ 1} = 1.68\ \text{kN/m}^1 \cdot 1.0442\ \text{m} = 1.7543\ \text{kN}$

Vertical soil pressure due to superimposed loads:

Surcharge pressure (vertical): $P_{uniform,\ vertical,1} = q_{active,\ 1} \cdot H_{soil,\ active} \cdot K_{a*} \cdot \sin(\alpha_{soil\ active})$
$P_{uniform,\ vertical,1} = 1.68\ \text{kN/m}^1 \cdot 2.6659\ \text{m} \cdot 0.86603 \cdot \sin(30\ ^\circ) = 1.9393\ \text{kN}$

Total vertical force downwards: $\sum P_{vertical} = 92.79124\ \text{kN}$

Horizontal forces:

Rankine active force

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

$$P_{a,\ retained,\ horizontal,1} = P_{0,\ 1} \cdot H_{soil\ active,\ 1} + \tfrac{1}{2} \cdot \gamma_{soil\ active,\ 1} \cdot H^2_{soil\ active,\ 1} \cdot 1\ \text{m} \cdot K_{a,1} \cdot \cos(\alpha_{soil\ active})$$
$$P_{a,\ retained,\ horizontal,1} = 0\ \text{kN/m}^1 \cdot 2.6659\ \text{m} + \tfrac{1}{2} \cdot 18\ \text{kN/m}^3 \cdot 2.6659\ \text{m}^2 \cdot 1\ \text{m} \cdot 0.86603 \cdot \cos(30\ ^\circ) = 47.971\ \text{kN}$$

Total horizontal force (active soil): $P_{a,\ retained,\ horizontal} = 47.971386\ \text{kN}$

Rankine active force

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

$$P_{a,\ uniform,\ horizontal,1} = q_{active,\ 1} \cdot H_{soil,\ active} \cdot K_{a*} \cdot \cos(\alpha_{soil\ active})$$
$$P_{a,\ uniform,\ horizontal,1} = 1.68\ \text{kN/m}^1 \cdot 2.6659\ \text{m} \cdot 0.86603 \cdot \cos(30\ ^\circ) = 3.359\ \text{kN}$$

Total horizontal force leftwards: $\sum P_{horizontal\ leftwards} = 51.330384\ \text{kN}$

Rankine passive force

Horizontal Rankine passive resultant force per unit length

$$P_{p,1} = P_{0,\ 1} \cdot H_{soil\ passive,\ 1} + \frac{1}{2} \cdot \gamma_{soil\ passive,\ 1} \cdot H^2_{soil\ passive,\ 1} \cdot 1\ \text{m} \cdot K_{p,1}$$
$$P_{p,1} = 0\ \text{kN/m}^1 \cdot 0.67056\ \text{m} + \frac{1}{2} \cdot 18\ \text{kN/m}^3 \cdot 0.67056\ \text{m}^2 \cdot 1\ \text{m} \cdot 3 = 12.141\ \text{kN}$$

Total horizontal force (passive soil): $P_p = 12.140569\ \text{kN}$

Total horizontal force rightwards: $\sum P_{horizontal\ rightwards} = 12.140569\ \text{kN}$

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	11.314	0.737	8.333
Base	10.588	0.884	9.359
Active soil weight (layer 1)	34.929	1.334	46.608
Passive soil weight (layer 1)	4.571	0.305	1.393
Surcharge (load 1)	1.754	1.316	2.308
Vertical active soil pressure (all layers)	27.696	1.768	48.963
Vertical surcharge soil pressure (load 1)	1.939	1.768	3.428
Passive pressure (layer 1)	12.141	0.224	2.714

Total restoring moment: $\sum M_R = 123.105613\ \text{kN} * \text{m}$

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)	47.971	0.889	42.629
Surcharge earth pressure	3.359	1.333	4.477

Total overturning moment: $M_{OTM} = 47.105849\ \text{kN} * \text{m}$

Stability requirement against overturning

Factor of safety FS

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

$$FS = \frac{123.11\ \text{kNm}}{47.106\ \text{kNm}} = 2.6134 \geq 2$$

OVERTURNING: PASS
FS: 2.61

Bearing:

Soil Pressure Resultant Distance

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

Soil pressure resultant distance a

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

$$a = \frac{123.11\ \text{kNm} - 47.106\ \text{kNm}}{92.791\ \text{kN}} = 0.81904\ \text{m}$$

Soil pressure resultant eccentricity e

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

$$e = \left| \frac{1.7678 \text{ m}}{2} - 0.81904 \text{ m} \right| = 0.06488 \text{ m}$$

Uplift check

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

$$\frac{W_{base}}{6} = \frac{1.7678\ m}{6} = 0.295\ m\ > e = 0.065\ m$$

UPLIFT CHECK 1: PASS
Ratio: 0.220

Applied soil pressure distribution

Minimum soil pressure q_{min}

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

$$q_{min} = \frac{92.791 \text{ kN}}{1.7678 \text{ m} \cdot 1 \text{ m}} \cdot \left(1 - \frac{6 \cdot 0.06488 \text{ m}}{1.7678 \text{ m}}\right) = 40.931 \text{ kPa} > 0 \text{ kPa}$$

UPLIFT CHECK 2: PASS
Value: 40.93 > 0

Maximum soil pressure q_{max}

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

$$q_{max} = \frac{92.791 \text{ kN}}{1.7678 \text{ m} \cdot 1 \text{ m}} \cdot \left(1 + \frac{6 \cdot 0.06488 \text{ m}}{1.7678 \text{ m}}\right) = 64.046 \text{ kPa}$$

Stability requirement against bearing capacity failure

Factor of safety FS

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

$$FS = \frac{100 \text{ kPa}}{64.046 \text{ kPa}} = 1.5614 \geq 1.5$$

BEARING: PASS
FS: 1.56

Sliding:

Horizontal frictional resisting force

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

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

$$\mu \sum P + P_p = 0.7 \cdot 92.791 \text{ kN} + 12.141 \text{ kN} = 77.094 \text{ kN}$$

Total horizontal acting force

$$\sum P_{horizontal\ leftwards} = 51.330384 \text{ kN}$$

Stability requirement against sliding

Factor of safety FS

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

$$FS = \frac{77.094 \text{ kN}}{51.33 \text{ kN}} = 1.5019 \geq 1.5$$

SLIDING: PASS
FS: 1.50