Soil Pressure Acting on Wall

\[ \sigma_h = k_a \gamma z \]  

(Eq. 1)

Where:

- \( \sigma_h \) = soil pressure acting on wall
- \( k_a = \tan^2 \left( 45 - \frac{\phi}{2} \right) \), active earth pressure coefficient
- \( \gamma \) = unit weight of soil (approximately 100 lb/ft\(^3\))
- \( z \) = depth below ground surface
Given: \( \phi = 30 \text{ degrees} \)

Find: Soil pressure acting on wall at depths of 10 feet and 20 feet below the ground surface.

Given

Soil friction angle \( \phi := 30 \text{deg} \)

Soil unit weight \( \gamma := 100 \text{ lbf} \frac{\text{ft}}{\text{ft}^3} \)

Find: Soil pressure at depths of 10 and 20 feet below the ground surface

Active earth pressure coefficient

\[
K_a := \left( \tan \left( 45 \text{deg} - \frac{\phi}{2} \right) \right)^2 \quad K_a = 0.333
\]

Soil pressure at 10 ft

\[
\sigma_{h\_10} := K_a \gamma \cdot 10 \text{ft} \quad \sigma_{h\_10} = 333 \text{ lbf} \frac{\text{ft}}{\text{ft}^2}
\]

Soil pressure at 20 ft

\[
\sigma_{h\_20} := K_a \gamma \cdot 20 \text{ft} \quad \sigma_{h\_20} = 667 \text{ psf}
\]

Alternatively

Depth where soil pressure is calculated

\[
z := \left( \frac{10}{20} \right) \text{ft}
\]

Soil pressure

\[
\sigma_h := K_a \gamma \cdot z \quad \sigma_h = \left( \frac{333}{667} \right) \text{ psf}
\]
Surcharge Pressure Acting on Wall

A retaining wall with vehicles located behind the top of the wall is shown below. The vehicle weight imposes additional pressure on wall. The vehicle weight is called a surcharge load.

A simplification of the surcharge load used to determine the induced pressures on the wall is shown below.

\[ \Delta \sigma_a = k_a q \]  

(Eq. 2)

Where:
- \( \Delta \sigma_h \) = surcharge pressure on wall
- \( k_a \) = active earth pressure coefficient
- \( q \) = surcharge load in pounds per square foot
Given: surcharge load, \( q = 100 \text{ lb/ft}^2 \)
\( \phi = 30 \text{ degrees} \)

Find: The surcharge pressure acting on the wall at depths of 10 feet and 20 feet.

Given

Surcharge load \( q := 100 \text{psf} \)

Find: Surcharge pressure at depths of 10 and 20 feet below the ground surface

Surcharge pressure, \( \Delta \sigma_h := K_a \cdot q \)
Same at all depths
\( \Delta \sigma_h = 33.333 \text{psf} \)

Total Pressure Acting on Wall

Soil and Surcharge Pressure
\( \sigma_h + \Delta \sigma_h \)
Calculate Pullout Force on Reinforcement

Wall

20 ft

4 ft

4 ft

4 ft

4 ft

2 ft

Layer 1

Layer 2

Layer 3

Layer 4

Layer 5

Failure Plane

Reinforcement

\[
F_{pi} = (\sigma_h + \Delta \sigma_h) A_i
\]  

(Eq. 3)

where:

- \( F_{pi} \) = pullout force for reinforcement layer \( i \)
- \( (\sigma_h + \Delta \sigma_h) \) = horizontal pressure at depth of reinforcement layer \( i \)
- \( A_i \) = tributary area for reinforcement layer

\[
A_i = S_v S_h
\]  

(Eq. 4)

where:

- \( S_v \) = vertical spacing between reinforcement layers
- \( S_h \) = horizontal distance between reinforcement strips

Given:
Pressure distribution calculated for the retaining wall above, and a horizontal reinforcement spacing, \( S_h \), of 3 ft,

Find:
The pullout force for layer 3 (\( F_{p3} \))

Given:

- Horizontal spacing of reinforcement \( S_h \coloneq 3\text{ft} \)
- Vertical spacing of reinforcement \( S_v \coloneq 4\text{ft} \)

Find: The pullout force applied to the reinforcement

Total soil pressure at depths of 10 and 20 feet below the ground surface
\[
\sigma_{hT} \coloneq \Delta \sigma_h + \sigma_h
\]

\[
\sigma_{hT} = \left( \frac{367}{700} \right) \text{psf}
\]

Pullout force at depths of 10 and 20 feet below the ground surface
\[
F_p \coloneq (\Delta \sigma_h + \sigma_h) S_v S_h
\]

\[
F_p = \left( \frac{4400}{8400} \right) \text{lbf}
\]
Determine Reinforcement Length to Resist Pullout

Reinforcement resists pullout through the development of friction forces between the reinforcement and soil behind the failure plane.

![Diagram of wall with layers and failure plane](image)

Lf = distance from wall to failure plane
Le = distance from failure plane to end of reinforcement

\[ Lf = h \tan \alpha \]  

(Eq. 5)

Where:
- \( h \) = distance from base of wall to reinforcement layer \( i \)
- \( \alpha \) = angle between wall and failure plane

\[ Le = \frac{(F_{pi})FS}{2b\gamma z \tan\left(\frac{2}{3}\phi\right)} \]  

(Eq. 6)

Where:
- \( F_{pi} \) = pullout force for layer \( i \)
- \( FS \) = factor of safety
- \( b \) = width of reinforcement
- \( \gamma \) = soil unit weight
- \( z \) = depth below ground surface
- \( \phi \) = soil friction angle

Then the total reinforcement length, \( L \), is \( Lf + Le \).
**Given:** The retaining wall shown above, data from previous calculations (i.e. pullout force), reinforcement width of 0.5 ft, and a factor of safety of 1.5

**Find:** The reinforcement length for layer 3

**Given**

- Horizontal spacing of reinforcement: \( S_h := 3 \text{ ft} \)
- Vertical spacing of reinforcement: \( S_v := 4 \text{ ft} \)
- Reinforcement width: \( b := 0.5 \text{ ft} \)
- Factor of safety: \( FS := 1.5 \)

**Find:** Reinforcement length of Layer 3

- Distance from bottom of wall to layer 3: \( h_{10} := 10 \text{ ft} \)
- Angle between wall and failure plane: \( \alpha := 90\text{deg} - \left(45\text{deg} + \frac{\phi}{2}\right) \)
  \[ \alpha = 30\text{deg} \]
- Distance from wall to failure plane: \( L_{f_{-10}} := h_{10}\tan(\alpha) \)
  \[ L_{f_{-10}} = 5.8 \text{ ft} \]

- Effective length of reinforcement at depths of 10 and 20 feet below the ground surface: \( L_{e_{-10}} := \frac{4400\text{lbf} \cdot FS}{2 \cdot b \cdot \gamma \cdot 10\text{ft} \cdot \tan\left(\frac{2}{3}\phi\right)} \)
  \[ L_{e_{-10}} = 18.1 \text{ ft} \]

- Total reinforcement length:
  \[ L_{t_{-10}} := L_{f_{-10}} + L_{e_{-10}} \]
  \[ L_{t_{-10}} = 23.9 \text{ ft} \]
CE 115 Intro to Civil Eng: Geotechnical Engineering Lab

Location: BEL 123

Objective: Design and build the most economical mechanically stabilized earth (MSE) wall.

Tasks:
1. In your assigned group, create a Mathcad worksheet to determine the required reinforcement length for the MSE wall. This must be completed before the lab class begins. Email yourself a copy of the Mathcad worksheet prior to class.
2. Determine the soil friction angle by building a wall without reinforcement and measuring the angle of the failure plane behind the wall. Bring a protractor to measure the angle of the failure plane.

   Failure Plane Angle, $\theta = \rule{10cm}{1pt}$

   Soil Friction Angle, $\phi = \rule{10cm}{1pt}$

3. Use your Mathcad worksheet from Task 1 and the friction angle from Task 2 to determine how much reinforcement you will need to build your wall. Submit a request for the number of 0.25 in by 11 in strips of paper you need.

<table>
<thead>
<tr>
<th>Layer No.</th>
<th>Distance from Top of Wall (inches)</th>
<th>Reinforcement Length, L (inches)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
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</tbody>
</table>

4. Construct the MSE wall.

MSE Wall Design Data
Wall Height: 11 inches
Soil Unit Weight, $\gamma$: 100 lb/ft$^3$
Surcharge Load, $q$: 5 lb/ft$^2$
Factor of Safety: You choose
Reinforcement
   Width, $b$: 0.25 inches
   Horizontal Spacing, $S_h$: You choose. The box is 4 inches wide. Previously, only one strip was placed at each depth. As a result, $S_h$ was 4 inches.
   Vertical Spacing, $S_v$: You choose
Soil Friction Angle, $\phi$: Obtained from Task 2 (While creating the Mathcad worksheet, assume $\phi = 36$ degrees)

Wall Failure
Wall failure for this project is defined as 0.25 inches of outward movement/rotation of the wall face.