Ch 8
Retaining wall

• Types of retaining wall:
  1- Conventional retaining wall which is classified to: Gravity RW, Semi gravity RW, Cantilever RW, and Counter fort RW.
  2- Mechanically stabilized earth wall.

The reinforcement detailing for cantilever retaining wall shown in previous figure is general reinforcement, if it is required to sketch the main reinforcement it will be as follow:
Types of lateral earth pressure:

- At rest soil pressure:
  \[ \sigma_h = k_o \sigma_v \Rightarrow k_o = 1 - \sin \Phi \]

- Active soil pressure (Rankine, horizontal backfill, vertical wall)
  \[ \sigma_a = \left( \sigma_v + q \right) k_a - 2c \sqrt{k_a} \Rightarrow k_a = \tan^2 \left( 45 - \frac{\Phi}{2} \right) = \frac{1 - \sin \Phi}{1 + \sin \Phi} \]

- Passive soil pressure (Rankine, horizontal backfill, vertical wall)
  \[ \sigma_p = \left( \sigma_v + q \right) k_p + 2c \sqrt{k_p} \Rightarrow k_p = \tan^2 \left( 45 + \frac{\Phi}{2} \right) = \frac{1 + \sin \Phi}{1 - \sin \Phi} = \frac{1}{k_a} \]

Steps to design the retaining wall

1- Assume proper dimensions for the retaining wall (See P.378 fig.8.3.).
2- Check the adequacy of selected dimensions for:
   - Overturning.
   - Sliding.
   - Bearing capacity.
➢ Check for overturning:

\[(FS)_o \geq 2\]

\[(FS)_o = \frac{\sum M_R}{\sum M_o}\]

\(\sum M_R\): Summation of moments that resist the overturning about the toe.

\(\sum M_o\): Summation of moments that derive the overturning about the toe.

\[\Rightarrow \sum M_R = w_1 x_1 + w_2 x_2 + w_3 x_3 + w_4 x_4\]

\[\Rightarrow \sum M_o = P_a d_1 + P_a d_2\]

For conservative design, the passive soil action is neglected.

Note that for the above figure, we consider that the soil is sandy soil so that the passive pressure starts from zero. Also the active pressure starts from surcharge only as the term \(2c \sqrt{k} =0.00\) for sandy soils.

If \((FS)_o < 2:\)

➢ Increase the base width (B).

➢ Increase the passive force \((P_p)\).

➢ Check for sliding:

\[(FS)_s \geq 1.5\]

\[(FS)_s = \frac{\sum F_R}{\sum F_d}\]

\(\sum F_R\): Summation of forces that resist sliding.

\(\sum F_d\): Summation of forces that derive sliding.

\[\sum F_d = P_{a1} + P_{a2}\]

\[\sum F_R = \sum F_y \tan(k_1 \Phi_2) + B k_2 c_2 + P_p\]

\[\sum F_y = w_1 + w_2 + w_3 + w_4\]

\[k_1 \& k_2 = \left(\frac{1}{2} \rightarrow \frac{2}{3}\right)\]

If \((FS)_s < 1.5:\)

➢ Increase \(\sum F_R\) by increasing the base width B.

➢ Increase \(\sum F_R\) by adding key base so that the passive force will increase.
Check for bearing capacity:

\[(FS)_b \geq 3\]

\[(FS)_b = \frac{q_u}{q_{max}}\]

It is clear that there will be eccentricity for the retaining wall, so that the soil pressure won't be uniform under the wall base.

- The soil pressure at the toe = \[q_{max} = \frac{\sum F_y}{B} \left(1 + \frac{6e}{B}\right)\]
- The soil pressure at the heel = \[q_{min} = \frac{\sum F_y}{B} \left(1 - \frac{6e}{B}\right) \geq 0\]

\[e = \frac{B}{2} - X'\]

\[X' = \frac{M_{net}}{\sum F_y} \Rightarrow M_{net} = \sum M_R - \sum M_o\]

\[q_u = cN_c F_{ci} F_{cd} F_{ci} + qN_q F_{qi} F_{qd} F_{qi} + 0.5\gamma B' N_y F_{yd} F_{yd} F_{yd}\]

\[q = \gamma_2 D\]

\[B' = B - 2e\]

\[F_{cd} = F_{qd} - \frac{1 - F_{qd}}{N_c \tan \phi_2'}\]

\[F_{qd} = 1 + 2 \tan \phi_2' (1 - \sin \phi_2') \frac{D}{B'}\]

\[F_{yd} = 1\]

\[F_{ci} = F_{qi} = \left(1 - \frac{\psi^\circ}{90^\circ}\right)^2\]

\[F_{yi} = \left(1 - \frac{\psi^\circ}{\phi_2'^\circ}\right)^2\]

\[\psi^\circ = \tan^{-1} \left(\frac{P_d \cos \alpha}{\Sigma V}\right)\]
Note: You have to see examples 8.1 & 8.2

Example 1
For the shown retaining wall:
➢ Find the factor of safety against overturning and sliding.
➢ Find the soil pressure below the toe.
(Neglect passive action of soil), \( \gamma_{\text{concrete}} = 150 \text{pcf} \)

Solution
➢ Find the lateral pressure:
\[
\begin{align*}
k_a &= \tan^2 \left( 45 - \frac{\Phi_1}{2} \right) = \tan^2 \left( 45 - \frac{30}{2} \right) = 1/3 \\
\sigma_a &= \left( \sigma_v + q \right) k_a - 2c \sqrt{k_a} = (17.5 \times 121 + 0)(1/3) - 0 = 705.833 \text{ psf} \\
P_a &= \frac{1}{2} \times 705.833 \times 17.5 = 6176.04 \text{ lb/ft.}
\end{align*}
\]
Find \((FS)_o\): 

Find the vertical loads that will operate resisting moment to overturning:

<table>
<thead>
<tr>
<th>Part No.</th>
<th>W (Ib/ft)</th>
<th>X (ft) force arm about toe</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(\frac{1}{2} \times 0.8 \times 15 \times 150 = 900)</td>
<td>1.783</td>
</tr>
<tr>
<td>2</td>
<td>(1.5 \times 15 \times 150 = 3375)</td>
<td>2.8</td>
</tr>
<tr>
<td>3</td>
<td>(\frac{1}{2} \times 5.25 \times 15 \times 150 = 5906.25)</td>
<td>5.3</td>
</tr>
<tr>
<td>4</td>
<td>(10.3 \times 2.5 \times 150 = 3862.5)</td>
<td>5.15</td>
</tr>
<tr>
<td>5</td>
<td>(\frac{1}{2} \times 5.25 \times 15 \times 121 = 4764.375)</td>
<td>7.05</td>
</tr>
<tr>
<td>6</td>
<td>(1.5 \times 15 \times 121 = 2722.5)</td>
<td>9.55</td>
</tr>
</tbody>
</table>

\[\sum M_R = \sum w_i x_i = 121838.42 \text{Ib} \cdot \text{ft} / \text{ft}\]

\[\sum M_o = 6176.04 \times 17.5 / 3 = 36026.9 \text{Ib} \cdot \text{ft} / \text{ft}\]

\[(FS)_o = 121838.42 / 36026.9 = 3.38 > 2 \Rightarrow OK\]
Find \((FS)_S\):
\[\sum F_d = 6176.04 \text{lb/ft}\]
\[\sum F_R = \mu \sum F_y + Bc_a + P_p\]
\(\mu\): Coefficient of friction, \(\Rightarrow \mu = \tan{(2/3) \times 20} = 0.237\)
\[\sum F_y = 21530.625 \text{lb/ft}\]
\(c_a = 2/3 \times 1000 = 666.67 \text{psf}\)
\[\sum F_R = 0.237 \times 21530.625 + 10.3 \times 666.67 + 0 = 11969.46 \text{lb/ft}\]
\[(FS)_S = \frac{11969.46}{6176.04} = 1.93 > 1.5 \Rightarrow OK\]

Find the pressure at the toe:
The soil pressure at the toe = \(q_{max} = \frac{\sum F_y}{B} \left(1 + \frac{6e}{B}\right)\)
\[e = \frac{B}{2} - X'^{'}\]
\[X'^{'} = \frac{M_{net}}{\sum F_y} \Rightarrow M_{net} = \sum M_R - \sum M_o\]
\[X'^{'} = \frac{121838.42 - 36026.9}{21530.625} = 3.985 \text{ft}\]
\[e = 10.3/2 - 3.985 = 1.164 \text{ft}\]
\[q_{max} = \frac{21530.625}{10.3} \left(1 + \frac{6 \times 1.164}{10.3}\right) = 3508.272 \text{psf}\]