Solution to Assignment No. 6

Prob 1. (7.2 in the text)

Given: Consolidation data

Soil conditions shown in the graph

4m fill with \( p = 21 \text{ kN/m}^2 \)

Find: Total settlement caused by the fill \( 0.316 \text{ m} \)

Magnitude of rebound after removing the fill \( 0.043 \text{ m} \)

Solution:

First find out compression index \( C_c \) and recompression index \( C_r \).

From the \( e - \log \sigma_v' \) curve:

\[
C_c = \frac{\Delta e}{\log \frac{\sigma_v}{\sigma_i}} = \frac{1.217 - 0.994}{\log \frac{429}{54}} = 0.248
\]

\[
C_r = \frac{\Delta e}{\log \frac{\sigma_v}{\sigma_i}} = \frac{1.024 - 0.994}{\log \frac{429}{54}} = 0.033
\]

An analytic relationship between \( e \) and \( \log \sigma_v' \) helps find \( e \) at different consolidation pressure.

In loading stage:

\[
\frac{1.217 - e}{\log \sigma_v' - \log 54} = C_c
\]

In unloading stage:

\[
\frac{0.994 - e}{\log \sigma_v' - \log 429} = C_r
\]
Problem continued

\[
e = -0.033 \log \theta + 1.081
\]

**Fill** \( \gamma = 21 \text{ kN/m}^2 \)

<table>
<thead>
<tr>
<th>( \gamma' ) (kPa)</th>
<th>( \gamma' ) (kPa)</th>
<th>( e_0 )</th>
<th>( \Delta Z_1 ) (m)</th>
<th>( e_{\text{fin}} )</th>
<th>( \Delta Z_2 ) (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>45</td>
<td>129</td>
<td>1.225</td>
<td>0.102</td>
<td>1.124</td>
<td>-0.014</td>
</tr>
<tr>
<td>63</td>
<td>147</td>
<td>1.201</td>
<td>0.083</td>
<td>1.110</td>
<td>-0.011</td>
</tr>
<tr>
<td>81</td>
<td>165</td>
<td>1.174</td>
<td>0.070</td>
<td>1.097</td>
<td>-0.010</td>
</tr>
<tr>
<td>99</td>
<td>183</td>
<td>1.152</td>
<td>0.061</td>
<td>1.086</td>
<td>-0.008</td>
</tr>
<tr>
<td>( \Sigma \Delta Z )</td>
<td>0.316</td>
<td></td>
<td></td>
<td></td>
<td>-0.043</td>
</tr>
</tbody>
</table>

Divide the clay layer into 4 sublayers.

- \( \sigma_{\text{vo}}' \) is the initial vertical effective stress at the center point of each sublayer.
- \( \sigma' \) is the effective stress after consolidation is completed.

\[
\sigma' = \sigma_{\text{vo}}' + \Delta \sigma' \quad \Delta \sigma' = \gamma' \times 4 = 84 \text{ kPa}
\]

\[
\sigma_{\text{vo}}' = \gamma' \times h = (19-10) \times 9 = 9kPa
\]

\( e_0 \) is the void ratio before the fill is applied. \( e_{\text{fin}} \) is the void ratio after consolidation is completed. They can be obtained from \( e - \log \sigma' \) curve or from the loading stage formula.
Prob 1. Cont'd

$\Delta z_1$ is the settlement of each sublayer.

$$\Delta z_1 = \frac{H_0}{1 + e_0} C_c \frac{\delta v'}{\delta v_0}$$

$H_0 = 2 \text{ m}$

$\Delta z_2$ is the rebound of each sublayer.

$$\Delta z_2 = \frac{H_0}{1 + e_0} C_r \frac{\delta v'}{\delta v_0}$$

e - log $\sigma'v$ Prob 1

![Graph showing e-log $\sigma'v$ relationship]
Prob 2 (No. 7.4 in the text)

Given: Conditions in prob 1 (No. 7.2), Fill dumped rapidly

\( C_v = 2.4 \text{ m}^3/\text{year} \), double drainage

Find: \( u_e \) at the center of clay layer after 3 years

Solution:

\[
Hdr = \frac{\partial}{2} = 4 \text{ m}^2
\]

\[
T_v = \frac{C_v \cdot t}{Hdr} = \frac{2.4 \times 3}{16} = 0.45
\]

at \( \frac{z}{Hdr} = 1 \)

\( U_z = 0.58 = 1 - \frac{u_e}{u_0} \)

\( u_0 = \gamma \cdot H = 21 \times 4 = 84 \text{ kPa} \)

\( u_e = (1 - U_z) \cdot u_0 = (1 - 0.58) \times 84 = 35.3 \text{ kPa} \)
Prob 3 (No. 7.6 in the text)

Given: \( m_v = 0.83 \, \text{m}^3/\text{MN} \), \( C_v = 4.4 \, \text{m}^2/\text{yr} \)

Time to lower the water level: 40 weeks
Assume no change in the weight of sand

Find: \( S_{total} = 0.133 \, \text{m} \)

Settlement 2 years after the start of lowering: \( 0.098 \, \text{m} \)

Solution: Assume there is no interconnection between the two layers.

Due to the lowering of water level, there is an increase of effective stress at the bottom of the sand layer: \( \Delta \sigma'_d = \gamma w x 4 = 40 \, \text{kPa} \)
Therefore \( \psi_0 = 40 \, \text{kPa} \)
The pore pressure of the 2nd sand layer is completely independent of the two layers above it. And the total stress doesn't change (assumption). So there is no change of effective stress at the bottom of the clay layer. Therefore, \( \psi_0 = 0 \)
The initial excess pore pressure of the clay layer is of triangle shape.

\[ \Delta \sigma'_d = \frac{1}{2} \times \gamma w x 4 = \frac{40}{2} = 20 \, \text{kPa} \]
Prob 3 cont'd

\[ S_{\text{total}} = 3H = m \Delta \bar{H} \]

\[ = 0.83 \times 10^{-3} \text{ m}^3/\text{kN} \times 20 \text{ kPa} \times 8 \]

\[ = 0.133 \text{ m} \]

Correct for lowering time, the time used for calculation in:

\[ t = 2 - \left( \frac{40}{52} \right)/2 = 1.615 \text{ years} \]

\[ T_u = \frac{C_u t}{H_{\text{dur}}} = \frac{4.4 \times 1.615}{4^2} = 0.444 \]

From curve 1 of Fig 7.18 (Craig's Soil Mechanics)

\[ U = 0.74 \]

After 2 years:

\[ S = U S_{\text{total}} = 0.74 \times 0.133 \]

\[ = 0.098 \text{ m} \]
Prob 4.

Given:

Site 1: Load 105 kPa, settled 0.2 m in 10 years
\[ E_o = 0.8, C_o = 0.41 \]

Site 2: Load 105 kPa
\[ E_o = 0.6, C_o = 0.29 \]
\[ \gamma_{sand} = 17.3 \text{ kN/m}^3 \]
\[ \gamma_{clay} = 18.9 \text{ kN/m}^3 \]

Find:

a: \( \Delta Vo \) in the middle of clay layer of both sites.

b: \( \Delta Vo \) in the middle of clay layer

c: \( S_{total1} \)
\[ S_{total2} \]

d: percent of total settlement at Site 1

e: \( T_v \) for Site 1

f: \( C_v \) for Site 1

g: Assume same \( C_v \), the time needed to complete 60% settlement at Site 2.

Solution:

Assume the loads are of infinite dimensions on the plane.

\( \Delta Vo = \gamma_{sand} x 3 + \gamma_{sand} x 3 + \gamma_{clay} x 5 \)

Site 1:

\[ = 17.3 x 3 \quad + \quad 7.3 x 3 \quad + \quad 8.9 x 5 \]
\[ = 118.3 \text{ kPa} \]

Site 2:

\[ = 17.3 x 3 \quad + \quad 7.3 x 3 \quad + \quad 8.9 x 7.5 \]
\[ = 140.6 \text{ kPa} \]

6 - 7/12
Prob 4 cont'd

(b) After consolidation is completed, change in \( \Delta \bar{V} \) is equal to applied load.

Site 1: \( \Delta \bar{V} = 105 / 1.5 = 70.0 \text{ kPa} \)

Site 2: \( \Delta \bar{V} = 105.0 \text{ kPa} \)

(c) Divide Site 1 into 4 sublayers, Site 2 into 5 sublayers.

\[ S_{\delta} = \frac{H_0}{1 + e_0} \cdot C_0 \cdot \log \frac{\Delta \bar{V}}{\Delta \bar{V}_0} \]

Percent of total settlement: \( \frac{0.2}{1.156} = 17.3\% \)

6-8/12
Prob 4. cont'd

(6) \( U = 0.173 \) (Site 1)

From Fig 7.18 (P.23) Craig's Soil Mechanics curve 1

\[
T_U = 0.02 = \frac{Cv t}{H^2} = \frac{Cv \times 10}{5^2} \quad \text{double drainage}
\]

(7) \( Cv = 0.05 \text{ m}^2/\text{year} \) at Site 1

(8) Site 2 \( U = 0.6 \)

From the same figure curve 1 single drainage

\[
T_U = 0.29 = \frac{Cv t}{H^2} = \frac{0.05 \times t}{15^2}
\]

\( t = 1305 \text{ years} \)
Prob 5.

Given:

\[ s = 2 \text{ m}^2/\text{g} \]
\[ T_s = 73 \text{ dyne/cm} \]
\[ \omega = 30 \% \]

Find: \( u_a \) in kpa, psi, cm pf

Solution:

\[ u_a = -\frac{T_s \cdot s}{\omega} \cdot \frac{\text{cm}}{\text{cm}^3} \]

\[ = \frac{73 \cdot 9 \cdot \text{cm/s}^2/\text{cm} \times 2 \times 10^4 \cdot \text{cm}^2/\text{g} \times 1 \cdot \text{g/cm}^3}{0.3} \]

\[ = 4.87 \times 10^6 \text{ dyne/cm}^2 \]

1 dyne = \( 10^{-5} \) N

1 cm = \( 10^{-2} \) m

\[ u_a = -4.87 \times 10^6 \times 10^{-1} \frac{N}{m^2} \]

\[ = -487 \text{ kPa} \]

1 psi = 6.895 kPa

\[ u_a = -70.6 \text{ psi} \]

\[ u_a = -10.6 \text{ kPa} \]

\[ k = \frac{487}{9.8} = 49.7 \text{ m} = 4970 \text{ cm} \]

\[ p_f = \log(4970 \text{ cm}) = 3.7 \]
Prob 6.

Given:
\[ \begin{align*}
LL &= 45 \\
P_L &= 23 \\
8 - 2\mu &= 75\% \\
\% - 2\mu &= 38\% \\
\varepsilon_{vert} &= 50\% \frac{\Delta V}{V}
\end{align*} \]

Find PI

Soil Zone No.

\( V_o \)

\( V_h \)

\( \Delta P \)

\( \frac{\Delta V}{V} \)

Vertical shrinkage strain

Vertical shrinkage

Solution:

Reference:

http://ceprofis.civil.tamu.edu/lytton/cven_646.htm

CVEN 646 Handouts: Prediction of Movement in Expansive Clays

and CVEN 365 Handouts:

Suction - Volume Change Coefficients of Expansive Clay Minerals

\[ \begin{align*}
PI &= 45 - 23 = 22 \\
\text{From Figure 1 in the 2nd reference:} \\
\text{Zone No. is III}
\end{align*} \]