Problem 1. See class notes and web site: http://ceprofs.civil.tamu.edu/briaud/Intro to Moduli.pdf

Problem 2. See class notes.

Problem 3.

Sample calculations

1) Read $\Delta R/R_0 = 0.005$ and $P_p = 600$ kPa on the Pressuremeter Test curve, calculate

$$\frac{s}{B} = \frac{\Delta R}{4.2R_0} = 0.0012$$

Then the settlement is $s = 0.0012 \times 3000 = 3.6$ mm

2) Calculate $f$, 
\[ f = f_e \cdot f_i \cdot f_{\beta d} \cdot f_{L/B} = 0.689 \]

a) \[ f_e = 1 - 0.33\frac{e}{B} = 1 - 0.33(\frac{0.1}{3}) = 0.989 \quad \text{load eccentricity} \]

b) \[ f_i = 1 - \left[ \frac{\delta_{\text{deg}, e}}{90} \right]^2 = 1 - \left[ \frac{\tan^{-1}(\frac{900kN}{9000kN})}{90} \right]^2 = 0.996 \quad \text{load inclination} \]

c) \[ f_{\beta d} = 0.8 \left[ 1 + \left( \frac{d}{b} \right)^{0.1} \right] = 0.8 \left[ 1 + \left( \frac{2}{3} \right)^{0.1} \right] = 0.842 \quad \text{proportion of a slope} \]

d) \[ f_{L/B} = 0.8 + 0.2 \left( \frac{B}{L} \right) = 0.8 + 0.2 \left( \frac{3}{15} \right) = 0.84 \quad \text{shape of footing} \]

3) Read the \( \Gamma \) value from the graph for the given value of \( \frac{S}{B} \) or \( \frac{\Delta R}{4.2R_0} \). \( \Gamma = 2.25 \)

4) Calculate \( P_f = P_p \times \Gamma \times f = 60 \times 2.25 \times 0.689 = 93.0 \text{ kPa} \)

5) Calculate \( Q = P_f \times B \times L = 93.0 \times 3m \times 15m = 4,186 \text{ kN} \)

6) Iterate

<table>
<thead>
<tr>
<th>( \Delta R/R_0 )</th>
<th>( P_p )</th>
<th>( S/B )</th>
<th>( S(\text{mm}) )</th>
<th>( \Gamma )</th>
<th>( f )</th>
<th>( P_f )</th>
<th>( Q(\text{kN}) )</th>
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<td>0.0012</td>
<td>3.6</td>
<td>2.25</td>
<td>0.689</td>
<td>93.0</td>
<td>4,186</td>
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<td>0.0024</td>
<td>7.1</td>
<td>2.02</td>
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<td>167.0</td>
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<td>300</td>
<td>0.0071</td>
<td>21.4</td>
<td>1.60</td>
<td>0.689</td>
<td>330.7</td>
<td>14,882</td>
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<tr>
<td>0.050</td>
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<td>0.0119</td>
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<td>0.90</td>
<td>0.689</td>
<td>545.7</td>
<td>24,556</td>
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</tbody>
</table>

7) Draw the Load-Settlement Curve for the shallow foundation
Problem 4.

1) Ultimate Bearing Capacity (Undrained)

Read on Skempton Chart at \( D/B = 3/15 \), \( N_c = 6.5 \)

\[
P_u = N_c S_u + \gamma D = 6.5 \times 80 + 18 \times 3 = 574 \text{kN/m}^2
\]

2) \[
P = \frac{Q}{A} = \frac{154 \text{MN}}{\pi r^2} = 0.871 \text{MN} = 871 \text{kN/m}^2
\]

3) \( P > P_u \) (Tower of Pisa is unstable)

4) Redesign the foundation of Pisa

5) \[
P_{safe} = \frac{P_u}{F.S} = \frac{574 \text{kN/m}^2}{3} = 191.3 \text{kN/m}^2
\]

6) \[
P_{safe} \geq P = \frac{Q}{A} = \frac{154,000 \text{kN}}{\frac{\pi}{4} D^2}
\]

\( D \geq 32 \text{m} \)

* Settlement analysis should also be conducted to find if \( P_{safe} \) is allowable from the serviceability point of view.
1) \( P_{\text{wind}}(psf) = 0.00256 \times V^2\text{ (mph)} \times 1.2 = 0.00256 \times 120\text{mph}^2 \times 1.2 = 44.2\text{ psf} = 2.12kN/m^2 \)

2) \( H = 2.12kN/m^2 \times 366m \times 61m = 47,331kN \)

3) \( M_{\text{applied}} = H \times h = 47,331kN \times \left( \frac{366m}{2} + 20m \right) = 9,608 MN \cdot m \)

4) Weight of soil excavated = \( 20kN/m^3 \times 61m \times 61m \times 20m = 1,488,400kN \)

5) Total pressure under W.T.C = \( \frac{12,000,000kN}{61m \times 61m} = 3,225kN/m^2 \)

6) Effective pressure under W.T.C = \( \frac{12,000,000 - 20 \times 9.81 \times 61 \times 61}{61m \times 61m} = 3,029kN/m^2 \)

7) Effective Ultimate Bearing Capacity

\[
P_u = csN_c + \frac{1}{2} \gamma BsN_\gamma + \gamma Ds_qN_q
\]

\[
= \frac{1}{2} \times (20 - 9.81) \times 61 \times 0.8 \times 38 + (20 - 9.81) \times 20 \times 1.2 \times 33 = 17,519kN/m^2
\]
**Shape factor**

<table>
<thead>
<tr>
<th>Shape of base</th>
<th>$s_c$</th>
<th>$s_r$</th>
<th>$s_q$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strip</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
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<tr>
<td>Rectangular</td>
<td>$1+(0.2B/L)$</td>
<td>$1-(0.4B/L)$</td>
<td>$1+(0.2B/L)$</td>
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<tr>
<td>Square</td>
<td>1.3</td>
<td>0.8</td>
<td>1.2</td>
</tr>
<tr>
<td>Circle</td>
<td>1.3</td>
<td>0.6</td>
<td>1.2</td>
</tr>
</tbody>
</table>

\[
P_{\text{safe}} = \frac{P_u}{F.S} = \frac{17,519}{3} = 5,840 \text{ kN/m}^2
\]

8) \[
M_0 = \frac{1}{2} \left( P_{\text{max}} - P_{\text{ave}} \right) \times B \times 2 \times \left[ \frac{2}{3} \times \frac{B}{2} \right] = \left[ P_{\text{max}} - \frac{Q}{B^2} \right] \times \frac{B^2}{6} = (6,058 - 3,029) \times \frac{61^2}{6} = 1,878.5 \text{ MN} \cdot \text{m/m}
\]

9) \[
M = M_0 \times 61 = 114,588.5 \text{ MN} \cdot \text{m}
\]

\[
P_u = 17,519 \text{ kPa}
\]

\[
P_{\text{avg}} = 3,029 \text{ kPa}
\]

\[
P_{\text{max}} = 6,058 \text{ kPa}
\]
Problem 6.

1. Hard clay over soft clay

When $H$ is small, the footing punches through the hard clay. When $H$ is large, the failure remains in the hard clay (but settlement in the soft clay may control)

\[ P_u = \frac{2H}{B} S_{uH} + P_{US} = N_c S_{us} + \gamma H \]

\[ \therefore P_u = 2 \pi S_{uH} \approx N_c S_{uH} \]

\[ P_u = P_{US} + 2(H/B)S_{uH} \]

\[ (H/B)_c = \pi - (P_{US}/2S_{uH}) \]
2. Soft clay over hard clay

When $H$ is small, local edge failure occurs in the soft clay

\[ M_{@0} = 0 \]
\[ P_u \frac{H}{2} - S_{us} \pi HH = 0 \]
\[ \therefore P_u = 2\pi S_{us} \approx N_c S_{us} \]

When $H$ is large, global failure occurs in the soft clay

\[ M_{@0} = 0 \]
\[ P_u \frac{B}{2} - S_{us} \pi BB = 0 \]
\[ \therefore P_u = 2\pi S_{us} \approx N_c S_{us} \]