## Problems

**2.1** For a Shelby tube, given: outside diameter = 3 in. and inside diameter 2.874 in. What is the area ratio of the tube?

**2.2** A soil profile is shown in Figure P2.2 along with the standard penetration numbers in the clay layer. Use Eqs. (2.8) and (2.9) to determine the variation of $c_u$ and OCR with depth. What is the average value of $c_u$ and OCR?

**2.3** Following is the variation of the field standard penetration number ($N_{60}$) in a sand deposit:

| Depth (m) | $N_{60}$ |
|---|---|
| 1.5 | 6 |
| 3 | 8 |
| 4.5 | 9 |
| 6 | 8 |
| 7.9 | 13 |
| 9 | 14 |

The groundwater table is located at a depth of 6 m. Given: the dry unit weight of sand from 0 to a depth of 6 m is 18 kN/m$^3$, and the saturated unit weight of sand for depth 6 to 12 m is 20.2 kN/m$^3$. Use the relationship of Skempton given in Eq. (2.12) to calculate the corrected penetration numbers.

**2.4** For the soil profile described in Problem 2.3, estimate an average peak soil friction angle. Use Eq. (2.28).

**2.5** Repeat Problem 2.4 using Eq. (2.27).

**2.6** Refer to Problem 2.3. Using Eq. (2.20), determine the average relative density of sand.

**2.7** The following table gives the variation of the field standard penetration number ($N_{60}$) in a sand deposit:

| Depth (m) | $N_{60}$ |
|---|---|
| 1.5 | 5 |
| 3.0 | 11 |
| 4.5 | 14 |
| 6.0 | 18 |
| 7.5 | 16 |
| 9.0 | 21 |

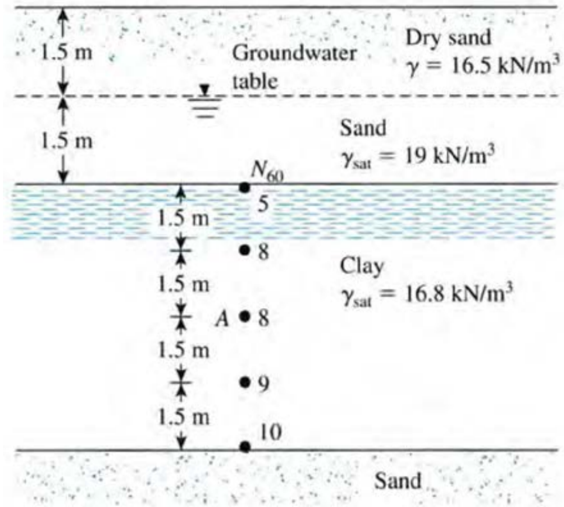


Figure P2.2

**2.15** In a deposit of normally consolidated dry sand, a cone penetration test was conducted. Following are the results:

| Depth (m) | Point resistance of cone, $q_c$ (MN/m²) |
|---|---|
| 1.5 | 2.06 |
| 3.0 | 4.23 |
| 4.5 | 6.01 |
| 6.0 | 8.18 |
| 7.5 | 9.97 |
| 9.0 | 12.42 |

Assuming the dry unit weight of sand to be 16 kN/m³, estimate the average peak friction angle, $\phi'$, of the sand. Use Eq. (2.48).

**2.16** Refer to Problem 2.15. Using Eq. (2.46), determine the variation of the relative density with depth.

**2.17** In the soil profile shown in Figure P2.17, if the cone penetration resistance ($q_c$) at $A$ (as determined by an electric friction-cone penetrometer) is 0.8 MN/m.², estimate

a. The undrained cohesion, $c_u$

b. The overconsolidation ratio, OCR

**2.22** The results of a refraction survey (Figure 2.42a) at a site are given in the following table. Determine the thickness and the $P$-wave velocity of the materials encountered.

| Distance from the source of disturbance (m) | Time of first arrival of $P$-waves (sec × 10³) |
|---|---|
| 2.5 | 5.08 |
| 5.0 | 10.16 |
| 7.5 | 15.24 |
| 10.0 | 17.01 |
| 15.0 | 20.02 |
| 20.0 | 24.2 |
| 25.0 | 27.1 |
| 30.0 | 28.0 |
| 40.0 | 31.1 |
| 50.0 | 33.9 |

### *Correlation between $N_{60}$ and Relative Density of Granular Soil*

An approximate relationship between the corrected standard penetration number and the relative density of sand is given in Table 2.8. The values are approximate primarily because the effective overburden pressure and the stress history of the soil significantly influence the $N_{60}$ values of sand. Kulhawy and Mayne (1990) modified an empirical relationship for relative density that was given by Marcuson and Bieganousky (1977), which can be expressed as

$$D_r(\%) = 12.2 + 0.75\left[222N_{60} + 2311 - 711\text{OCR} - 779\left(\frac{\sigma'_o}{p_a}\right) - 50C_u^2\right]^{0.5} \quad (2.19)$$

where

$D_r$ = relative density

$\sigma'_o$ = effective overburden pressure

$C_u$ = uniformity coefficient of sand

$$\text{OCR} = \frac{\text{preconsolidation pressure}, \sigma'_c}{\text{effective overburden pressure}, \sigma'_o}$$

$p_a$ = atmospheric pressure

Meyerhof (1957) developed a correlation between $D_r$ and $N_{60}$ as

$$N_{60} = \left[17 + 24\left(\frac{\sigma'_o}{p_a}\right)\right]D_r^2$$

or

$$D_r = \left\{\frac{N_{60}}{\left[17 + 24\left(\frac{\sigma'_o}{p_a}\right)\right]}\right\}^{0.5} \quad (2.20)$$

Equation (2.20) provides a reasonable estimate only for clean, medium fine sand.

Cubrinovski and Ishihara (1999) also proposed a correlation between $N_{60}$ and the relative density of sand ($D_r$) that can be expressed as

$$D_r(\%) = \left[\frac{N_{60}\left(0.23 + \frac{0.06}{D_{50}}\right)^{1.7}}{9}\left(\frac{1}{\frac{\sigma'_o}{p_a}}\right)\right]^{0.5}(100) \quad (2.21)$$