# SOLUTIONS MANUAL

*Chapters 1–11*

SECOND EDITION

# FOUNDATION DESIGN

*Principles and Practices*

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# Chapter 2 — Performance Requirements

**2.1** A proposed column has the following design loads:

Axial load: $P_D = 200$ k, $P_L = 170$ k, $P_E = 50$ k, $P_W = 60$ k (all compression)

Shear load: $V_D = 0$, $V_L = 0$, $V_E = 40$ k, $V_W = 48$ k

Compute the design axial and shear loads for foundation design using ASD.

**Solution**

(2.1) $P = P_D = 200k$

$V = V_D = 0k$

(2.2) $P = P_D + P_L = 200 + 170 = \boxed{370k}$ ← Controls

$V = V_D + V_L = 0k$

(2.3A) $P = 0.75(P_D + P_L + P_W) = 0.75(200 + 170 + 60) = 322k$

$V = 0.75(V_D + V_L + V_W) = 0.75(0 + 0 + 48) = \boxed{36k}$ ← Controls

(2.4A) $P = 0.75(P_D + P_W) = 0.75(200 + 60) = 195k$

$V = 0.75(V_D + V_W) = 0.75(0 + 48) = 36k$

**2.2** Repeat Problem 2.1 using LRFD with the ACI load factors.

**Solution**

(2.7) $U = 1.4D + 1.7L$

$P_u = 1.4(200) + 1.7(170) = 569k$

$V_u = 0$

(2.12) $U = 0.9D + 1.3W$

$P_u = 0.9(200) + 1.3(60) = 258k$

$V_u = 0.9(0) + 1.3(48) = 62k$

(2.13) $U = 0.9D + 1.43E$

$P_u = 0.9(200) + 1.43(50) = 251k$

$V_u = 0.9(0) + 1.43(40) = 57k$

(2.14) $U = 0.75(1.4D + 1.7L + 1.7W)$

$P_u = 0.75[1.4(200) + 1.7(170) + 1.7(60)] = 503k$

$V_u = 0.75[0 + 0 + 1.7(48)] = 61k$

(2.15) $U = 0.75[1.4D + 1.7L + 1.87E]$

$P_u = 0.75[1.4(200) + 1.7(170) + 1.87(50)] = \boxed{662k}$ ← Controls

$V_u = 0.75[0 + 0 + 1.87(40)] = \boxed{75k}$ ← Controls

**2.3** A certain foundation will experience a bearing capacity failure when it is subjected to a downward load of 2200 kN. Using ASD with a factor of safety of 3, determine the maximum allowable load that will satisfy geotechnical strength requirements.

**Solution**

$$P_{all} = \frac{2200}{3} = \boxed{733 \text{ kN}}$$

**2.4** A steel pile foundation with a cross-sectional area of 15.5 $in^2$ and $F_y$ = 50 $k/in^2$ is to carry axial compressive dead and live loads, of 300 and 200 k, respectively. Using LRFD with the ANSI/ASCE load factors and a resistance factor of 0.75, determine whether this pile satisfies structural strength requirements for axial compression.

**Solution**

$$P_u = 1.2(300) + 1.6(200) = 680 \text{ k}$$

$$\phi P_n = 0.75(15.5)(50) = 581 \text{ k}$$

$$P_u > \phi P_n \quad \therefore \text{ Not Acceptable}$$

**2.5** A seven-story steel-frame office building will have columns spaced 7 m on center and will have typical interior and exterior finishes. Compute the allowable total and differential settlements for this building.

**Solution**

$$\boxed{\delta_a = 25 \text{ mm}}$$

$$\theta_a = 1/500$$

$$\delta_{Da} = (1/500)(7000) = \boxed{14 \text{ mm}}$$

**2.6** A two-story reinforced concrete art museum is to be built using an unusual architectural design. It will include many tile murals and other sensitive wall finishes. The column spacing will vary between 5 and 8 m. Compute the allowable total and differential settlements for this buiding.

**Solution**

$\delta_a = 15mm$

$\theta_a = 1/1000$

$\delta_{Da} = 1/1000\ (5000) = 5mm$

**2.7** A 40 ft × 60 ft one-story agricultural storage building will have corrugated steel siding and no interior finish or interior columns. However, it will have two roll-up doors. Compute the allowable total and differential settlement for this building.

**Solution**

$\delta_a = 2.0\ in$

$\theta_a = 1/250$

$\delta_{Da} = (1/250)(40)(12) = 2\ in \rightarrow$ Use $\delta_{Da} = 1\ in$

Use extra stiffening around roll-up doors

**2.8** A sandy soil has 0.03 percent sulfates. Evaluate the potential for sulfate attack of concrete exposed to this soil and recommend preventive design measures, if needed.

**Solution**

Per Table 2.3 → No problem with Sulfates

**2.9** A certain clayey soil contains 0.30 percent sulfates. Would you anticipate a problem with concrete foundations in this soil? Are any preventive measures necessary? Explain.

**Solution**

Per table 2.3 → Severe problem with Sulfates

Use Type V Cement

W:C ratio $\leq 0.45$

**2.10** A series of 50-ft long steel piles are to be driven into a natural sandy soil. The groundwater table is at a depth of 35 ft below the ground surface. Would you anticipate a problem with corrosion? What additional data could you gather to make a more informed decision?

**Solution**

Probably not a problem. Be sure salt water is not present.

**2.11** A one-story steel warehouse building is to be built of structural steel. The roof is to be supported by steel trusses that will span the entire 70 ft width of the building and supported on columns adjacent to the exterior walls. These trusses will be placed 24 ft on center. No interior columns will be present. The walls will be made of corrugated steel. There will not be any roll-up doors. Compute the allowable total and differential settlements.

**Solution**

$\delta_a = 2$ in

$\theta_a = 1/450$

$\delta_{DA} = (1/450)(24)(12) = 1$ in

**2.12** The grandstands for a minor league baseball stadium are to be built of structural steel. The structural engineer plans to use a very wide column spacing (25 m) to provide the best spectator visibility. Compute the allowable total and differential settlements.

**Solution**

$\delta_a = 50$ mm

$\theta_a = 1/450$

$\delta_{DA} = (1/450)(25000)(100$ mm $\rightarrow$ use 50 mm

**2.13** The owner of a 100-story building purchased a plumb bob with a very long string. He selected a day with no wind, and then gently lowered the plumb bob from his penthouse office window. When it reached the sidewalk, it was 1.0 m from the side of the building. Is this building tilting excessively? Explain.

**Solution**

Estimated height $= (100)(3) = 300$ m

tilt $= \frac{1}{300} > 1/500$ ∴ Not acceptable

**2.14** A two-story department store identical to the one in Figure 2.12 is to be built. This structure will have reinforced masonry exterior walls. The ground floor will be slab-on-grade. The reinforced concrete upper floor and roof will be supported on a steel-frame with columns 50 ft on-center. Compute the allowable total and differential settlements for this structure.

**Solution**

$\delta_a = 1$ in

$\theta_a = 1/500$

$\delta_{DA} = (1/500)(50)(12) = 1$ in

# Chapter 3 — Soil Mechanics

3.1 Explain the difference between moisture content and degree of saturation.

**Solution**

Moisture content is the ratio of the mass of water to the mass of solids, while degree of saturation is the percentage of the volume of voids filled with water. Both parameters are zero when the soil is completely dry, and increase when the amount of water increases. However, the degree of saturation has a maximum possible value of 100%, whereas the moisture content can exceed 100%.

3.2 A certain saturated sand ($S$ = 100%) has a moisture content of 25.1% and a specific gravity of solids of 2.68. It also has a maximum index void ratio of 0.84 and a minimum index void ratio of 0.33. Compute its relative density and classify its consistency.

**Solution**

$$e = \frac{w G_s}{S} = \frac{(0.251)(2.68)}{1} = 0.673$$

$$D_r = \frac{e_{max} - e}{e_{max} - e_{min}} \times 100\% = \frac{0.84 - 0.673}{0.84 - 0.33} \times 100\% = \boxed{33\%}$$

the soil is $\boxed{\text{Loose}}$

3.3 Consider a soil that is being placed as a fill and compacted using a sheepsfoot roller (a piece of construction equipment). Will the action of the roller change the void ratio of the soil? Explain.

**Solution**

The volume of the solids remains constant, but compaction reduces the total volume and thus reduces the volume of the voids. This results in a lower void ratio.

3.4 A sample of soil has a volume of 0.45 $ft^3$ and a weight of 53.3 lb. After being dried in an oven, it has a weight of 45.1 lb. It has a specific gravity of solids of 2.70. Compute its moisture content and degree of saturation before it was placed in the oven.

**Solution**

$$w = \frac{W_w}{W_s} \times 100\% = \frac{53.3 - 45.1}{45.1} \times 100\% = \mathbf{18.2\%}$$

$$\gamma = \frac{W}{V} = \frac{53.3}{0.45} = 118.4 \text{ lb/ft}^3$$

$$\gamma_d = \frac{\gamma}{1 + w} = \frac{118.4}{1 + 0.182} = 100.2 \text{ lb/ft}^3$$

$$w = S\left(\frac{\gamma_w}{\gamma_d} - \frac{1}{G_s}\right) \rightarrow 0.182 = S\left(\frac{62.4}{100.2} - \frac{1}{2.70}\right) \rightarrow S = \mathbf{72.1\ \%}$$

3.5 A site is underlain by a soil that has a unit weight of 18.7 kN/$m^3$ above the groundwater table and 19.9 kN/$m^3$ below. The groundwater table is located at a depth of 3.5 m below the ground surface. Compute the total vertical stress, pore water pressure, and effective vertical stress at the following depths below the ground surface:

a. 2.2 m
b. 4.0 m
c. 6.0 m

**Solution**

| Part | Depth (m) | $\sigma_z$ (kPa) | u (kPa) | $\sigma_z'$ (kPa) |
|---|---|---|---|---|
| a | 2.2 | 41.1 | 0 | 41.1 |
| b | 4.0 | 75.4 | 4.9 | 70.5 |
| c | 6.0 | 115.2 | 24.5 | 90.7 |