

# CHAPTER 2

| (2-1) | Sieve No. | Size Opening (mm) | Mass Retained (g) | Percent Retained | Cumulative Percent Retained | Percent Passing |
|-------|-----------|-------------------|-------------------|------------------|-----------------------------|-----------------|
|       | 3/8 in.   | 9.50              | 0                 | 0                | 0                           | 100             |
|       | No. 4     | 4.75              | 42                | 4.2              | 4.2                         | 95.8            |
|       | No. 10    | 2.00              | 146               | 14.6             | 18.8                        | 81.2            |
|       | No. 40    | 0.425             | 458               | 45.8             | 64.6                        | 35.4            |
|       | No. 100   | 0.150             | 218               | 21.8             | 86.4                        | 13.6            |
|       | No. 200   | 0.075             | 73                | 7.3              | 93.7                        | 6.3             |
|       | Pan       |                   | 63                | 6.3              | 100.0                       | 0               |
|       |           |                   | 1000              | 100.0            |                             |                 |

Gradation curve is given on page 2.

- (2-2) (1) Eq. (2-3):  $PI = 29 - 19 = 10\%$   
AASHTO classification: A-2-4 (0)  
(2) USCS classification: SC

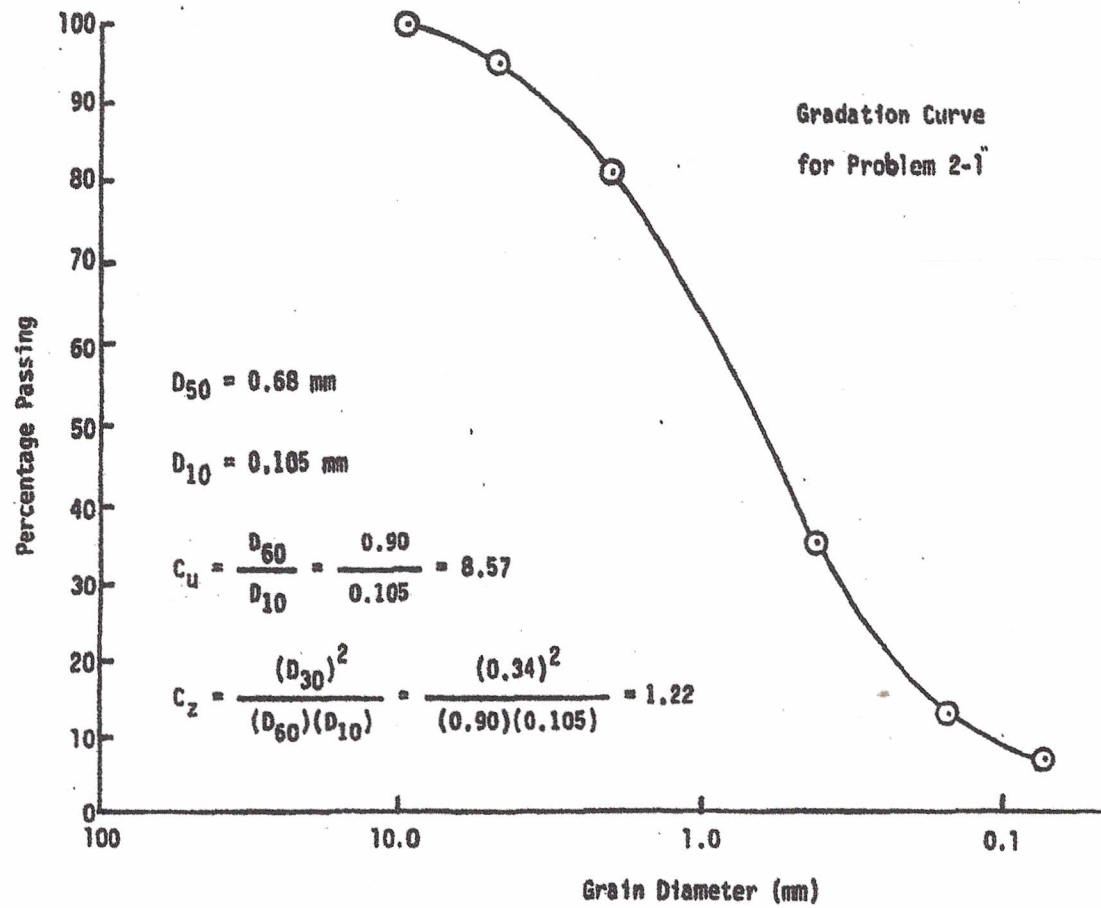
- (2-3) (a) Eq. (2-10):  $w = [(62 - 50)/50](100) = 24.0\%$   
(b) Eq. (2-11):  $\gamma = 62/0.56 = 110.7 \text{ lb/ft}^3$   
(c) Eq. (2-12):  $\gamma_d = 50/0.56 = 89.3 \text{ lb/ft}^3$   
(d) Eq. (2-15):  $2.64 = 50/(62.4V_s)$ ;  $V_s = 0.304 \text{ ft}^3$   
 $V_w = (62 - 50)/62.4 = 0.192 \text{ ft}^3$   
 $V_v = 0.56 - 0.304 = 0.256 \text{ ft}^3$   
Eq. (2-7):  $e = 0.256/0.304 = 0.84$   
(e) Eq. (2-8):  $n = [(0.064 + 0.192)/0.56](100) = 45.7\%$   
(f) Eq. (2-9):  $S = [0.192/(0.064 + 0.192)](100) = 75.0\%$

- (2-4) (a) Eq. (2-10):  $w = [(141.5 - 122.7)/122.7](100) = 15.3\%$   
(b) Eq. (2-15):  $2.66 = 122.7/(1V_s)$ ;  $V_s = 46.1 \text{ cm}^3$   
 $V_v = 72 - 46.1 = 25.9 \text{ cm}^3$   
Eq. (2-7):  $e = 25.9/46.1 = 0.56$   
(c) Eq. (2-8):  $n = [(72 - 46.1)/72](100) = 36.0\%$   
(d)  $V_w = (141.5 - 122.7)/1 = 18.8 \text{ cm}^3$   
Eq. (2-9):  $S = (18.8/25.9)(100) = 72.6\%$   
(e) Eq. (2-11):  $\gamma = (141.5/72)(62.4) = 122.6 \text{ lb/ft}^3$   
(f) Eq. (2-12):  $\gamma_d = (122.7/72)(62.4) = 106.3 \text{ lb/ft}^3$

- (2-5) Work with  $1 \text{ ft}^3$  of specimen.

- (a) Eq. (2-10):  $18 = (W_w/W_s)(100)$ ;  $W_w = 0.18W_s$   
 $W_w + W_s = 118.5$ ;  $0.18W_s + W_s = 118.5$ ;  $W_s = 100.4 \text{ lb}$   
Eq. (2-12):  $\gamma_d = 100.4/1 = 100.4 \text{ lb/ft}^3$   
(b) Eq. (2-15):  $2.72 = 100.4/(62.4V_s)$ ;  $V_s = 0.59 \text{ ft}^3$   
 $V_v = 1 - 0.59 = 0.41 \text{ ft}^3$   
Eq. (2-7):  $e = 0.41/0.59 = 0.69$   
(c)  $W_w = (0.18)(100.4) = 18.1 \text{ lb}$   
 $V_w = 18.1/62.4 = 0.29 \text{ ft}^3$   
Eq. (2-9):  $S = (0.29/0.41)(100) = 70.7\%$

- (2-6) Work with  $1 \text{ ft}^3$  of specimen.



- (a) Eq. (2-7):  $0.56 = V_v/V_s$ ;  $V_v = 0.56V_s$   
 $V_v + V_s = 1$ ;  $0.56V_s + V_s = 1$ ;  $V_s = 0.64 \text{ ft}^3$   
 Eq. (2-15):  $2.64 = W_s/[(0.64)(62.4)]$ ;  $W_s = 105.4 \text{ lb}$   
 Eq. (2-10):  $15 = (W_w/105.4)(100)$ ;  $W_w = 15.8 \text{ lb}$   
 $W = 15.8 + 105.4 = 121.2 \text{ lb}$   
 Eq. (2-11):  $\gamma = 121.2/1 = 121.2 \text{ lb/ft}^3$
- (b) Eq. (2-12):  $\gamma_d = 105.4/1 = 105.4 \text{ lb/ft}^3$
- (c)  $V_v = 1 - 0.64 = 0.36 \text{ ft}^3$   
 Eq. (2-8):  $n = (0.36/1)(100) = 36.0\%$
- (d)  $V_w = 15.8/62.4 = 0.253 \text{ ft}^3$   
 Eq. (2-9):  $S = (0.253/0.36)(100) = 70.3\%$
- (2-7) Work with  $1 \text{ ft}^3$  of specimen.
- (a) Eq. (2-10):  $42 = (W_w/W_s)(100)$ ;  $W_w = 0.42W_s$   
 $W_w + W_s = 112.8$ ;  $0.42W_s + W_s = 112.8$ ;  $W_s = 79.4 \text{ lb}$   
 $W_w = 112.8 - 79.4 = 33.4 \text{ lb}$   
 $V_w = 33.4/62.4 = 0.54 \text{ ft}^3$   
 $V_s = 1 - 0.54 = 0.46 \text{ ft}^3$   
 Eq. (2-7):  $e = 0.54/0.46 = 1.17$   
 (Because  $S = 100\%$ ,  $V_v = V_w$ .)
- (b) Eq. (2-15):  $G_s = 79.4/[(0.46)(62.4)] = 2.77$
- (2-8) Work with  $1 \text{ ft}^3$  of specimen.
- (a) Eq. (2-10):  $26 = (W_w/15.80)(100)$ ;  $W_w = 4.11 \text{ kN}$   
 $V_w = 4.11/9.81 = 0.419 \text{ m}^3$   
 $V_s = 1 - 0.419 = 0.581 \text{ m}^3$   
 $\gamma_{\text{sat}} = (4.11 + 15.80)/1 = 19.91 \text{ kN/m}^3$
- (b) Eq. (2-7):  $e = 0.419/0.581 = 0.72$   
 (Because  $S = 100\%$ ,  $V_v = V_w$ .)
- (c) Eq. (2-15):  $G_s = 15.80/[(0.581)(9.81)] = 2.77$
- (2-9) Work with  $1 \text{ ft}^3$  of specimen.
- (a) Eq. (2-7):  $1.33 = V_v/V_s$ ;  $V_v = 1.33 V_s$   
 $V_v + V_s = 1$ ;  $1.33V_s + V_s = 1$ ;  $V_s = 0.43 \text{ ft}^3$   
 $V_w = 1 - 0.43 = 0.57 \text{ ft}^3$   
 $W_w = (62.4)(0.57) = 35.6 \text{ lb}$   
 Eq. (2-10):  $48 = (35.6/W_s)(100)$ ;  $W_s = 74.2 \text{ lb}$   
 $W = 74.2 + 35.6 = 109.8 \text{ lb}$   
 Eq. (2-11):  $\gamma = 109.8/1 = 109.8 \text{ lb/ft}^3$
- (b) Eq. (2-15):  $G_s = 74.2/[(0.43)(62.4)] = 2.77$
- (2-10) Work with  $1 \text{ ft}^3$  of specimen.
- (a) Eq. (2-10):  $35 = (W_w/W_s)(100)$ ;  $W_w = 0.35W_s$   
 $V_v = W_w/62.4 = 0.35W_s/62.4 = 0.005609W_s$   
 Eq. (2-15):  $2.70 = W_s/[(V_s)(62.4)]$   
 $V_s = W_s/[(2.70)(62.4)] = 0.005935W_s$   
 Eq. (2-7):  $e = (0.005609W_s)/(0.005935W_s) = 0.945$
- (b) From (a),  $V_v = 0.945V_s$   
 $V_v + V_s = 1$ ;  $0.945V_s + V_s = 1$ ;  $V_s = 0.514 \text{ ft}^3$   
 $V_w = 1 - 0.514 = 0.486 \text{ ft}^3$   
 $W_w = (62.4)(0.486) = 30.3 \text{ lb}$   
 Eq. (2-15):  $2.70 = W_s/[(0.514)(62.4)]$ ;  $W_s = 86.6 \text{ lb}$

$$W = 86.6 + 30.3 = 116.9 \text{ lb}$$

$$\text{Eq. (2-11): } \gamma = 116.9/1 = 116.9 \text{ lb/ft}^3$$

(2-11) Work with 1 ft<sup>3</sup> of specimen.

$$(a) \text{ Eq. (2-7): } 0.85 = V_w/V_s; \quad V_w = 0.85V_s$$

$$V_w + V_s = 1; \quad 0.85V_s + V_s = 1; \quad V_s = 0.54 \text{ ft}^3$$

$$V_w = 1 - 0.54 = 0.46 \text{ ft}^3$$

$$\text{Eq. (2-9): } 42 = (V_w/0.46)(100); \quad V_w = 0.193 \text{ ft}^3$$

$$W_w = (62.4)(0.193) = 12.04 \text{ lb}$$

$$\text{Eq. (2-15): } 2.74 = W_s/[(0.54)(62.4)]; \quad W_s = 92.33 \text{ lb}$$

$$\text{Eq. (2-10): } w = (12.04/92.33)(100) = 13.04\%$$

$$W = 92.33 + 12.04 = 104.37 \text{ lb/ft}^3$$

$$(b) \text{ Eq. (2-11): } \gamma = 104.37/1 = 104.4 \text{ lb/ft}^3$$

(2-12) (a)  $W_w = 1.445 - 1.301 = 0.144 \text{ kN}$

$$\text{Eq. (2-10): } w = (0.144/1.301)(100) = 11.1\%$$

$$(b) \text{ Eq. (2-15): } 2.65 = 1.301/[(V_s)(9.81)]; \quad V_s = 0.050 \text{ m}^3$$

$$V_v = 0.082 - 0.050 = 0.032 \text{ m}^3$$

$$\text{Eq. (2-7): } e = 0.032/0.050 = 0.64$$

$$(c) \text{ Eq. (2-8): } n = (0.032/0.082)(100) = 39.0\%$$

$$(d) V_w = (1.445 - 1.301)/9.81 = 0.015 \text{ m}^3$$

$$\text{Eq. (2-9): } S = (0.015/0.032)(100) = 46.9\%$$

$$(e) \text{ Eq. (2-11): } \gamma = 1.445/0.082 = 17.62 \text{ kN/m}^3$$

$$(f) \text{ Eq. (2-12): } \gamma_d = 1.301/0.082 = 15.87 \text{ kN/m}^3$$

(2-13) Work with 1 m<sup>3</sup> of specimen.

$$(a) W_w + W_s = 18.55 \text{ kN}$$

$$\text{Eq. (2-10): } 12.3 = (W_w/W_s)(100); \quad W_w = 0.123W_s$$

$$0.123W_s + W_s = 18.55; \quad W_s = 16.52 \text{ kN}$$

$$\text{Eq. (2-12): } \gamma_d = 16.52/1 = 16.52 \text{ kN/m}^3$$

$$(b) \text{ Eq. (2-15): } 2.72 = 16.52/[(V_s)(9.81)]; \quad V_s = 0.619 \text{ m}^3$$

$$V_v = 1 - 0.619 = 0.381 \text{ m}^3$$

$$\text{Eq. (2-7): } e = 0.381/0.619 = 0.62$$

$$(c) W_w = (0.123)(16.52) = 2.03 \text{ kN}$$

$$V_w = 2.03/9.81 = 0.207 \text{ m}^3$$

$$\text{Eq. (2-9): } S = (0.207/0.381)(100) = 54.3\%$$

(2-14) Work with 1 m<sup>3</sup> of specimen.

$$W_w + W_s = 18.85 \text{ kN}$$

$$\text{Eq. (2-10): } 5.2 = (W_w/W_s)(100); \quad W_w = 0.052W_s$$

$$0.052W_s + W_s = 18.85; \quad W_s = 17.92 \text{ kN}$$

$$W_w = (0.052)(17.92) = 0.93 \text{ kN}$$

$$V_w = 0.93/9.81 = 0.095 \text{ m}^3$$

$$\text{Eq. (2-15): } 2.66 = 17.92/[(V_s)(9.91)]; \quad V_s = 0.687 \text{ m}^3$$

$$V_v = 1 - 0.687 = 0.313 \text{ m}^3$$

$$\text{Eq. (2-7): } e_0 = 0.313/0.687 = 0.46$$

$$\text{Eq. (2-18): } D_r = [(0.92 - 0.46)/(0.92 - 0.38)](100) = 85.2\%$$

(2-15)  $V_s = V - V_v$

$$\text{Eq. (2-7): } e = V_w/(V - V_v) = (V_w/V)/(V/V - V_v/V)$$

$$\text{Because } V_w/V = n, e = n/(1 - n)$$

(2-16):  $V = V_v + V_s$

Eq. (2-8):  $n = V_v / (V_v + V_s) = (V_v/V_s) / (V_v/V_s + V_s/V_s)$

Because  $V_v/V_s = e$ ,  $n = e / (e + 1)$

(2-17) Work with 1 ft<sup>3</sup> of specimen.

(a) Eq. (2-8):  $38 = (V_v/V)(100)$

$V_v = 0.38V = (0.38)(1) = 0.38 \text{ ft}^3$

$V_s = 1 - V_v = 1 - 0.38 = 0.62 \text{ ft}^3$

Eq. (2-7):  $e = 0.38/0.62 = 0.61$

(b)  $W_s = (0.62)(2.66)(62.4) = 102.9 \text{ lb}$

Eq. (2-9):  $35 = (W_w/0.38)(100)$ ;  $V_w = 0.133 \text{ ft}^3$

$W_w = (0.133)(62.4) = 8.30 \text{ lb}$

$W = 8.30 + 102.9 = 111.2 \text{ lb}$

Eq. (2-11):  $\gamma = 111.2/1 = 111.2 \text{ lb/ft}^3$

(2-18) Let subscript "b" denote soil in borrow pit and subscript "d" denote soil in the dam.

Eq. (2-7):  $1.12 = (V_v)_b / (V_s)_b$ ;  $(V_v)_b = 1.12(V_s)_b$

$(V_v)_b + (V_s)_b = V_b$ ;  $1.12(V_s)_b + (V_s)_b = V_b$

$(V_b)$  is the total volume of soil from the borrow pit.)

$(V_s)_b = 0.4717V_b$

Eq. (2-7):  $0.78 = (V_v)_d / (V_s)_d$ ;  $(V_v)_d = 0.78(V_s)_d$

$(V_v)_d + (V_s)_d = 5,000,000$

$0.78(V_s)_d + (V_s)_d = 5,000,000$ ;  $(V_s)_d = 2,808,989 \text{ m}^3$

Because  $(V_s)_b = (V_s)_d$ ,  $0.4717V_b = 2,808,989$

$V_b = 5,955,000 \text{ m}^3$

(2-19) Work with 1 ft<sup>3</sup> of specimen.

$W_w + W_s = 128.2 \text{ lb}$

Eq. (2-10):  $14.5 = (W_w/W_s)(100)$ ;  $W_w = 0.145W_s$

$0.145W_s + W_s = 128.2$ ;  $W_s = 112.0 \text{ lb}$

$W_w = 128.2 - 112.0 = 16.2 \text{ lb}$  (initially)

Drying reduces the weight of water by  $128.2 - 118.8$ , or  $9.4 \text{ lb}$ . Hence, the weight of water after drying is  $16.2 - 9.4$ , or  $6.8 \text{ lb}$ .

Eq. (2-10):  $w_{\text{new}} = (6.8/112.0)(100) = 6.1\%$

(2-20) Work with 1 m<sup>3</sup> of specimen.

(a)  $W_w + W_s = 17.98$

Eq. (2-10):  $7.6 = (W_w/W_s)(100)$ ;  $W_w = 0.076W_s$

$0.076W_s + W_s = 17.98$ ;  $W_s = 16.71 \text{ kN}$

$W_w = 17.98 - 16.71 = 1.27 \text{ kN}$

Eq. (2-15):  $2.65 = 16.71 / [(V_s)(9.81)]$ ;  $V_s = 0.643 \text{ m}^3$

$V_v = 1 - 0.643 = 0.357 \text{ m}^3$

Eq. (2-7):  $e_0 = 0.357/0.643 = 0.56$

Eq. (2-18):  $62 = [(e_{\text{max}} - 0.56)/(e_{\text{max}} - 0.35)](100)$ ;  $e_{\text{max}} = 0.90$

(b)  $V_v + V_s = 1$

Eq. (2-7):  $0.90 = V_v/V_s$ ;  $V_v = 0.90V_s$

$0.90V_s + V_s = 1$ ;  $V_s = 0.526 \text{ m}^3$

$V_v = 1 - 0.526 = 0.474 \text{ m}^3$

Eq. (2-15):  $2.65 = W_s / [(0.526)(9.81)]$ ;  $W_s = 13.67 \text{ kN}$

Eq. (2-10):  $7.6 = (W_w/13.67)(100)$ ;  $W_w = 1.04 \text{ kN}$

$W = 13.67 + 1.04 = 14.71 \text{ kN}$

Eq. (2-11):  $\gamma_{\text{min}} = 14.71/1 = 14.71 \text{ kN/m}^3$

(2-21) Work with 1 ft<sup>3</sup> of specimen.

$$V_v + V_s = 1$$

$$\text{Eq. (2-7): } 0.85 = V_v/V_s; \quad V_v = 0.85 V_s$$

$$0.85 V_s + V_s = 1; \quad V_s = 0.541 \text{ ft}^3$$

$$V_v = 1 - 0.541 = 0.459 \text{ ft}^3$$

$$\text{Eq. (2-9): } 30.4 = (V_w/0.459)(100); \quad V_w = 0.140 \text{ ft}^3$$

For the degree of saturation to be 100%,  $V_w$  must be equal to  $V_v$ . Hence, a volume of water of 0.459 - 0.140, or 0.319 ft<sup>3</sup>, must be added to each cubic foot. This is (0.319)(62.4), or 19.9 lb of water.

(2-22) (a) Work with 1 ft<sup>3</sup> of specimen.

$$V_v + V_s = 1$$

$$\text{Eq. (2-18): } 47 = [(0.95 - e_0)/(0.95 - 0.38)](100); \quad e_0 = 0.68$$

$$\text{Eq. (2-7): } 0.68 = V_v/V_s; \quad V_v = 0.68 V_s$$

$$0.68 V_s + V_s = 1; \quad V_s = 0.595 \text{ ft}^3$$

$$V_v = 1 - 0.595 = 0.405 \text{ ft}^3$$

$$\text{Eq. (2-15): } 2.65 = W_s/[(0.595)(62.4)]; \quad W_s = 98.4 \text{ lb}$$

$$\text{Eq. (2-12): } \gamma_d = 98.4/1 = 98.4 \text{ lb/ft}^3$$

$$W_w = (0.405)(62.4) = 25.3 \text{ lb (if saturated)}$$

$$W = 25.3 + 98.4 = 123.7 \text{ lb}$$

$$\text{Eq. (2-11): } \gamma = 123.7/1 = 123.7 \text{ lb/ft}^3$$

(b) Work with 1 m<sup>3</sup> of specimen.

$$V_v + V_s = 1$$

$$\text{Eq. (2-18): } 47 = [(0.95 - e_0)/(0.95 - 0.38)](100); \quad e_0 = 0.68$$

$$\text{Eq. (2-7): } 0.68 = V_v/V_s; \quad V_v = 0.68 V_s$$

$$0.68 V_s + V_s = 1; \quad V_s = 0.595 \text{ m}^3$$

$$V_v = 1 - 0.595 = 0.405 \text{ m}^3$$

$$\text{Eq. (2-15): } 2.65 = W_s/[(0.595)(9.81)]; \quad W_s = 15.47 \text{ kN}$$

$$\text{Eq. (2-12): } \gamma_d = 15.47/1 = 15.47 \text{ kN/m}^3$$

$$W_w = (0.405)(9.81) = 3.97 \text{ kN (if saturated)}$$

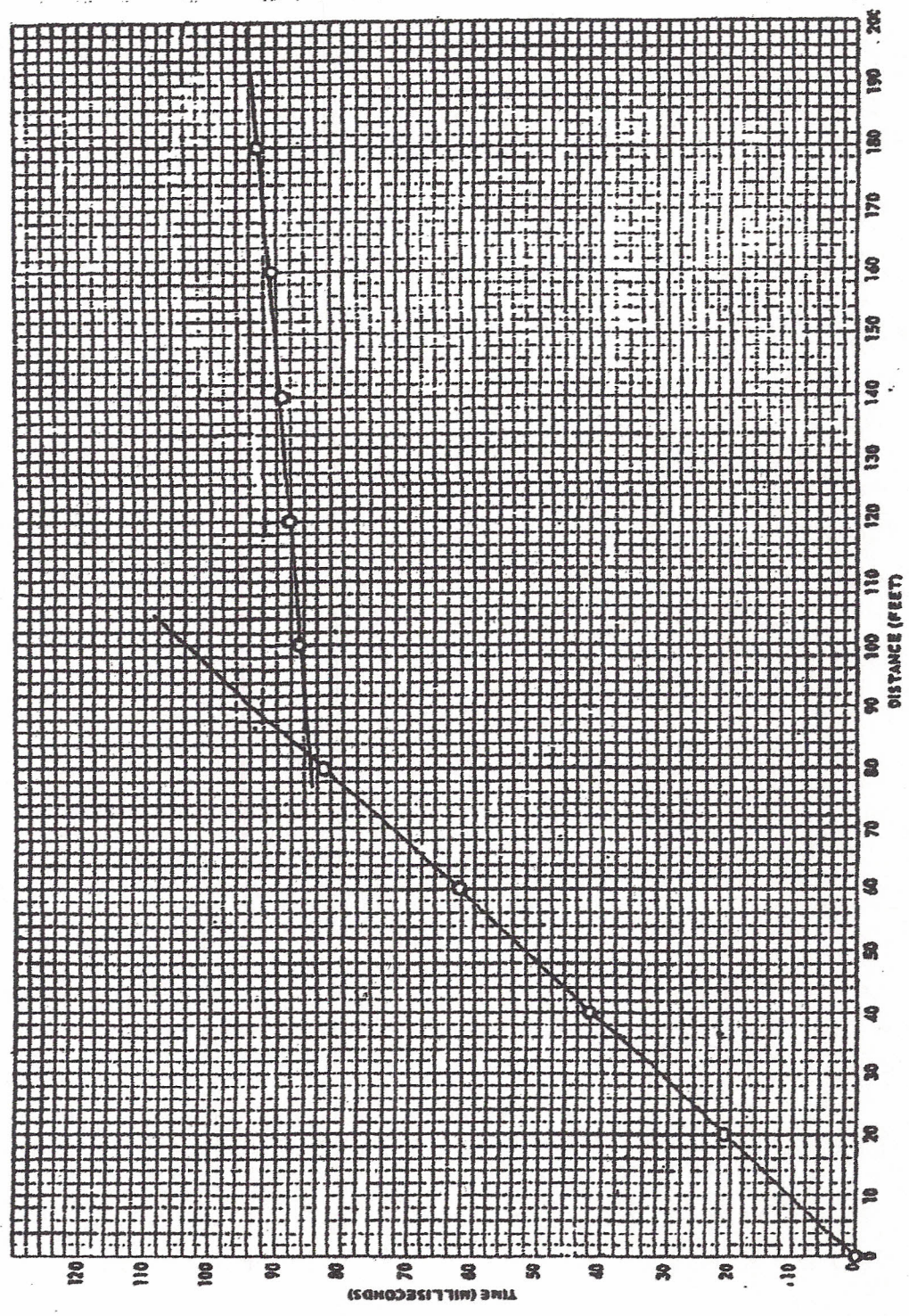
$$W = 15.47 + 3.97 = 19.44 \text{ kN}$$

$$\text{Eq. (2-11): } \gamma = 19.44/1 = 19.44 \text{ kN/m}^3$$

# CHAPTER 3

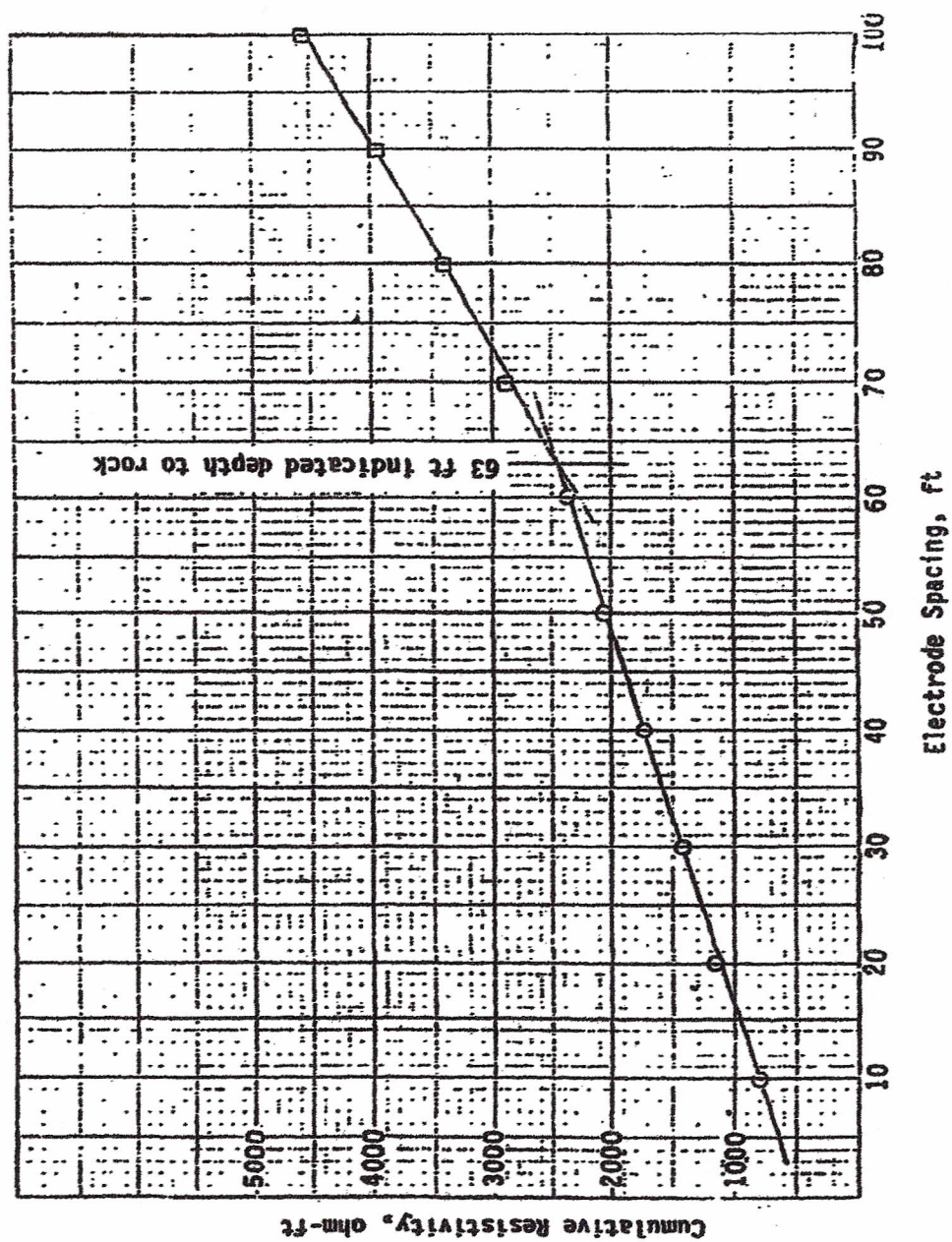
- (3-1) (a)  $p_0 = (10)(120)/2000 = 0.600 \text{ ton/ft}^2$   
Eq. (3-1):  $C_N = 0.77 \log_{10} (20/0.600) = 1.17$   
 $N_{\text{corrected}} = (1.17)(26) = 30$   
(b)  $10 \text{ ft} = 3.048 \text{ m}$  and  $120 \text{ lb/ft}^3 = 18.85 \text{ kN/m}^3$   
 $p_0 = (3.048)(18.85) = 57.45 \text{ kN/m}^2$   
Eq. (3-3):  $N_{\text{corrected}} = (26)(100/57.45)^{1/2} = 34$
- (3-2) (a)  $p_0 = [(8)(120) + (2)(120 - 62.4)]/2000 = 0.538 \text{ ton/ft}^2$   
Eq. (3-1):  $C_N = 0.77 \log_{10} (20/0.538) = 1.21$   
 $N_{\text{corrected}} = (1.21)(26) = 31$   
(b)  $p_0 = 1.08 \text{ kips/ft}^2 = 51.71 \text{ kN/m}^2$   
Eq. (3-3):  $N_{\text{corrected}} = (26)(100/51.71)^{1/2} = 36$
- (3-3) (a)  $p_0 = (7)(20.40) = 142.8 \text{ kN/m}^2$   
Eq. (3-2):  $C_N = 0.77 \log_{10} (1915/142.8) = 0.868$   
 $N_{\text{corrected}} = (0.868)(22) = 19$   
(b) Eq. (3-3):  $N_{\text{corrected}} = (22)(100/142.8)^{1/2} = 18$
- (3-4) (a)  $p_0 = (2)(20.40) + (5)(20.40 - 9.81) = 93.75 \text{ kN/m}^2$   
Eq. (3-2):  $C_N = 0.77 \log_{10} (1915/93.75) = 1.01$   
 $N_{\text{corrected}} = (1.01)(22) = 22$   
(b) Eq. (3-3):  $N_{\text{corrected}} = (22)(100/93.75)^{1/2} = 23$
- (3-5) Eq. (3-4):  $c = 61/\{(\pi)[(4/12)^2(8/12)(1/2) + (4/12)^3(1/6)]\} = 449 \text{ lb/ft}^2$   
From Fig. 3-17 with  $PI = 40\%$ ,  $\mu = 0.85$ . Hence,  $c_{\text{corrected}} = (0.85)(449) = 382 \text{ lb/ft}^2$
- (3-6) A plot of time versus distance is given on page 8.  
slope<sub>line 1</sub> =  $0.083/80 = 0.001038$   
slope<sub>line 2</sub> =  $(0.093 - 0.08675)/(180 - 100) = 0.00007813$   
 $v_1 = \text{reciprocal of slope}_{\text{line 1}} = 1/0.001038 = 963 \text{ ft/sec}$   
 $v_2 = \text{reciprocal of slope}_{\text{line 2}} = 1/0.00007813 = 12,800 \text{ ft/sec}$   
 $L = 82 \text{ ft}$  (from plot on page 8)  
Eq. (3-6):  $H_1 = (82/2)[(12,800 - 963)/(12,800 + 963)]^{1/2} = 38 \text{ ft}$   
With  $v_1 = 963 \text{ ft/sec}$ , according to Table 3-3, the subsurface material in the first layer is estimated to be normal sand or loose sand above the water table. With  $v_2 = 12,800 \text{ ft/sec}$ , according to Table 3-3, the subsurface material in the second layer is estimated to be hard limestone, basalt, granite, or unweathered gneiss.

| (3-7) | Electrode Spacing<br>(ft) | Resistance<br>(ohms) | Resistivity<br>(ohm-ft) | Cumulative Resistivity<br>(ohm-ft) |
|-------|---------------------------|----------------------|-------------------------|------------------------------------|
|       | 10                        | 12.73                | 800                     | 800                                |
|       | 20                        | 2.79                 | 351                     | 1151                               |
|       | 30                        | 1.46                 | 275                     | 1426                               |
|       | 40                        | 1.15                 | 289                     | 1715                               |
|       | 50                        | 1.05                 | 330                     | 2045                               |
|       | 60                        | 0.84                 | 317                     | 2362                               |
|       | 70                        | 1.21                 | 532                     | 2894                               |
|       | 80                        | 1.00                 | 503                     | 3397                               |
|       | 90                        | 0.97                 | 549                     | 3946                               |
|       | 100                       | 0.95                 | 597                     | 4543                               |



Electrode spacing (column 1 in the preceding table) gives the approximate depth of subsurface material included in a given measurement. Resistivity (column 3 in the table) is computed from Eq. (3-7), where  $D$  is electrode spacing (column 1) and  $R$  is resistance (column 2). Hence, for the first row in the table,  $\rho = (2)(\pi)(10)(12.73) = 800$  ohm-ft

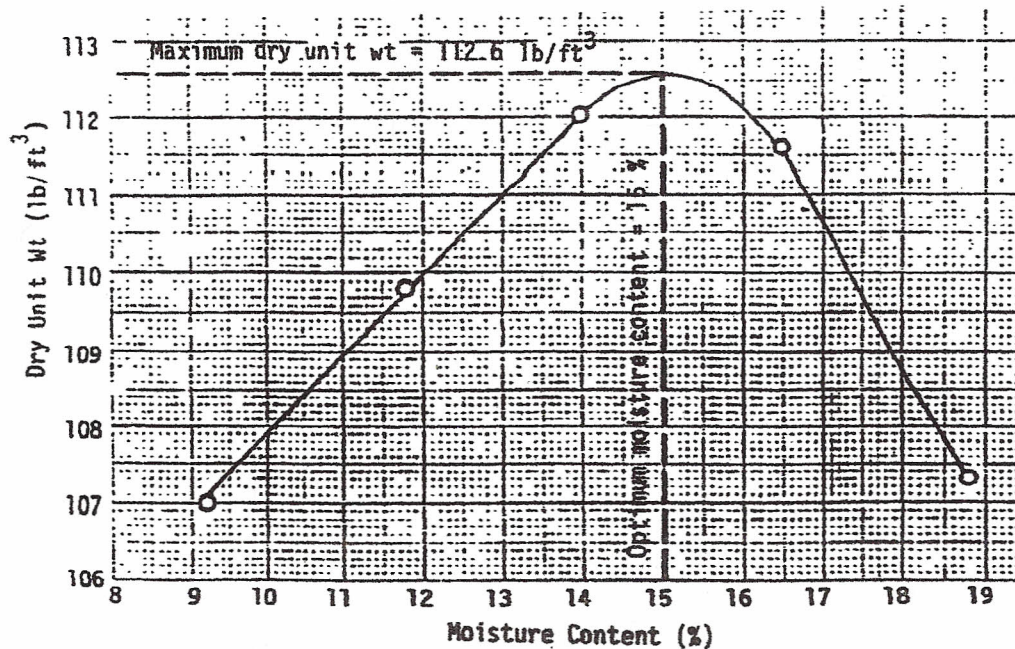
Values in column 4 are cumulative resistivity values. A plot of electrode spacing versus cumulative resistivity is shown on page 10. From this plot, the thickness of the first soil layer is determined to be approximately 63 ft. Because the resistivity of the upper layer is in the range from 50 to 500 ohm-ft, according to Table 3-4, the subsurface material in this layer is estimated to be moist to dry silty and sandy soils. Because the resistivity of the lower layer is in the range from 500 to 1000 ohm-ft, according to Table 3-4, the subsurface material in this layer is estimated to be well-fractured to slightly fractured bedrock with moist-soil-filled cracks.



# Chapter 4

- (4-1) Eq. (2-11):  $\gamma = [(3815 - 2050)/453.6]/(1/30) = 116.7 \text{ lb/ft}^3$   
 Eq. (4-1):  $\gamma_d = 116.7/(1 + 0.091) = 107.0 \text{ lb/ft}^3$

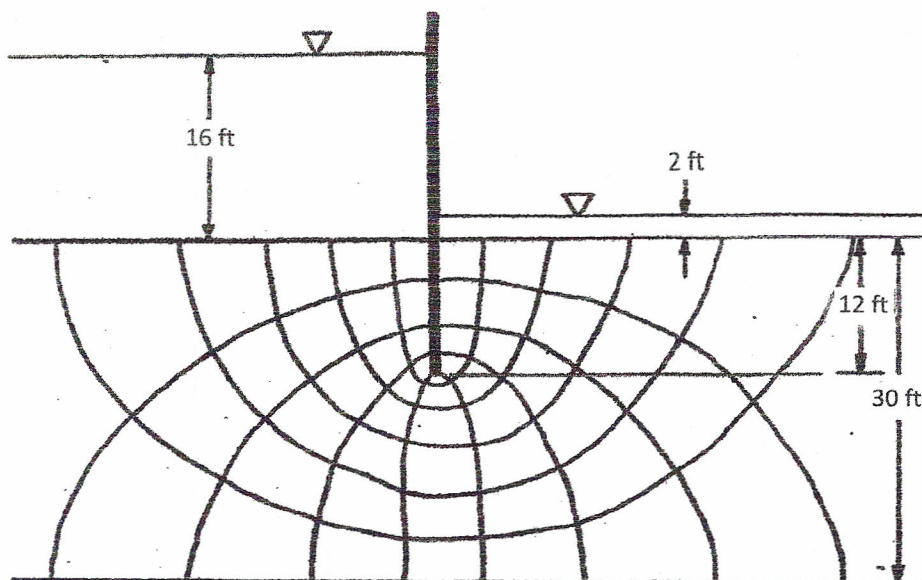
(4-2)



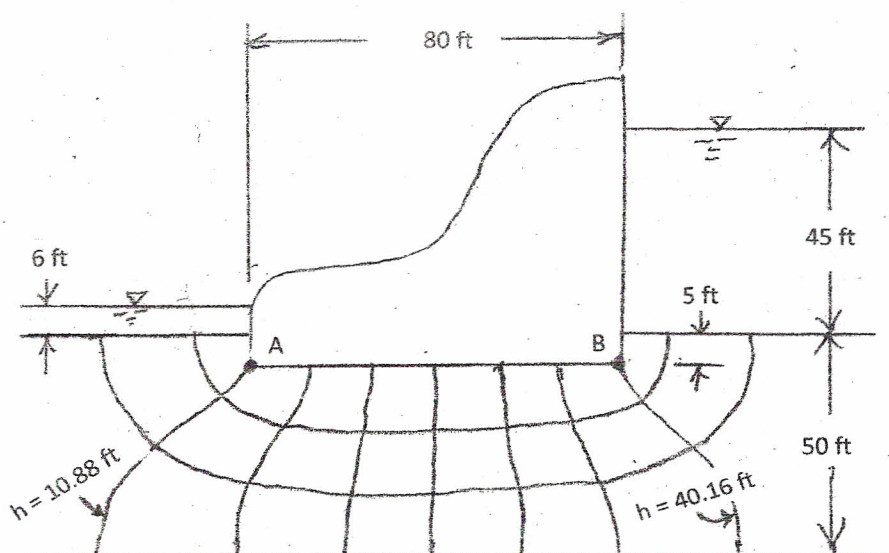
- (4-3) 95% of the maximum dry unit weight =  $(0.95)(112.6) = 107.0 \text{ lb/ft}^3$   
 From the compaction curve of Problem 4-2, the range of water content most likely to attain 95% or more of the maximum dry unit weight is 9% to 19%.
- (4-4) From Table 4-3, with maximum dry unit weight =  $104.8 \text{ lb/ft}^3$  and optimum moisture content = 20.7%, the possible type of soil for this sample is estimated to be A-7-6 clay or A-6 silty clay.
- (4-5) Weight of soil used in test hole =  $845 - 323 = 522 \text{ g}$   
 Volume of test hole =  $(522/453.6)/100 = 0.0115 \text{ ft}^3$   
 Eq. (2-11):  $\gamma = (648/453.6)/0.0115 = 124.2 \text{ lb/ft}^3$   
 Eq. (4-1):  $\gamma_d = 124.2/(1 + 0.16) = 107.1 \text{ lb/ft}^3$
- (4-6) Percent compaction achieved =  $(107.1/112.6)(100) = 95.1\%$
- (4-7) Let subscript "b" denote soil in borrow pit and subscript "f" denote soil in the fill.  
 Eq. (2-7):  $0.68 = (V_v)_b / (V_s)_b$ ;  $(V_v)_b = 0.68(V_s)_b$   
 $(V_v)_b + (V_s)_b = V_b$ ;  $0.68(V_s)_b + (V_s)_b = V_b$   
 $(V_b \text{ is the total volume of soil from the borrow pit.})$   
 $(V_s)_b = 0.5952V_b$   
 Eq. (2-7):  $0.45 = (V_v)_f / (V_s)_f$ ;  $(V_v)_f = 0.45(V_s)_f$   
 $(V_v)_f + (V_s)_f = 2500$   
 $0.45(V_s)_f + (V_s)_f = 2500$ ;  $(V_s)_f = 1724 \text{ m}^3$   
 Because  $(V_s)_b = (V_s)_f$ ,  $0.5952V_b = 1724$   
 $V_b = 2897 \text{ m}^3$
- (4-8) Eq. (4-3):  $D = (0.5)[(20)(10)]^{1/2} = 7.1 \text{ m}$

## CHAPTER 5

- (5-1)  $k = [(3.60 \times 10^{-2})/2.54](1/12) = 1.18 \times 10^{-3} \text{ ft/sec}$   
 Eq. (5-4):  $q = (1.18 \times 10^{-3})(1/5)(400/144) = 6.56 \times 10^{-4} \text{ ft}^3/\text{sec}$
- (5-2)  $v = 2000/[(20)(60)]/60.0 = 0.28 \text{ cm/s}$   
 Eq. (5-8):  $v_{\text{actual}} = (0.028)(1 + 0.71)/0.71 = 0.067 \text{ cm/s}$
- (5-3)  $A = (\pi)(10.0)^2/4 = 78.54 \text{ cm}^2$   
 Eq. (5-11):  $k = (500)(12.0)/[(78.54)(152)(4.9)] = 0.103 \text{ cm/s}$
- (5-4)  $A = (\pi)(10.20)^2/4 = 81.71 \text{ cm}^2$   
 $T = (35)(60) = 2100 \text{ s}$   
 Eq. (5-18):  $k = \{(2.3)(1.95)(16.2)/[(81.71)(2100)]\} \log(100.0/92.0) = 1.53 \times 10^{-5} \text{ cm/s}$
- (5-5)  $q = 185/7.48/60 = 0.4122 \text{ ft}^3/\text{sec}$   
 Eq. (5-28):  $k = (0.4122) \ln(100/50)/[(\pi)(15^2 - 12^2)] = 1.123 \times 10^{-3} \text{ ft/sec, or } 0.0342 \text{ cm/s}$
- (5-6)  $q = 205/7.48/60 = 0.4568 \text{ ft}^3/\text{sec}$   
 Eq. (5-23):  $k = (0.4568) \ln(150/75)/[(2)(\pi)(12)(20 - 16)] = 1.05 \times 10^{-3} \text{ ft/sec, or } 0.0320 \text{ cm/s}$
- (5-7) Eq. (5-29):  $k = 0.18^2 = 0.0324 \text{ cm/s}$
- (5-8) Eq. (5-30):  $k = (0.35)(0.25)^2 = 0.0219 \text{ cm/s}$
- (5-9) Eq. (5-42):  $h = (4)(0.00504)/[(0.008/12)(62.4)] = 0.485 \text{ ft, or } 5.8 \text{ in.}$
- (5-10) Eq. (5-37):  $k_y = 20/[6/(2.6 \times 10^{-7}) + 4/(3.2 \times 10^{-7}) + 10/(2.3 \times 10^{-7})] = 2.53 \times 10^{-7} \text{ cm/s}$   
 Eq. (5-5):  $q = [(2.53 \times 10^{-7})/2.54/12](70/20)(35,000) = 0.00102 \text{ ft}^3/\text{sec}$   
 Loss in one year =  $(0.00102)(60 \times 60 \times 24 \times 365) = 32,200 \text{ ft}^3$
- (5-11) Eq. (5-39):  $k_x = [(6)(1.8 \times 10^{-6}) + (4)(2.4 \times 10^{-6}) + (10)(1.1 \times 10^{-6})]/20 = 1.57 \times 10^{-6} \text{ cm/s}$
- (5-12) The flow net is shown on page 13.  
 $k = (8.80 \times 10^{-3})/2.54/12 = 2.89 \times 10^{-4} \text{ ft/sec}$   
 Eq. (5-48):  $q = (2.89 \times 10^{-4})(16 - 2)(6/9) = 0.00270 \text{ ft}^3/\text{sec per ft}$
- (5-13) The flow net is shown on page 13.  
 $k = (6.82 \times 10^{-3})/2.54/12 = 2.24 \times 10^{-4} \text{ ft/sec}$   
 Eq. (5-48):  $q = (2.24 \times 10^{-4})(45 - 6)(3/8) = 0.00328 \text{ ft}^3/\text{sec per ft}$
- (5-14) The flow net is shown on page 13.  
 $\Delta H = h/N_d = (45 - 6)/8 = 4.88 \text{ ft}$   
 $h_A = 6 + 4.88 = 10.88 \text{ ft}$   
 $h_B = 6 + (7)(4.88) = 40.16 \text{ ft}$   
 $p_A = (5 + 10.88)(62.4) = 990.9 \text{ lb/ft}^2$   
 $p_B = (5 + 40.16)(62.4) = 2818.0 \text{ lb/ft}^2$   
 Total uplift force =  $(1/2)(990.9 + 2818.0)(80) = 152,400 \text{ lb, or } 152.4 \text{ kips}$



Flow net for Problem (5-12)



Flow net for Problems (5-13) and (5-14)

## CHAPTER 6

- (6-1) Eq. (6-2):  $\bar{p} = (20.72)(2.5) + (20.72 - 9.81)(6) + (19.69 - 9.81)(7) = 186 \text{ kN/m}^2$   
 Eq. (6-3):  $\mu_w = (9.81)(6 + 7) = 128 \text{ kN/m}^2$   
 Eq. (6-4):  $p_{\text{total}} = 186 + 128 = 314 \text{ kN/m}^2$
- (6-2) Eq. (6-7):  $p = (3)(200,000)/\{(2)(\pi)(15)^2[1 + (0/15)^2]^{5/2}\} = 424 \text{ lb/ft}^2$
- (6-3) Eq. (6-7):  $p = (3)(200,000)/\{(2)(\pi)(15)^2[1 + (10/15)^2]^{5/2}\} = 169 \text{ lb/ft}^2$
- (6-4)  $P = (5000)(10)(7.5) = 375,000 \text{ lb}$   
 Eq. (6-10):  $p = 375,000/[(10 + 12)(7.5 + 12)] = 874 \text{ lb/ft}^2$
- (6-5)  $P = (195)(2)(3) = 1170 \text{ kN}$   
 Eq. (6-10): (a)  $p_{\text{(at 1 m)}} = 1170/[(2 + 1)(3 + 1)] = 97.50 \text{ kN/m}^2$   
                   : (b)  $p_{\text{(at 3 m)}} = 1170/[(2 + 3)(3 + 3)] = 39.00 \text{ kN/m}^2$   
                   : (c)  $p_{\text{(at 5 m)}} = 1170/[(2 + 5)(3 + 5)] = 20.89 \text{ kN/m}^2$
- (6-6) (a)  $z/a = 18/12 = 1.5$ ;  $r/a = 0/10 = 0$ ; Influence coefficient = 0.424  
 $p = (0.424)(4500) = 1908 \text{ lb/ft}^2$   
 (b)  $z/a = 18/12 = 1.5$ ;  $r/a = 6/12 = 0.5$ ; Influence coefficient = 0.374  
 $p = (0.374)(4500) = 1683 \text{ lb/ft}^2$
- (6-7) (a)  $z/a = 3/(3/2) = 2.0$ ;  $r/a = (3/2)/(3/2) = 1.0$ ; Influence coefficient = 0.194  
 $p = (0.194)(250) = 48.50 \text{ kN/m}^2$   
 (b) Overburden pressure at 3-m depth =  $(3)(16.38) = 49.14 \text{ kN/m}^2$   
 Total vertical pressure =  $48.50 + 49.14 = 97.64 \text{ kN/m}^2$
- (6-8)  $mz = 12$ ;  $z = 15$ ;  $m = 12/15 = 0.80$   
 $nz = 8$ ;  $z = 15$ ;  $n = 8/15 = 0.533$   
 Influence coefficient = 0.115  
 $p = (0.115)(6000) = 690 \text{ lb/ft}^2$
- (6-9)  $mz = 6$ ;  $z = 25$ ;  $m = 6/25 = 0.24$   
 $nz = 6$ ;  $z = 25$ ;  $n = 6/25 = 0.24$   
 Influence coefficient = 0.026  
 $p = (4)(0.026)(5000) = 520 \text{ lb/ft}^2$
- (6-10) Divide the footing area into four equal parts, each 1 m by 1m. For each part,  
 $mz = 1$ ;  $z = 4$ ;  $m = 1/4 = 0.25$   
 $nz = 1$ ;  $z = 4$ ;  $n = 1/4 = 0.25$   
 Influence coefficient = 0.027  
 Net vertical pressure increment at base of footing =  $1000/[(2)(2)] - (16.80)(1.8) = 219.8 \text{ kN/m}^2$   
 $p = (4)(0.027)(219.8) = 23.74 \text{ kN/m}^2$
- (6-11) (a) Divide the area into three rectangular parts:  
 Part 1, upper left area, 16 ft by 12 ft  
 Part 2, lower left area, 16 ft by 12 ft  
 Part 3, lower right area, 20 ft by 12 ft  
 Part 1:  $mz = 16$ ;  $z = 24$ ;  $m = 16/24 = 0.667$   
            $nz = 12$ ;  $z = 24$ ;  $n = 12/24 = 0.500$

Influence coefficient = 0.101

Part 2:  $mz = 16$ ;  $z = 24$ ;  $m = 16/24 = 0.667$

$nz = 12$ ;  $z = 24$ ;  $n = 12/24 = 0.500$

Influence coefficient = 0.101

Part 3:  $mz = 20$ ;  $z = 24$ ;  $m = 20/24 = 0.833$

$nz = 12$ ;  $z = 24$ ;  $n = 12/24 = 0.500$

Influence coefficient = 0.112

$p = (0.101 + 0.101 + 0.112)(2000) = 628 \text{ lb/ft}^2$

(b) Divide the area into three rectangular parts:

Part 1, left area, 16 ft by 24 ft

Part 2, bottom area, 36 ft by 12 ft

Part 3, lower left area, 16 ft by 12 ft

Part 1:  $mz = 16$ ;  $z = 24$ ;  $m = 16/24 = 0.667$

$nz = 24$ ;  $z = 24$ ;  $n = 24/24 = 1.000$

Influence coefficient = 0.145

Part 2:  $mz = 36$ ;  $z = 24$ ;  $m = 36/24 = 1.500$

$nz = 12$ ;  $z = 24$ ;  $n = 12/24 = 0.500$

Influence coefficient = 0.131

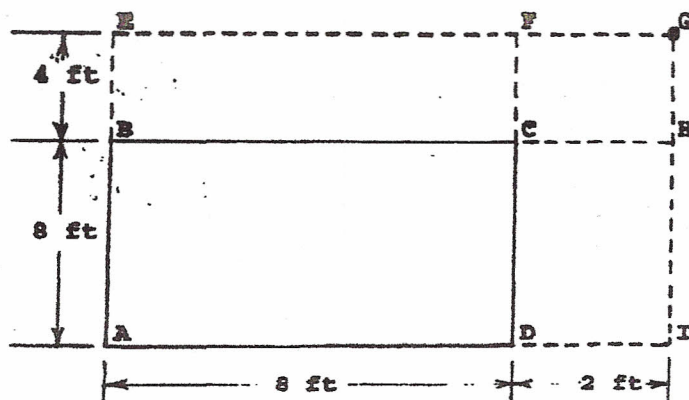
Part 3:  $mz = 16$ ;  $z = 24$ ;  $m = 16/24 = 0.667$

$nz = 12$ ;  $z = 24$ ;  $n = 12/24 = 0.500$

Influence coefficient = 0.101

$p = (0.145 + 0.131 - 0.101)(2000) = 350 \text{ lb/ft}^2$

(6-12) (a) Below point G:



Area AEGI:  $mz = 12$ ;  $z = 12$ ;  $m = 12/12 = 1.000$

$nz = 10$ ;  $z = 12$ ;  $n = 10/12 = 0.833$

Influence coefficient = 0.163

Area BEGH:  $mz = 4$ ;  $z = 12$ ;  $m = 4/12 = 0.333$

$nz = 10$ ;  $z = 12$ ;  $n = 10/12 = 0.833$

Influence coefficient = 0.083

Area DFGI:  $mz = 12$ ;  $z = 12$ ;  $m = 12/12 = 1.000$

$nz = 2$ ;  $z = 12$ ;  $n = 2/12 = 0.167$

Influence coefficient = 0.045

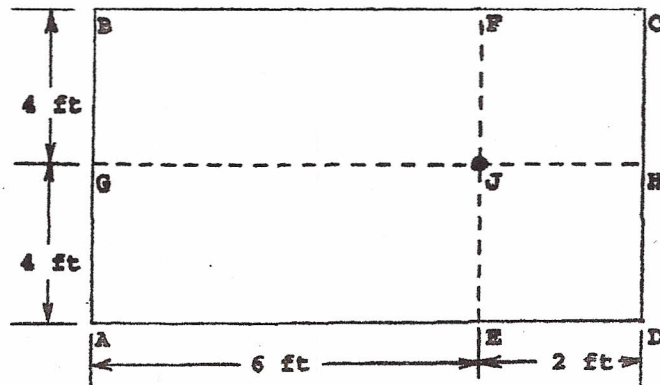
Area CFGH:  $mz = 4$ ;  $z = 12$ ;  $m = 4/12 = 0.333$

$nz = 2$ ;  $z = 12$ ;  $n = 2/12 = 0.167$

Influence coefficient = 0.022

$P = (0.163 - 0.083 - 0.045 + 0.022)(2500) = 142 \text{ lb/ft}^2$

(b) Below point J:

Area BFJG:  $mz = 4$ ;  $z = 12$ ;  $m = 4/12 = 0.333$  $nz = 6$ ;  $z = 12$ ;  $n = 6/12 = 0.500$ 

Influence coefficient = 0.062

Area GJEA: same as Area BFJC:

Influence coefficient = 0.062

Area FCHJ:  $mz = 4$ ;  $z = 12$ ;  $m = 4/12 = 0.333$  $nz = 2$ ;  $z = 12$ ;  $n = 2/12 = 0.167$ 

Influence coefficient = 0.022

Area JHDE: same as Area FCHJ:

Influence coefficient = 0.022

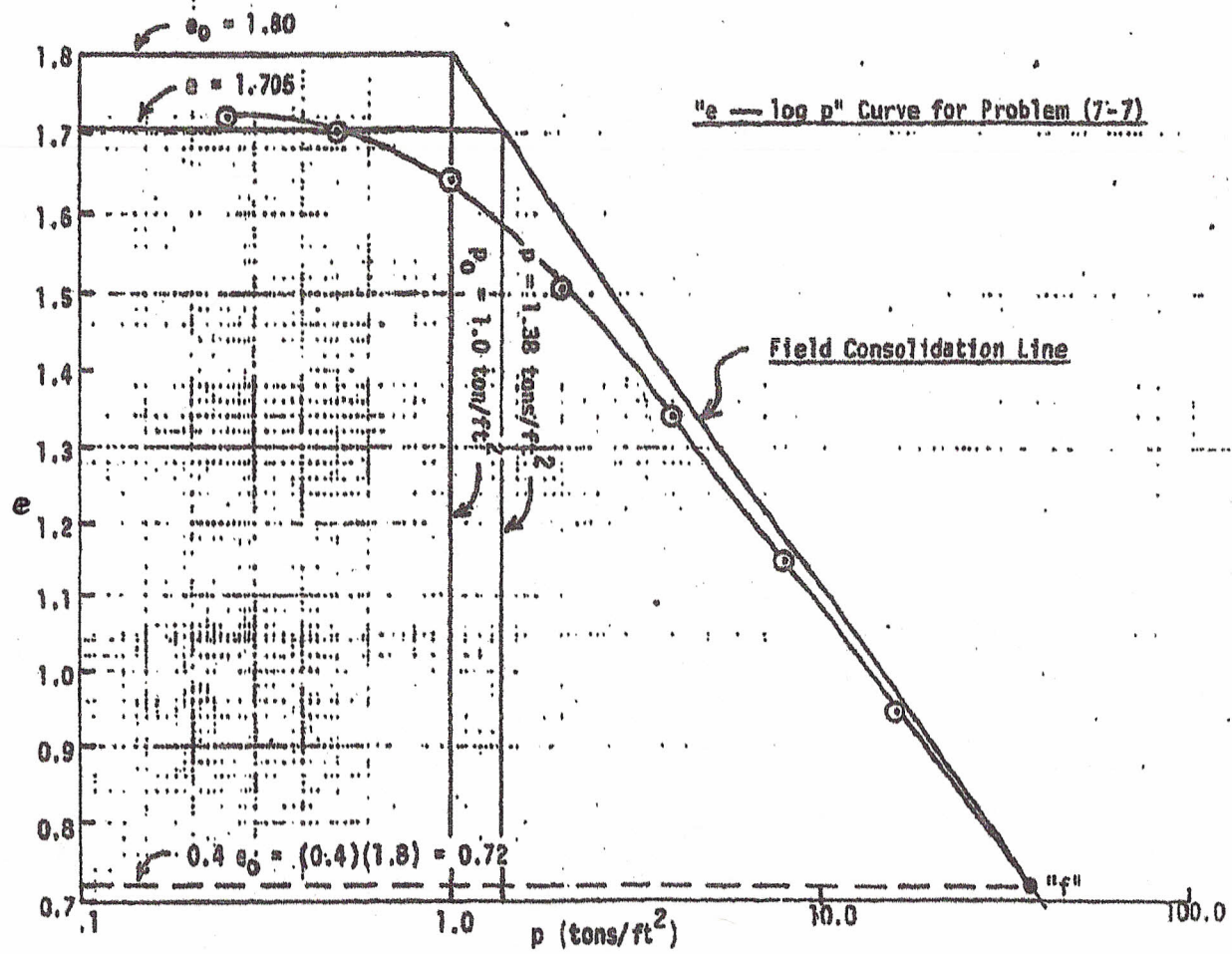
 $p = (0.062 + 0.062 + 0.022 + 0.022)(2500) = 420 \text{ lb/ft}^2$ (6-13) Reduction in vertical pressure at base of foundation (i.e., 5 m below ground level) =  $(18.60)(5) = 93.0 \text{ kN/m}^2$ . $mz = 58 \text{ m}$ ;  $z = 15 \text{ m}$ ;  $m = 58/15 = 3.87$  $nz = 38 \text{ m}$ ;  $z = 15 \text{ m}$ ;  $n = 38/15 = 2.53$ 

Influence coefficient = 0.243

The reduction at one corner of the building at a depth of 15 m below the original surface =  $(0.243)(93.0) = 22.6 \text{ kN/m}^2$ .(6-14)  $mz = 20/2 = 10 \text{ ft}$ ;  $z = 10 + 6 = 16 \text{ ft}$ ;  $m = 10/16 = 0.625$  $nz = 15/2 = 7.5 \text{ ft}$ ;  $z = 10 + 6 = 16 \text{ ft}$ ;  $n = 7.5/16 = 0.469$  $I_1 = 0.094$  $p_1 = (4)(0.094)\{1500/[(20)(15)]\} = 1.88 \text{ kips/ft}^2$  $mz = 10 \text{ ft}$ ;  $z = 6 \text{ ft}$ ;  $m = 10/6 = 1.67$  $nz = 7.5 \text{ ft}$ ;  $z = 6 \text{ ft}$ ;  $n = 7.5/6 = 1.25$  $I_2 = 0.21$  $p_2 = (4)(0.21)\{118/1000\}(10) = 0.99 \text{ kips/ft}^2$  $p = p_1 + p_2 = 1.88 + 0.99 = 2.87 \text{ kips/ft}^2$

## CHAPTER 7

- (7-1) Eq. (7-29):  $c_v = (0.196)[(0.74/12)/2]^2/6.2 = 0.0000301 \text{ ft}^2/\text{min}$   
 Eq. (7-24):  $a_v = (1.167 - 1.108)/(2000 - 1000) = 0.0000590$   
 Eq. (7-23):  $k = (0.0000301)(0.0000590)(62.4)/[1 + (1.167 + 1.108)/2] = 5.18 \times 10^{-8} \text{ ft/min} = 6.22 \times 10^{-7} \text{ in./min} = 2.63 \times 10^{-8} \text{ cm/s}$
- (7-2)  $p_0 = (19.21)(150.0 - 146.2) + (19.21 - 9.81)(146.2 - 144.8) + (17.28 - 9.81)(144.8 - 136.6)/2 = 116.8 \text{ kN/m}^2$
- (7-3) Let  $e_1 = 1.09$ ;  $p_1 = 100 \text{ kN/m}^2$ ;  $e_2 = 0.89$ ;  $p_2 = 400 \text{ kN/m}^2$   
 Eq. (7-4):  $C_c = (1.09 - 0.89)/[\log(400/100)] = 0.332$   
 Let  $e_1 = 1.09$ ;  $p_1 = 100 \text{ kN/m}^2$ ;  $p_2 = 800 \text{ kN/m}^2$   
 Eq. (7-4):  $0.332 = (1.09 - e_2)/[\log(800/100)]$   
 $e_2 = 0.79$
- (7-4) Eq. (7-15):  $S_c = [(1.026 - 0.978)/(1 + 1.026)](10.0) = 0.237 \text{ m}$
- (7-5)  $p_0$  at midheight of clay layer  $= (18.92)(100.0 - 98.5) + (18.92 - 9.81)(98.5 - 92.6) + (17.25 - 9.81)[(92.6 - 84.2)/2] = 113.38 \text{ kN/m}^2$   
 Net consolidation pressure at base of foundation  $= 1000/[(2)(2)] - [(100.0 - 98.5)(18.92) + (98.5 - 96.0)(18.92 - 9.81)] = 198.84 \text{ kN/m}^2$   
 $mz = 1.0$ ;  $z = 96.0 - (92.6 + 84.2)/2 = 7.6$ ;  $m = 1.0/7.6 = 0.132$   
 $nz = 1.0$ ;  $z = 7.6$ ;  $n = 1.0/7.6 = 0.132$   
 Influence coefficient  $= 0.0085$   
 $\Delta p = (4)(0.0085)(198.84) = 6.76 \text{ kN/m}^2$   
 $p = p_0 + \Delta p = 113.38 + 6.76 = 120.14 \text{ kN/m}^2$   
 $H = 92.6 - 84.2 = 8.4 \text{ m}$   
 Eq. (7-19):  $S_c = (0.60)[(8.4)/[1 + 1.058]] \log(120.14/113.38) = 0.062 \text{ m}$
- (7-6) From Fig. 7-17, for 90% primary consolidation,  $T_v = 0.848$ .  
 (a)  $H = (92.6 - 84.2)/2 = 4.20 \text{ m}$   
 Eq. (7-29):  $t_{90} = [0.848/(6.98 \times 10^{-6})](4.20)^2 = 2,143,000 \text{ min, or } 4.08 \text{ yr}$   
 (b)  $T_v$  and  $c_v$  are the same as for (a).  
 $H = 92.6 - 84.2 = 8.40 \text{ m}$   
 Eq. (7-29):  $t_{90} = [0.848/(6.98 \times 10^{-6})](8.40)^2 = 8,572,000 \text{ min, or } 16.3 \text{ yr}$
- (7-7) (a)  $p_0$  at midheight of clay layer  $= (120)(100 - 85) + (103 - 62.4)(85 - 76)/2 = 1983 \text{ lb/ft}^2$ , or  $1.0 \text{ ton/ft}^2$   
 $0.4e_0 = (0.4)(1.80) = 0.72$   
 The "e-log p" curve is shown on page 18.  
 (b) Effective weight of excavation  $= (120)(100 - 94) = 720 \text{ lb/ft}^2$ , or  $0.36 \text{ ton/ft}^2$   
 Net consolidation pressure at base of footing  $= 200/[(9)(9)] - 0.36 = 2.11 \text{ tons/ft}^2$   
 Divide the footing area into four equal parts, each 4.5 ft by 4.5 ft. For each part,  
 $mz = 4.5$ ;  $z = 13.5$ ;  $m = 4.5/13.5 = 0.333$   
 $nz = 4.5$ ;  $z = 13.5$ ;  $n = 4.5/13.5 = 0.333$   
 Influence coefficient  $= 0.045$   
 $\Delta p = (4)(0.045)(2.11) = 0.38 \text{ ton/ft}^2$   
 $p = p_0 + \Delta p = 1.0 + 0.38 = 1.38 \text{ tons/ft}^2$   
 With  $p = 1.38 \text{ tons/ft}^2$ , from field consolidation line,  $e = 1.705$ .  
 Eq. (7-15):  $S_c = [(1.80 - 1.705)/(1 + 1.80)](85 - 76) = 0.305 \text{ ft, or } 3.66 \text{ in.}$
- (7-8)  $p = p_0 + \Delta p = 108 + 52 = 160 \text{ kN/m}^2$



$$[p = 160 \text{ kN/m}^2] > [p_0' = 125 \text{ kN/m}^2]; \quad \text{Use Eq. (7-22).}$$

$$S_c = (0.06)[3.8/(1 + 0.70)] \log (125/108) + (0.30)[3.8/(1 + 0.70)] \log (160/125) = 0.080 \text{ m, or 80 mm}$$

(7-9) Because the compressible clay layer is underlain by permeable sand and gravel, this is a double drainage for clay layer, with  $H = (85 - 76)/2 = 4.5 \text{ ft}$ .

(1) When  $U = 10\%$ ,  $T_v = 0.0077$  (from Fig. 7-17).

$$\text{Eq. (7-29): } t_{10} = [0.0077/(2.18 \times 10^{-3})](4.5 \times 12)^2 = 10,300 \text{ min, or 0.020 yr}$$

(2) When  $U = 20\%$ ,  $T_v = 0.0314$

$$t_{20} = [0.0314/(2.18 \times 10^{-3})](4.5 \times 12)^2 = 42,001 \text{ min, or 0.080 yr}$$

(3) When  $U = 30\%$ ,  $T_v = 0.0707$

$$t_{30} = [0.0707/(2.18 \times 10^{-3})](4.5 \times 12)^2 = 94,569 \text{ min, or 0.180 yr}$$

(4) When  $U = 40\%$ ,  $T_v = 0.126$

$$t_{40} = [0.126/(2.18 \times 10^{-3})](4.5 \times 12)^2 = 168,539 \text{ min, or 0.321 yr}$$

(5) When  $U = 50\%$ ,  $T_v = 0.196$

$$t_{50} = [0.196/(2.18 \times 10^{-3})](4.5 \times 12)^2 = 262,172 \text{ min, or 0.499 yr}$$

(6) When  $U = 60\%$ ,  $T_v = 0.286$

$$t_{60} = [0.286/(2.18 \times 10^{-3})](4.5 \times 12)^2 = 382,558 \text{ min, or 0.728 yr}$$

(7) When  $U = 70\%$ ,  $T_v = 0.403$

$$t_{70} = [0.403/(2.18 \times 10^{-3})](4.5 \times 12)^2 = 539,059 \text{ min, or 1.026 yr}$$

(8) When  $U = 80\%$ ,  $T_v = 0.567$

$$t_{80} = [0.567/(2.18 \times 10^{-3})](4.5 \times 12)^2 = 758,428 \text{ min, or 1.443 yr}$$

(9) When  $U = 90\%$ ,  $T_v = 0.848$

$$t_{90} = [0.848/(2.18 \times 10^{-3})](4.5 \times 12)^2 = 1,134,297 \text{ min, or 2.158 yr}$$

| U (fraction of total settlement) | Settlement | Time     |
|----------------------------------|------------|----------|
| (%)                              | (in.)      | (yr)     |
| 10                               | 0.37       | 0.020    |
| 20                               | 0.73       | 0.080    |
| 30                               | 1.10       | 0.180    |
| 40                               | 1.46       | 0.321    |
| 50                               | 1.83       | 0.499    |
| 60                               | 2.20       | 0.728    |
| 70                               | 2.56       | 1.026    |
| 80                               | 2.93       | 1.443    |
| 90                               | 3.29       | 2.158    |
| 100                              | 3.66       | $\infty$ |

The time-versus-settlement curve is given on page 20.

(7-10)  $p = p_0 + \Delta p = 108 + 52 = 160 \text{ kN/m}^2$

$$[p = 160 \text{ kN/m}^2] < [p_0' = 185 \text{ kN/m}^2]; \quad \text{Use Eq. (7-21)}$$

$$S_c = (0.06)[3.8/(1 + 0.70)] \log (160/108) = 0.023 \text{ m, or 23 mm}$$

(7-11) (1) When  $U = 90\%$ ,  $T_v = 0.848$  (from Fig. 7-17).

$H = 12 \text{ ft}$  (single drainage)

$$\text{Eq. (7-29): } t_{90} = [0.848/(9.04 \times 10^{-4})](12 \times 12)^2 = 19,451,469 \text{ min, or 37 yr}$$

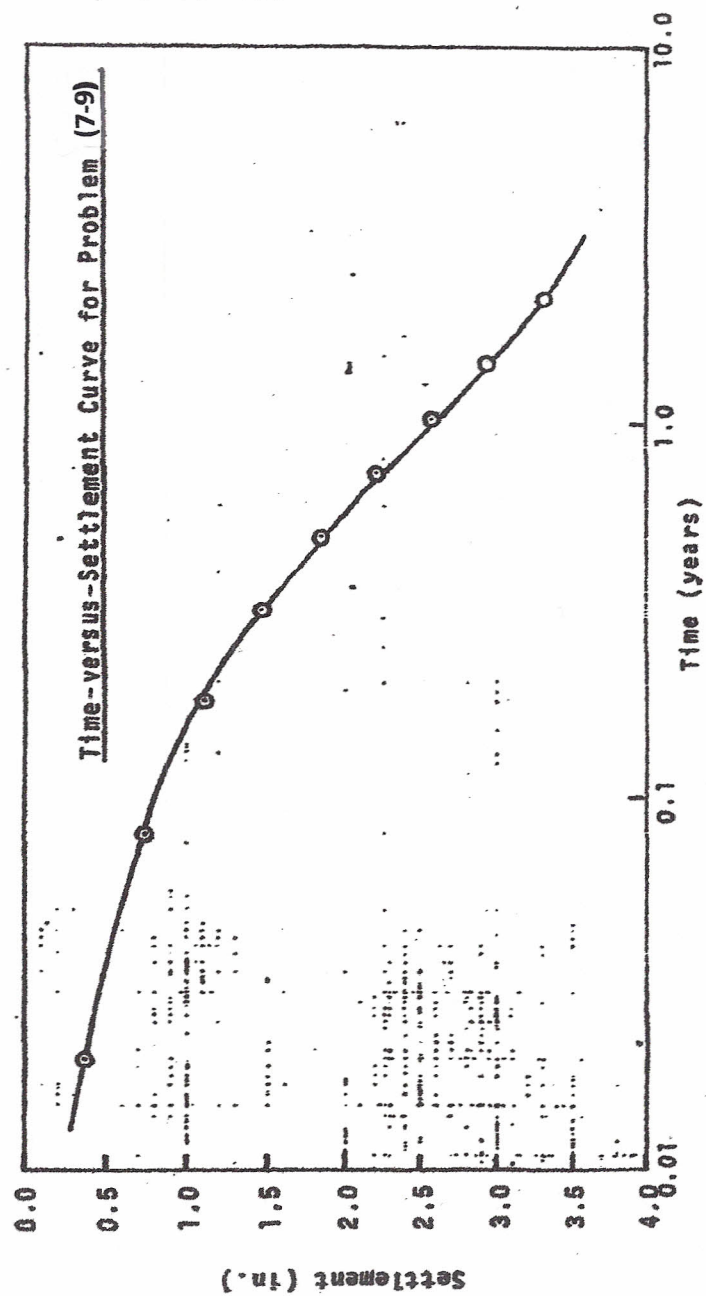
(2)  $1 \text{ yr} = 525,600 \text{ min}$

$$\text{Eq. (7-29): } 525,600 = [T_v/(9.04 \times 10^{-4})](12 \times 12)^2$$

$$T_v = 0.023$$

From Fig. 7-17, with  $T_v = 0.023$ ,  $U = 15\%$ .

$$\text{Settlement at } 1 \text{ yr} = (0.15)(4.60) = 0.69 \text{ in.}$$



(3)  $U = (1/4.60)(100) = 21.7\%$

From Fig. 7-17, with  $U = 21.7\%$ ,  $T_v = 0.040$ .

Eq. (7-29):  $t = 0.040 / (9.04 \times 10^{-4}) (12 \times 12)^2 = 917,522 \text{ min, or } 1.75 \text{ yr}$

(7-12) From Fig. 7-21, with a natural water content of 35%,  $C_\alpha = 0.007$ .

$H = 92.6 - 84.2 = 8.4 \text{ m}$

Eq. (7-30):  $S_s = (0.007)(8.4) \log (40/14) = 0.027 \text{ m}$

(7-13) The appropriate depths for calculating the average corrected N-values are 6 ft to 15 ft.

For a depth of 5 ft, average corrected N-value = 28.

For a depth of 7.5 ft, average corrected N-value =  $(28 + 27)/2 = 28$ .

For a depth of 10 ft, average corrected N-value =  $(28 + 27 + 30)/3 = 28$ .

For a depth of 12.5 ft, average corrected N-value =  $(28 + 27 + 30 + 28)/4 = 28$ .

For a depth of 15 ft, average corrected N-value =  $(28 + 27 + 30 + 28 + 23)/5 = 27$ .

The lowest average corrected N-value is 27.

$q = 300 / [(9)(9)] = 3.70 \text{ tons/ft}^2$

Eq. (7-31):  $s_{\max} = [(2)(3.70)/27][(2)(9)/(1+9)]^2 = 0.89 \text{ in.}$

(7-14) From Problem 7-13,  $s_{\max} = 0.89 \text{ in. on dry sand.}$

$p_d = (130)(6 + 9/2) = 1365 \text{ lb/ft}^2$

$p_w = (8)(130) + (6 + 4.5 - 8)(130 - 62.4) = 1209 \text{ lb/ft}^2$

Eq. (7-32):  $x_B = 1365/1209 = 1.129$

$s_{\max} = (1.129)(0.89) = 1.00 \text{ in.}$

(7-15) Eq. (7-31):  $1 = (2q/18)[(2)(6)/(1+6)]^2$   
 $q = 3.06 \text{ tons/ft}^2$

(7-16)  $p_d = (118)(6 + 6/2) = 1062 \text{ lb/ft}^2$   
 $P_w = (118)(8) + (118 - 62.4)(1) = 1000 \text{ lb/ft}^2$   
 Eq. (7-32):  $x_B = 1062/1000 = 1.062$

From Problem 7-15, if no groundwater was encountered,  $q = 3.06 \text{ tons/ft}^2$  for 1 in. of settlement. When the groundwater table is at a depth below the base of the footing less than  $B/2$ , the  $s_{\max}$  computed should be multiplied by  $x_B$ . Therefore, in this problem,  $q = 3.06 \text{ tons/ft}^2$  will produce  $(1)(1.062) \text{ in.}$  of settlement.

Therefore,  $3.06/1.062 = q_{\text{allowable for 1-in. settlement}}/1$

$q_{\text{allowable for 1-in. settlement}} = 2.88 \text{ tons/ft}^2$

(7-17) For Eq. (7-33),

$p_0 = (17.5)(1) = 17.5 \text{ kN/m}^2$

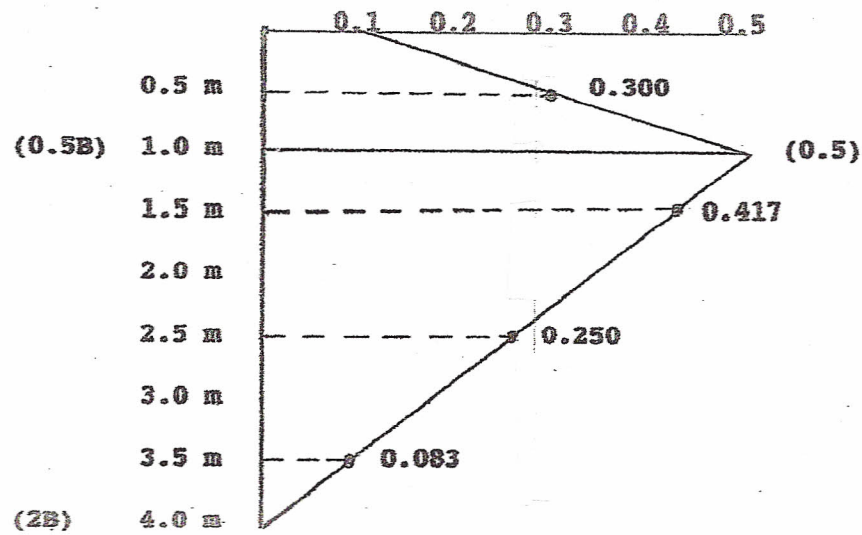
$\Delta p = 800 / [(2)(2)] - (17.5)(1) = 182.5 \text{ kN/m}^2$

$C_1 = 1 - (0.5)(17.5/182.5) = 0.952$

$C_2 = 1 + 0.2 \log [(10)(4)] = 1.32$

The value of the summation term in Eq. (7-33) is  $10.5 \times 10^{-5} \text{ m}^3/\text{kN}$  (determined from the graph and the table on page 22).

Eq. (7-33):  $S_{t(4 \text{ yr})} = (0.952)(1.32)(182.5)(10.5 \times 10^{-5}) = 0.024 \text{ m, or } 24 \text{ mm}$



| A*  | B   | C      | D     | E                     |
|-----|-----|--------|-------|-----------------------|
| 1.0 | 0.5 | 10,000 | 0.300 | $3.00 \times 10^{-5}$ |
| 1.0 | 1.5 | 10,000 | 0.417 | $4.17 \times 10^{-5}$ |
| 1.0 | 2.5 | 10,000 | 0.250 | $2.50 \times 10^{-5}$ |
| 1.0 | 3.5 | 10,000 | 0.083 | $0.83 \times 10^{-5}$ |

$$\text{Sum} = 10.50 \times 10^{-5} \text{ m}^3/\text{kN}$$

\*Column headings are:

- A Layer thickness ( $\Delta z$ ), m
- B Depth from base of footing to center of layer, m
- C Modulus of elasticity of sand layer ( $E_s$ ),  $\text{kN/m}^2$
- D Strain influence factor for soil zone  $z$  depth below foundation (obtained from graph above) ( $I_z$ ), dimensionless
- E  $(I_z/E_s)(\Delta z)$ ,  $\text{m}^3/\text{kN}$