(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.

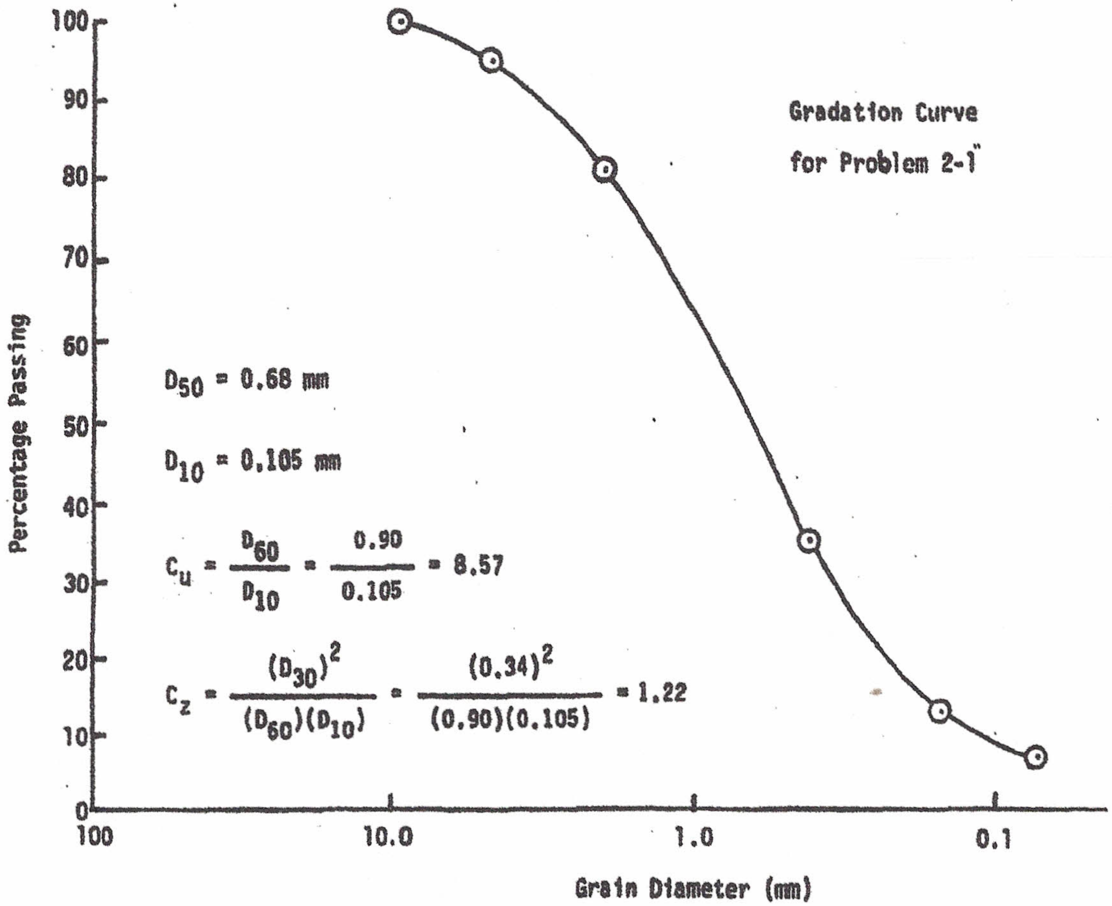
(2-2)
(1) Eq. (2-3): PI = 29 – 19 = 10%
AASHTO classification: A-2-4 (0)
(2) USCS classification: SC

(2-3)
(a) Eq. (2-10): $w = [(62 - 50)/50](100) = 24.0\%$
(b) Eq. (2-11): $\gamma = 62/0.56 = 110.7\ lb/ft^3$
(c) Eq. (2-12): $\gamma_d = 50/0.56 = 89.3\ lb/ft^3$
(d) Eq. (2-15): $2.64 = 50/(62.4V_s)$; $V_s = 0.304\ ft^3$
$V_w = (62 - 50)/62.4 = 0.192\ ft^3$
$V_v = 0.56 - 0.304 = 0.256\ ft^3$
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): $2.66 = 122.7/(1V_s)$; $V_s = 46.1\ cm^3$
$V_v = 72 - 46.1 = 25.9\ cm^3$
Eq. (2-7): $e = 25.9/46.1 = 0.56$
(c) Eq. (2-8): $n = [(72 - 46.1)/72](100) = 36.0\%$
(d) $V_w = (141.5 - 122.7)/1 = 18.8\ cm^3$
Eq. (2-9): $S = (18.8/25.9)(100) = 72.6\%$
(e) Eq. (2-11): $\gamma = (141.5/72)(62.4) = 122.6\ lb/ft^3$
(f) Eq. (2-12): $\gamma_d = (122.7/72)(62.4) = 106.3\ lb/ft^3$

(2-5) Work with 1 ft^3 of specimen.
(a) Eq. (2-10): $18 = (W_w/W_s)(100)$; $W_w = 0.18W_s$
$W_w + W_s = 118.5$; $0.18W_s + W_s = 118.5$; $W_s = 100.4\ lb$
Eq. (2-12): $\gamma_d = 100.4/1 = 100.4\ lb/ft^3$
(b) Eq. (2-15): $2.72 = 100.4/(62.4V_s)$; $V_s = 0.59\ ft^3$
$V_v = 1 - 0.59 = 0.41\ ft^3$
Eq. (2-7): $e = 0.41/0.59 = 0.69$
(c) $W_w = (0.18)(100.4) = 18.1$ ib
$V_w = 18.1/62.4 = 0.29\ ft^3$
Eq. (2-9): $S = (0.29/0.41)(100) = 70.7\%$

(2-6) Work with 1 ft^3 of specimen.


Gradation Curve
for Problem 2-1
Percentage Passing
Grain Diameter (mm)
100
90
80
70
60
50
40
30
20
10
0
100
10.0
1.0
0.1
D_{50} = 0.68 mm
D_{10} = 0.105 mm
$C_u = \frac{D_{60}}{D_{10}} = \frac{0.90}{0.105} = 8.57$
$C_z = \frac{(D_{30})^2}{(D_{60})(D_{10})} = \frac{(0.34)^2}{(0.90)(0.105)} = 1.22$

(a) Eq. (2-7): $0.56 = V_v/V_s$; $V_v = 0.56V_s$
$V_v + V_s = 1$; $0.56V_s + V_s = 1$; $V_s = 0.64\ ft^3$
Eq. (2-15): $2.64 = W_s/[(0.64)(62.4)]$; $W_s = 105.4$ lb
Eq. (2-10): $15 = (W_w/105.4)(100)$; $W_w = 15.8$ lb
$W = 15.8 + 105.4 = 121.2$ lb
Eq. (2-11): $\gamma = 121.2/1 = 121.2\ lb/ft^3$
(b) Eq. (2-12): $\gamma_d = 105.4/1 = 105.4\ lb/ft^3$
(c) $V_v = 1 - 0.64 = 0.36\ ft^3$
Eq. (2-8): $n = (0.36/1)(100) = 36.0\%$
(d) $V_w = 15.8/62.4 = 0.253\ ft^3$
Eq. (2-9): $S = (0.253/0.36)(100) = 70.3\%$

(2-7) Work with 1 ft^3 of specimen.
(a) Eq. (2-10): $42 = (W_w/W_s)(100)$; $W_w = 0.42W_s$
$W_w + W_s = 112.8$; $0.42W_s + W_s = 112.8$; $W_s = 79.4$ lb
$W_w = 112.8 - 79.4 = 33.4$ lb
$V_w = 33.4/62.4 = 0.54\ ft^3$
$V_s = 1 - 0.54 = 0.46\ ft^3$
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 ft^3 of specimen.
(a) Eq. (2-10): $26 = (W_w/15.80)(100)$; $W_w = 4.11$ kN
$V_w = 4.11/9.81 = 0.419\ m^3$
$V_s = 1 - 0.419 = 0.581\ m^3$
$\gamma_{sat} = (4.11 + 15.80)/1 = 19.91\ kN/m^3$
(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 ft^3 of specimen.
(a) Eq. (2-7): $1.33 = V_v/V_s$; $V_v = 1.33\ V_s$
$V_v + V_s = 1$; $1.33V_s + V_s = 1$; $V_s = 0.43\ ft^3$
$V_w = 1 - 0.43 = 0.57\ ft^3$
$W_w = (62.4)(0.57) = 35.6$ lb
Eq. (2-10): $48 = (35.6/W_s)(100)$; $W_s = 74.2$ lb
$W = 74.2 + 35.6 = 109.8$ lb
Eq. (2-11): $\gamma = 109.8/1 = 109.8\ lb/ft^3$
(b) Eq. (2-15): $G_s = 74.2/[(0.43)(62.4)] = 2.77$

(2-10) Work with 1 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), $V_v = 0.945V_s$
$V_v + V_s = 1$; $0.945V_s + V_s = 1$; $V_s = 0.514\ ft^3$
$V_w = 1 - 0.514 = 0.486\ ft^3$
$W_w = (62.4)(0.486) = 30.3$ lb
Eq. (2-15): $2.70 = W_s/[(0.514)(62.4)]$; $W_s = 86.6$ lb

$W = 86.6 + 30.3 = 116.9$ lb
Eq. (2-11): $\gamma = 116.9/1 = 116.9$ lb/ft^3

(2-11) Work with 1 ft^3 of specimen.
(a) Eq. (2-7): $0.85 = V_v/V_s$; $V_v = 0.85V_s$
$V_v + V_s = 1$; $0.85V_s + V_s = 1$; $V_s = 0.54$ ft^3
$V_v = 1 - 0.54 = 0.46$ ft^3
Eq. (2-9): $42 = (V_w/0.46)(100)$; $V_w = 0.193$ ft^3
$W_w = (62.4)(0.193) = 12.04$ lb
Eq. (2-15): $2.74 = W_s/[(0.54)(62.4)]$; $W_s = 92.33$ lb
Eq. (2-10): $w = (12.04/92.33)(100) = 13.04\%$
$W = 92.33 + 12.04 = 104.37$ lb/ft^3
(b) Eq. (2-11): $\gamma = 104.37/1 = 104.4$ lb/ft^3

(2-12) (a) $W_w = 1.445 - 1.301 = 0.144$ kN
Eq. (2-10): $w = (0.144/1.301)(100) = 11.1\%$
(b) Eq. (2-15): $2.65 = 1.301/[(V_s)(9.81)]$; $V_s = 0.050$ m^3
$V_v = 0.082 - 0.050 = 0.032$ m^3
Eq. (2-7): $e = 0.032/0.050 = 0.64$
(c) Eq. (2-8): $n = (0.032/0.082)(100) = 39.0\%$
(d) $V_w = (1.445 - 1.301)/9.81 = 0.015$ m^3
Eq. (2-9): $S = (0.015/0.032)(100) = 46.9\%$
(e) Eq. (2-11): $\gamma = 1.445/0.082 = 17.62$ kN/m^3
(f) Eq. (2-12): $\gamma_d = 1.301/0.082 = 15.87$ kN/m^3

(2-13) Work with 1 m^3 of specimen.
(a) $W_w + W_s = 18.55$ kN
Eq. (2-10): $12.3 = W_w/W_s)(100)$; $W_w = 0.123W_s$
$0.123W_s + W_s = 18.55$; $W_s = 16.52$ kN
Eq. (2-12): $\gamma_d = 16.52/1 = 16.52$ kN/m^3
(b) Eq. (2-15): $2.72 = 16.52/[(V_s)(9.81)]$; $V_s = 0.619$ m^3
$V_v = 1 - 0.619 = 0.381$ m^3
Eq. (2-7): $e = 0.381/0.619 = 0.62$
(c) $W_w = (0.123)(16.52) = 2.03$ kN
$V_w = 2.03/9.81 = 0.207$ m^3
Eq. (2-9): $S = (0.207/0.381)(100) = 54.3\%$

(2-14) Work with 1 m^3 of specimen.
$W_w + W_s = 18.85$ kN
Eq. (2-10): $5.2 = (W_w/W_s)(100)$; $W_w = 0.052W_s$
$0.052W_s + W_s = 18.85$; $W_s = 17.92$ kN
$W_w = (0.052)(17.92) = 0.93$ kN
$V_w = 0.93/9.81 = 0.095$ m^3
Eq. (2-15): $2.66 = 17.92/[(V_s)(9.91)]$; $V_s = 0.687$ m^3
$V_v = 1 - 0.687 = 0.313$ m^3
Eq. (2-7): $e_0 = 0.313/0.687 = 0.46$
Eq. (2-18): $D_r = [(0.92 - 0.46)/(0.92 - 0.38)](100) = 85.2\%$

(2-15) $V_s = V - V_v$
Eq. (2-7): $e = V_v/(V - V_v) = (V_v/V)/(V/V - V_v/V)$
Because $V_v/V = n$, $e = n/(1 - n)$

(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^3 of specimen.

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

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

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

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

(b) $W_s = (0.62)(2.66)(62.4) = 102.9$ lb

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

$W_w = (0.133)(62.4) = 8.30$ lb

$W = 8.30 + 102.9 = 111.2$ lb

Eq. (2-11): $\Upsilon = 111.2/1 = 111.2\ lb/ft^3$

(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): $0.78 = (V_v)_d/(V_s)_d$; $(V_v)_d = 0.78(V_s)_d$

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

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

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

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

(2-19) Work with 1 ft^3 of specimen.

$W_w + W_s = 128.2$ lb

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

$0.145W_s + W_s = 128.2$; $W_s = 112.0$ lb

$W_w = 128.2 - 112.0 = 16.2$ lb (initially)

Drying reduces the weight of water by 128.2 – 118.8, or 9.4 lb. Hence, the weight of water after drying is 16.2 – 9.4, or 6.8 lb.

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

(2-20) Work with 1 m^3 of specimen.

(a) $W_w + W_s = 17.98$

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

$0.076W_s + W_s = 17.98$; $W_s = 16.71$ kN

$W_w = 17.98 - 16.71 = 1.27$ kN

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

$V_v = 1 - 0.643 = 0.357\ m^3$

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

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

(b) $V_v + V_s = 1$

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

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

$V_v = 1 - 0.526 = 0.474\ m^3$

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

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

$W = 13.67 + 1.04 = 14.71$ kN

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

(2-21) Work with 1 ft^3 of specimen.

$V_v + V_s = 1$

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

$0.85\ V_s + V_s = 1$; $V_s = 0.541\ ft^3$

$V_v = 1 - 0.541 = 0.459\ ft^3$

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

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^3, 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^3 of specimen.

$V_v + V_s = 1$

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

Eq. (2-7): $0.68 = V_v/V_s$; $V_v = 0.68V_s$

$0.68V_s + V_s = 1$; $V_s = 0.595\ ft^3$

$V_v = 1 - 0.595 = 0.405\ ft^3$

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

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

$W_w = (0.405)(62.4) = 25.3$ lb (if saturated)

$W = 25.3 + 98.4 = 123.7$ lb

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

(b) Work with 1 m^3 of specimen.

$V_v + V_s = 1$

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

Eq. (2-7): $0.68 = V_v/V_s$; $V_v = 0.68V_s$

$0.68V_s + V_s = 1$; $V_s = 0.595\ m^3$

$V_v = 1 - 0.595 = 0.405\ m^3$

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

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

$W_w = (0.405)(9.81) = 3.97$ kN (if saturated)

$W = 15.47 + 3.97 = 19.44$ kN

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

(3-1) (a) $p_0 = (10)(120)/2000 = 0.600$ ton/ft^2
Eq. (3-1): $C_N = 0.77 \log_{10}(20/0.600) = 1.17$
$N_{corrected} = (1.17)(26) = 30$
(b) 10 ft = 3.048 m and 120 lb/ft^3 = 18.85 kN/m^3
$p_0 = (3.048)(18.85) = 57.45$ kN/m^2
Eq. (3-3): $N_{corrected} = (26)(100/57.45)^{1/2} = 34$

(3-2) (a) $p_0 = [(8)(120) + (2)(120 - 62.4)]/2000 = 0.538$ ton/ft^2
Eq. (3-1): $C_N = 0.77 \log_{10}(20/0.538) = 1.21$
$N_{corrected} = (1.21)(26) = 31$
(b) $p_0 = 1.08$ kips/ft^2 = 51.71 kN/m^2
Eq. (3-3): $N_{corrected} = (26)(100/51.71)^{1/2} = 36$

(3-3) (a) $p_0 = (7)(20.40) = 142.8$ kN/m^2
Eq. (3-2): $C_N = 0.77 \log_{10}(1915/142.8) = 0.868$
$N_{corrected} = (0.868)(22) = 19$
(b) Eq. (3-3): $N_{corrected} = (22)(100/142.8)^{1/2} = 18$

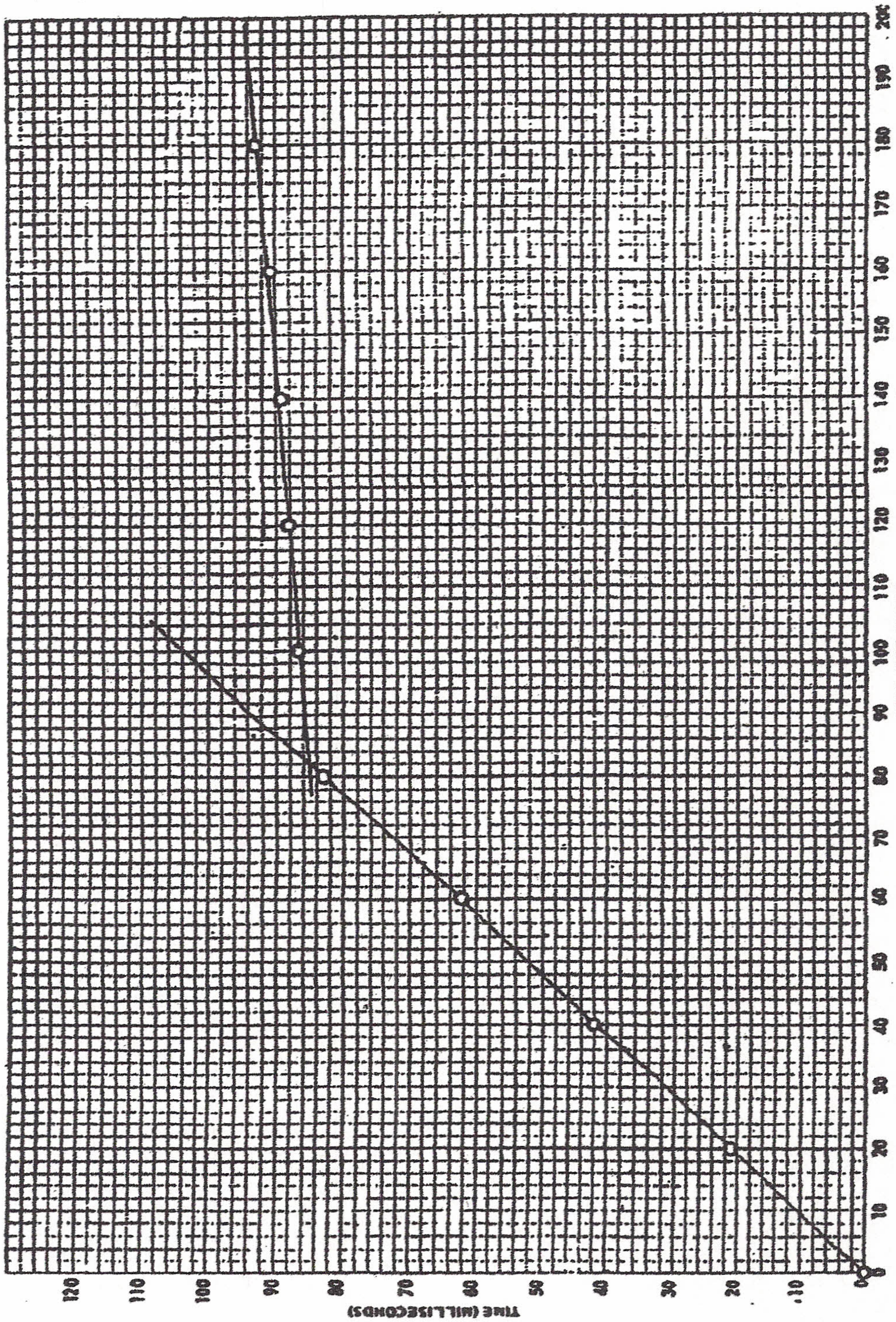
(3-4) (a) $p_0 = (2)(20.40) + (5)(20.40 - 9.81) = 93.75$ kN/m^2
Eq. (3-2): $C_N = 0.77 \log_{10}(1915/93.75) = 1.01$
$N_{corrected} = (1.01)(22) = 22$
(b) Eq. (3-3): $N_{corrected} = (22)(100/93.75)^{1/2} = 23$

(3-5) Eq. (3-4): $c = 61/\{(\pi)[(4/12)^2(8/12)(1/2) + (4/12)^3(1/6)]\} = 449$ lb/ft^2
From Fig. 3-17 with PI = 40%, $\mu = 0.85$. Hence, $c_{corrected} = (0.85)(449) = 382$ lb/ft^2

(3-6) A plot of time versus distance is given on page 8.
$slope_{line\ 1} = 0.083/80 = 0.001038$
$slope_{line\ 2} = (0.093 - 0.08675)/(180 - 100) = 0.00007813$
v_1 = reciprocal of $slope_{line\ 1} = 1/0.001038 = 963$ ft/sec
v_2 = reciprocal of $slope_{line\ 2} = 1/0.00007813 = 12{,}800$ ft/sec
L = 82 ft (from plot on page 8)
Eq. (3-6): $H_1 = (82/2)[(12{,}800 - 963)/(12{,}800 + 963)]^{1/2} = 38$ ft
With v_1 = 963 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 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)

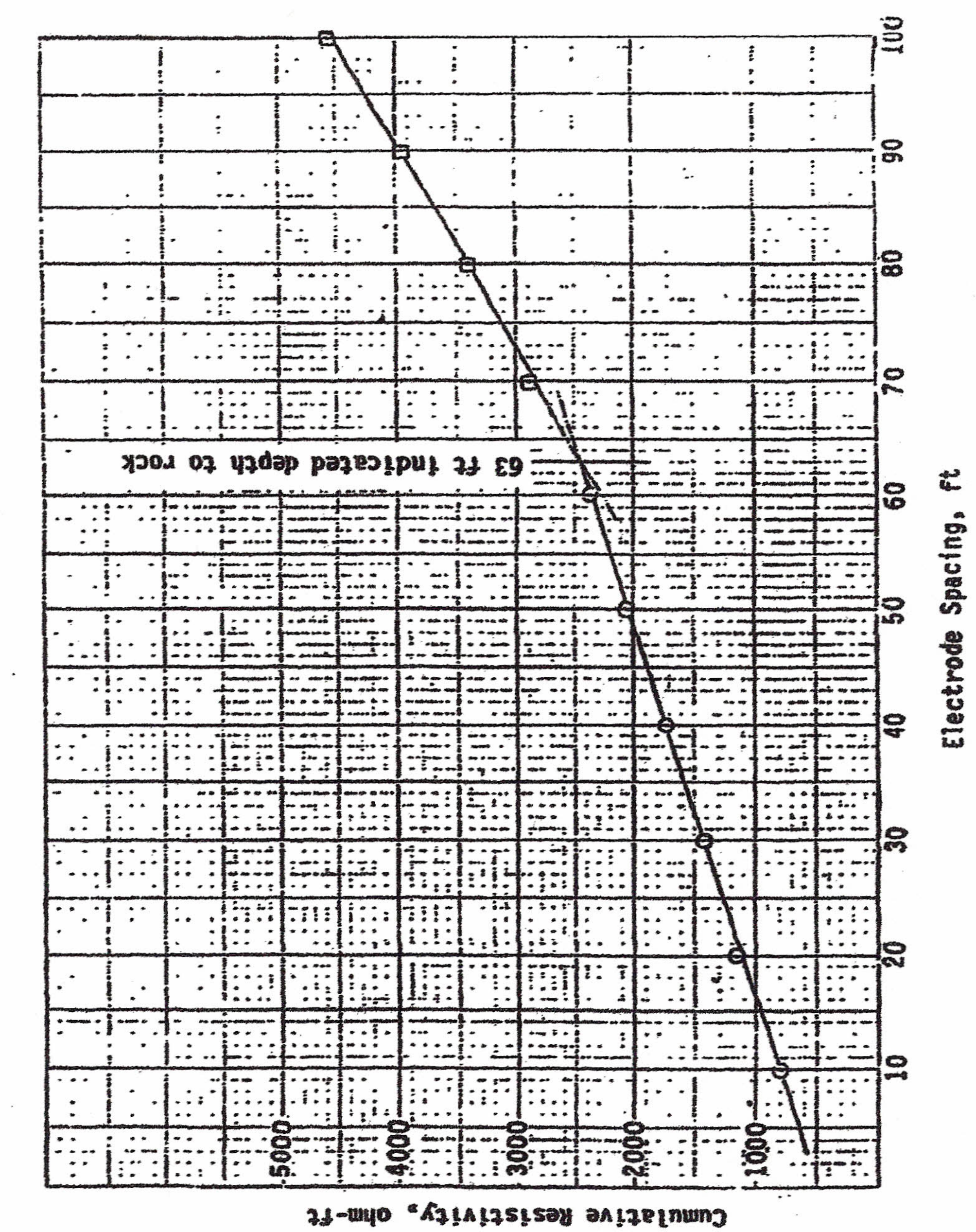
Electrode Spacing (ft)	**Resistance (ohms)**	**Resistivity (ohm-ft)**	**Cumulative Resistivity (ohm-ft)**
10	12.73	800	800
20	2.79	351	1151
30	1.46	275	1426
40	1.15	289	1715
50	1.05	330	2045
60	0.84	317	2362
70	1.21	532	2894
80	1.00	503	3397
90	0.97	549	3946
100	0.95	597	4543


DISTANCE (FEET)
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200
TIME (MILLISECONDS)
0 10 20 30 40 50 60 70 80 90 100 110 120

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

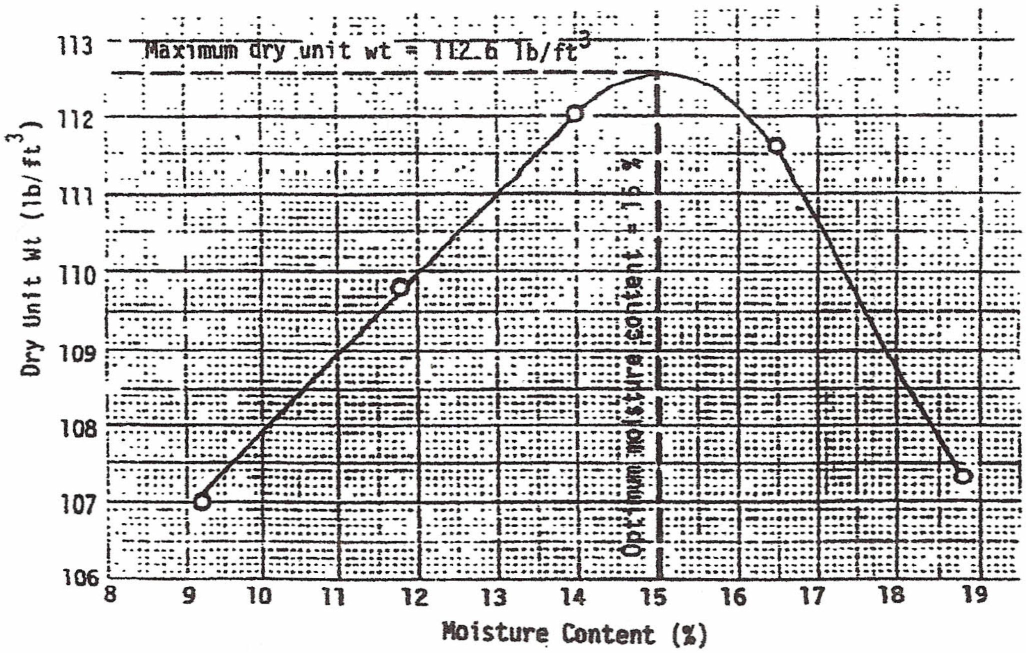
Values in column 4 are cumulative resistivity values. A plot of electrode spacing versus cumulative resistivity is shown on page 10. From this plot, the thickness of the first soil layer is determined to be approximately 63 ft. Because the resistivity of the upper layer is in the range from 50 to 500 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.



63 ft indicated depth to rock
Electrode Spacing, ft
10
20
30
40
50
60
70
80
90
100
Cumulative Resistivity, ohm-ft
1000
2000
3000
4000
5000

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

(4-2)



(4-3) 95% of the maximum dry unit weight = (0.95)(112.6) = 107.0 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 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 g
Volume of test hole = $(522/453.6)/100 = 0.0115\ ft^3$
Eq. (2-11): $\Upsilon = (648/453.6)/0.0115 = 124.2\ lb/ft^3$
Eq. (4-1): $\Upsilon_d = 124.2/(1 + 0.16) = 107.1\ lb/ft^3$

(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 is the total volume of soil from the borrow pit.)
$(V_s)_b = 0.5952V_b$
Eq. (2-7): $0.45 = (V_v)_f/(V_s)_f$; $(V_v)_f = 0.45(V_s)_f$
$(V_v)_f + (V_s)_f = 2500$
$0.45(V_s)_f + (V_s)_f = 2500$; $(V_s)_f = 1724\ m^3$
Because $(V_s)_b = (V_s)_f$, $0.5952V_b = 1724$
$V_b = 2897\ m^3$

(4-8) Eq. (4-3): $D = (0.5)[(20)(10)]^{1/2} = 7.1\ m$

CHAPTER 5

(5-1) $k = [(3.60 \times 10^{-2})/2.54](1/12) = 1.18 \times 10^{-3}$ ft/sec
Eq. (5-4): $q = (1.18 \times 10^{-3})(1/5)(400/144) = 6.56 \times 10^{-4}$ ft^3/sec

(5-2) $v = 2000/[(20)(60)]/60.0 = 0.28$ cm/s
Eq. (5-8): $v_{actual} = (0.028)(1 + 0.71)/0.71 = 0.067$ cm/s

(5-3) $A = (\pi)(10.0)^2/4 = 78.54$ cm^2
Eq. (5-11): $k = (500)(12.0)/[(78.54)(152)(4.9)] = 0.103$ cm/s

(5-4) $A = (\pi)(10.20)^2/4 = 81.71$ cm^2
$T = (35)(60) = 2100$ s
Eq. (5-18): $k = \{(2.3)(1.95)(16.2)/[(81.71)(2100)]\}\log(100.0/92.0) = 1.53 \times 10^{-5}$ cm/s

(5-5) $q = 185/7.48/60 = 0.4122$ ft^3/sec
Eq. (5-28): $k = (0.4122)\ln(100/50)/[(\pi)(15^2 - 12^2)] = 1.123 \times 10^{-3}$ ft/sec, or 0.0342 cm/s

(5-6) $q = 205/7.48/60 = 0.4568$ ft^3/sec
Eq. (5-23): $k = (0.4568)\ln(150/75)/[(2)(\pi)(12)(20 - 16)] = 1.05 \times 10^{-3}$ ft/sec, or 0.0320 cm/s

(5-7) Eq. (5-29): $k = 0.18^2 = 0.0324$ cm/s

(5-8) Eq. (5-30): $k = (0.35)(0.25)^2 = 0.0219$ cm/s

(5-9) Eq. (5-42): $h = (4)(0.00504)/[(0.008/12)(62.4)] = 0.485$ ft, or 5.8 in.

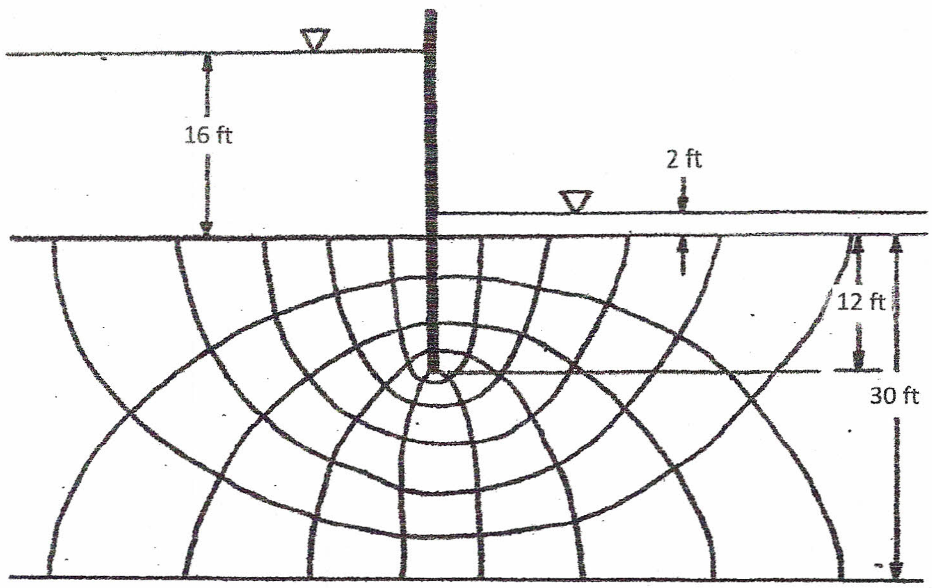
(5-10) Eq. (5-37): $k_y = 20/[6/(2.6 \times 10^{-7}) + 4/(3.2 \times 10^{-7}) + 10/(2.3 \times 10^{-7})] = 2.53 \times 10^{-7}$ cm/s
Eq. (5-5): $q = [(2.53 \times 10^{-7})/2.54/12](70/20)(35{,}000) = 0.00102$ ft^3/sec
Loss in one year = $(0.00102)(60 \times 60 \times 24 \times 365) = 32{,}200$ ft^3

(5-11) Eq. (5-39): $k_x = [(6)(1.8 \times 10^{-6}) + (4)(2.4 \times 10^{-6}) + (10)(1.1 \times 10^{-6})]/20 = 1.57 \times 10^{-6}$ cm/s

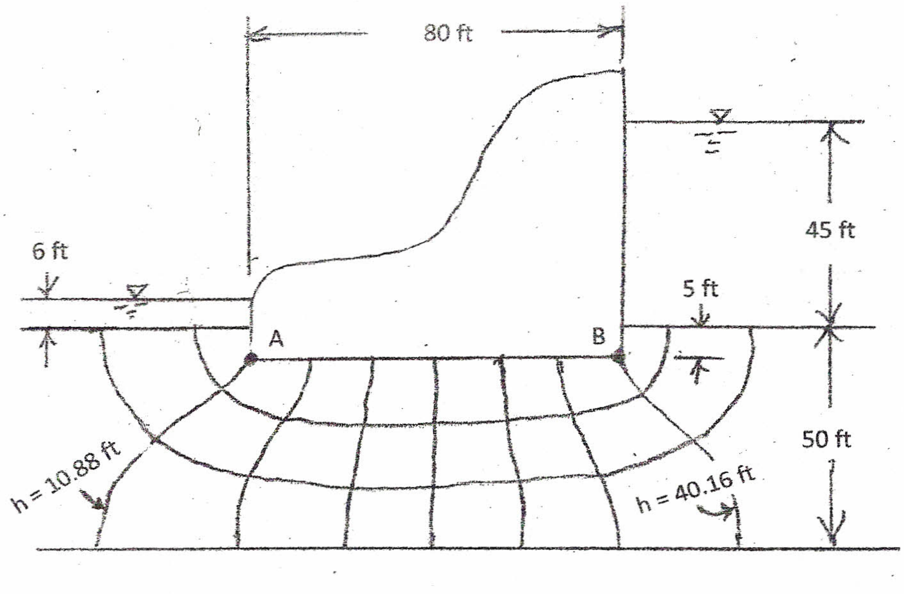
(5-12) The flow net is shown on page 13.
$k = (8.80 \times 10^{-3})/2.54/12 = 2.89 \times 10^{-4}$ ft/sec
Eq. (5-48): $q = (2.89 \times 10^{-4})(16 - 2)(6/9) = 0.00270$ ft^3/sec per ft

(5-13) The flow net is shown on page 13.
$k = (6.82 \times 10^{-3})/2.54/12 = 2.24 \times 10^{-4}$ ft/sec
Eq. (5-48): $q = (2.24 \times 10^{-4})(45 - 6)(3/8) = 0.00328$ ft^3/sec per ft

(5-14) The flow net is shown on page 13.
$\Delta H = h/N_d = (45 - 6)/8 = 4.88$ ft
$h_A = 6 + 4.88 = 10.88$ ft
$h_B = 6 + (7)(4.88) = 40.16$ ft
$p_A = (5 + 10.88))(62.4) = 990.9$ lb/ft^2
$p_B = (5 + 40.16)(62.4) = 2818.0$ lb/ft^2
Total uplift force = $(1/2)(990.9 + 2818.0)(80) = 152{,}400$ lb, or 152.4 kips



Flow net for Problem (5-12)



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

(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): $p_{total} = 186 + 128 = 314\ \text{kN/m}^2$

(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) $P = (5000)(10)(7.5) = 375{,}000$ lb
Eq. (6-10): $p = 375{,}000/[(10 + 12)(7.5 + 12)] = 874\ \text{lb/ft}^2$

(6-5) $P = (195)(2)(3) = 1170$ kN
Eq. (6-10): (a) $p_{(at\ 1\ m)} = 1170/[(2 + 1)(3 + 1)] = 97.50\ \text{kN/m}^2$
: (b) $p_{(at\ 3\ m)} = 1170/[(2 + 3)(3 + 3)] = 39.00\ \text{kN/m}^2$
: (c) $p_{(at\ 5\ m)} = 1170/[(2 + 5)(3 + 5)] = 20.89\ \text{kN/m}^2$

(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

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

(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

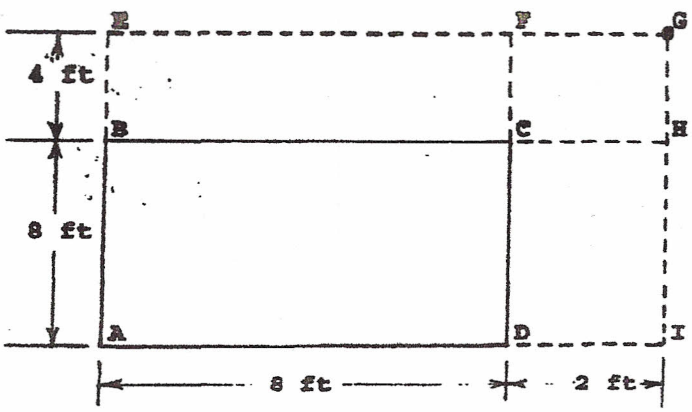
Part 1: mz = 16; z = 24; m = 16/24 = 0.667
nz = 24; z = 24; n = 24/24 = 1.000
Influence coefficient = 0.145

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

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

(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

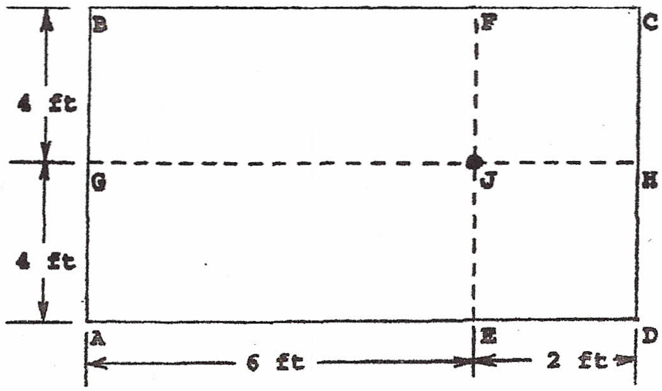
Area BEGH: mz = 4; z = 12; m = 4/12 = 0.333
nz = 10; z = 12; n = 10/12 = 0.833
Influence coefficient = 0.083

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

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

(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 kN/m^2.
mz = 58 m; z = 15 m; m = 58/15 = 3.87
nz = 38 m; z = 15 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 kN/m^2.

(6-14) mz = 20/2 = 10 ft; z = 10 + 6 = 16 ft; m = 10/16 = 0.625
nz = 15/2 = 7.5 ft; z = 10 +6 = 16 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 ft; z = 6 ft; m = 10/6 = 1.67
nz = 7.5 ft; z = 6 ft; n = 7.5/6 = 1.25
$I_2 = 021$
$p_2 = (4)(0.21)\{118/1000\}(10) = 0.99\ \text{kips/ft}^2$
$p = p_1 + p_2 = 1.88 + 0.99 = 2.87\ \text{kips/ft}^2$

(7-1) Eq. (7-29): $c_v = (0.196)[(0.74/12)/2]^2/6.2 = 0.0000301\ ft^2/min$
Eq. (7-24): $a_v = (1.167 - 1.108)/(2000 - 1000) = 0.0000590$
Eq. (7-23): $k = (0.0000301)(0.0000590)(62.4)/[1 + (1.167 + 1.108)/2)] = 5.18 \times 10^{-8}\ ft/min = 6.22 \times 10^{-7}$ in./min $= 2.63 \times 10^{-8}$ cm/s

(7-2) $p_0 = (19.21)(150.0 - 146.2) + (19.21 - 9.81)(146.2 - 144.8) + (17.28 - 9.81)(144.8 - 136.6)/2 = 116.8\ kN/m^2$

(7-3) Let $e_1 = 1.09$; $p_1 = 100\ kN/m^2$; $e_2 = 0.89$; $p_2 = 400\ kN/m^2$
Eq. (7-4): $C_c = (1.09 - 0.89)/[\log (400/100)] = 0.332$
Let $e_1 = 1.09$; $p_1 = 100\ kN/m^2$; $p_2 = 800\ kN/m^2$
Eq. (7-4): $0.332 = (1.09 - e_2)/[\log (800/100)]$
$e_2 = 0.79$

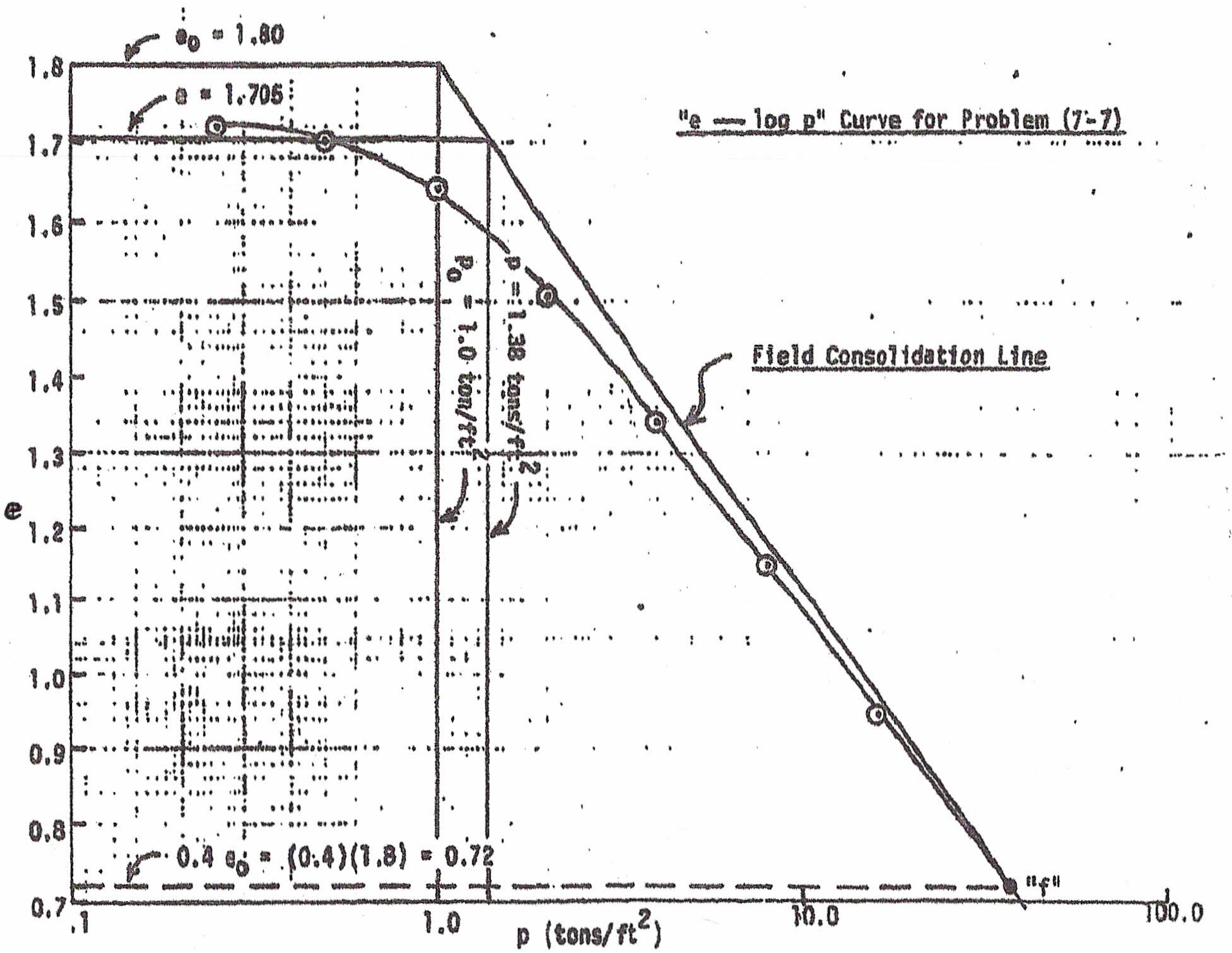
(7-4) Eq. (7-15): $S_c = [(1.026 - 0.978)/(1 + 1.026)](10.0) = 0.237$ m

(7-5) p_o at midheight of clay layer $= (18.92)(100.0 - 98.5) + (18.92 - 9.81)(98.5 - 92.6) + (17.25 - 9.81)[(92.6 - 84.2)/2] = 113.38\ kN/m^2$
Net consolidation pressure at base of foundation $= 1000/[(2)(2)] - [(100.0 - 98.5)(18.92) + (98.5 - 96.0)(18.92 - 9.81)] = 198.84\ kN/m^2$
$mz = 1.0$; $z = 96.0 - (92.6 + 84.2)/2 = 7.6$; $m = 1.0/7.6 = 0.132$
$nz = 1.0$; $z = 7.6$; $n = 1.0/7.6 = 0.132$
Influence coefficient = 0.0085
$\Delta p = (4)(0.0085)(198.84) = 6.76\ kN/m^2$
$p = p_0 + \Delta p = 113.38 + 6.76 = 120.14\ kN/m^2$
$H = 92.6 - 84.2 = 8.4$ m
Eq. (7-19): $S_c = (0.60)[(8.4)/[1 + 1.058)] \log (120.14/113.38) = 0.062$ m

(7-6) From Fig. 7-17, for 90% primary consolidation, $T_v = 0.848$.
(a) $H = (92.6 - 84.2)/2 = 4.20$ m
Eq. (7-29): $t_{90} = [0.848/(6.98 \times 10^{-6})](4.20)^2 = 2{,}143{,}000$ min, or 4.08 yr
(b) T_v and c_v are the same as for (a).
$H = 92.6 - 84.2 = 8.40$ m
Eq. (7-29): $t_{90} = [0.848/(6.98 \times 10^{-6})](8.40)^2 = 8{,}572{,}000$ min, or 16.3 yr

(7-7) (a) p_0 at midheight of clay layer $= (120)(100 - 85) + (103 - 62.4)(85 - 76)/2 = 1983\ lb/ft^2$, or $1.0\ ton/ft^2$
$0.4e_0 = (0.4)(1.80) = 0.72$
The "e-log p" curve is shown on page 18.
(b) Effective weight of excavation $= (120)(100 - 94) = 720\ lb/ft^2$, or $0.36\ ton/ft^2$
Net consolidation pressure at base of footing $= 200/[(9)(9)] - 0.36 = 2.11\ tons/ft^2$
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
$\Delta p = (4)(0.045)(2.11) = 0.38\ ton/ft^2$
$p = p_0 + \Delta p = 1.0 + 0.38 = 1.38\ tons/ft^2$
With $p = 1.38\ tons/ft^2$, from field consolidation line, $e = 1.705$.
Eq. (7-15): $S_c = [(1.80 - 1.705)/(1 + 1.80)](85 - 76) = 0.305$ ft, or 3.66 in.

(7-8) $p = p_0 + \Delta p = 108 + 52 = 160\ kN/m^2$



e₀ = 1.80
e = 1.705
"e — log p" Curve for Problem (7-7)
Field Consolidation Line
p₀ = 1.0 ton/ft²
p = 1.38 tons/ft²
0.4 e₀ = (0.4)(1.8) = 0.72
"f"
e
p (tons/ft²)
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
.1
1.0
10.0
100.0

$[p = 160\ \text{kN/m}^2] > [p_0' = 125\ \text{kN/m}^2]$; Use Eq. (7-22).
$S_c = (0.06)[3.8/(1 + 0.70)] \log (125/108) + (0.30)[3.8/(1 + 0.70)] \log (160/125) = 0.080$ 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 ft.

(1) When U = 10%, $T_v = 0.0077$ (from Fig. 7-17).
Eq. (7-29): $t_{10} = [0.0077/(2.18 \times 10^{-3})](4.5 \times 12)^2 = 10{,}300$ min, or 0.020 yr

(2) When U = 20%, $T_v = 0.0314$
$t_{20} = [0.\ 0314/(2.18 \times 10^{-3})](4.5 \times 12)^2 = 42{,}001$ min, or 0.080 yr

(3) When U = 30%, $T_v = 0.0707$
$t_{30} = [0.\ 0707/(2.18 \times 10^{-3})](4.5 \times 12)^2 = 94{,}569$ min, or 0.180 yr

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

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

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

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

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

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

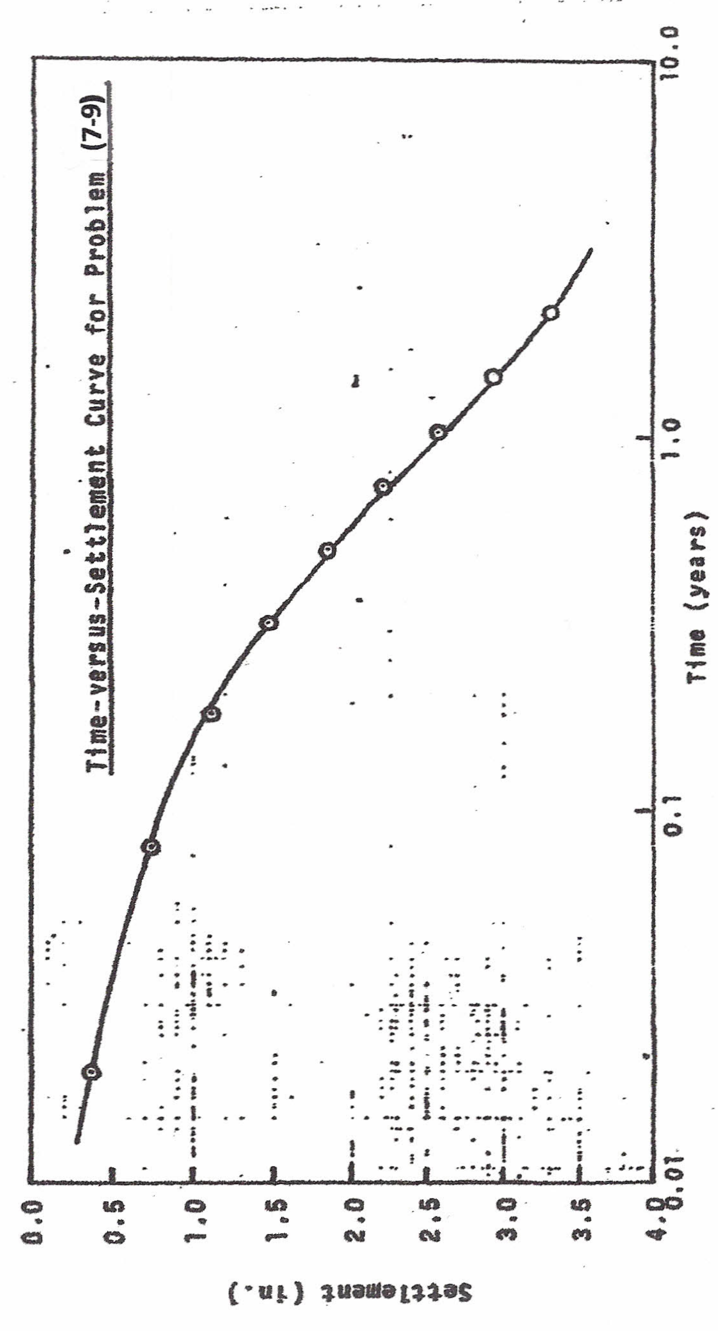
U (fraction of total settlement) (%)	Settlement (in.)	Time (yr)
10	0.37	0.020
20	0.73	0.080
30	1.10	0.180
40	1.46	0.321
50	1.83	0.499
60	2.20	0.728
70	2.56	1.026
80	2.93	1.443
90	3.29	2.158
100	3.66	∞

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

(7-10) $p = p_0 + \Delta p = 108 + 52 = 160\ \text{kN/m}^2$
$[p = 160\ \text{kN/m}^2] < [p_0' = 185\ \text{kN/m}^2]$; Use Eq. (7-21)
$S_c = (0.06)[3.8/(1 + 0.70)] \log (160/108) = 0.023$ m, or 23 mm

(7-11) (1) When U = 90%, $T_v = 0.848$ (from Fig. 7-17).
H = 12 ft (single drainage)
Eq. (7-29): $t_{90} = [0.848/(9.04 \times 10^{-4})](12 \times 12)^2 = 19{,}451{,}469$ min, or 37 yr

(2) 1 yr = 525,600 min
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%.
Settlement at 1 yr = (0.15)(4.60) = 0.69 in.


Time-versus-Settlement Curve for Problem (7-9)
Settlement (in.)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Time (years)
0.01
0.1
1.0
10.0

(3) $U = (1/4.60)(100)$ 21.7%
From Fig. 7-17, with U = 21.7%, $T_v = 0.040$.
Eq. (7-29): $t = 0.040/(9.04 \times 10^{-4})](12 \times 12)^2 = 917{,}522$ min, or 1.75 yr

(7-12) From Fig. 7-21, with a natural water content of 35%, $C_\alpha = 0.007$.
$H = 92.6 - 84.2 = 8.4$ m
Eq. (7-30): $S_s = (0.007)(8.4) \log (40/14) = 0.027$ m

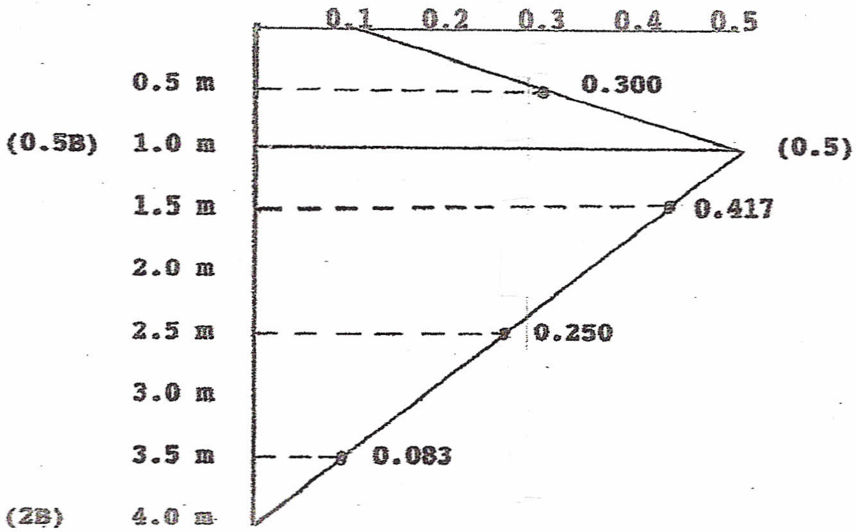
(7-13) The appropriate depths for calculating the average corrected N-values are 6 ft to 15 ft.
For a depth of 5 ft, average corrected N-value = 28.
For a depth of 7.5 ft, average corrected N-value = (28 + 27)/2 = 28.
For a depth of 10 ft, average corrected N-value = (28 + 27 + 30)/3 = 28.
For a depth 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.
$q = 300/[(9)(9)] = 3.70$ tons/ft^2
Eq. (7-31): $s_{max} = [(2)(3.70)/27][(2)(9)/(1 + 9)]^2 = 0.89$ in.

(7-14) From Problem 7-13, $s_{max} = 0.89$ in. on dry sand.
$p_d = (130)(6 + 9/2) = 1365$ lb/ft^2
$p_w = (8)(130) + (6 + 4.5 - 8)(130 - 62.4) = 1209$ lb/ft^2
Eq. (7-32): $x_B = 1365/1209 = 1.129$
$s_{max} = (1.129)(0.89) = 1.00$ in.

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

(7-16) $p_d = (118)(6 + 6/2) = 1062$ lb/ft^2
$P_w = (118)(8) + (118 - 62.4)(1) = 1000$ lb/ft^2
Eq. (7-32): $x_B = 1062/1000 = 1.062$
From Problem 7-15, if no groundwater was encountered, q = 3.06 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 tons/ft^2 will produce (1)(1.062) in. of settlement.
Therefore, $3.06/1.062 = q_{\text{allowable for 1-in. settlement}}/1$
$q_{\text{allowable for 1-in. settlement}} = 2.88$ tons/ft^2

(7-17) For Eq. (7-33),
$p_0 = (17.5)(1) = 17.5$ kN/m^2
$\Delta p = 800/[(2)(2)] - (17.5)(1) = 182.5$ 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 10.5×10^{-5} m^3/kN (determined from the graph and the table on page 22).
Eq. (7-33): $S_{t(4\ yr)} = (0.952)(1.32)(182.5)(10.5 \times 10^{-5}) = 0.024$ m, or 24 mm



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

Sum = 10.50×10^{-5} m^3/kN

*Column headings are:

A Layer thickness (Δz), m

B Depth from base of footing to center of layer, m

C Modulus of elasticity of sand layer (E_s), kN/m^2

D Strain influence factor for soil zone z depth below foundation (obtained from graph above) (I_z), dimensionless

E $(I_z/E_s)(\Delta z)$, m^3/kN