APPENDIX D

PILE CAPACITY COMPUTATIONS

D-1. General. After the shear strength and stratification has been selected, the capacity of piles may be computed. The geotechnical engineer computes the capacity of a single pile placed in the subgrade at various levels, then furnishes to the structural engineer a curve relating the pile tip elevation to the axial capacity. These computations may be for any number of pile types, i.e., timber, concrete, steel H-pile, etc., and the computations should be both in the construction shear strength case Q and the long-term shear strength case S. Therefore, two curves for each compression and tension loading will be produced and the designer should use the lowest composite in selecting an allowable load.

D-2. Example Computations. Included are examples for soil profiles consisting of soft clay, sand, silt, and alternating layers. To reduce the number of computations, a timber pile at a single tip elevation is shown. These computations must be made at each change in soil property and at a close enough interval to describe the curve mentioned in Paragraph D-1. In the examples, each of the various tip elevations used a timber pile having a 12-inch butt diameter and a 7-inch tip diameter, with the butt driven flush to the ground surface.

a. Uniform Clay Profile. This example was developed for a bottom of slab elevation of +10.0 feet.* Using the shear strengths from the laboratory testing, two shear strength trends are developed. The example trend is shown below:

Average Laboratory Test Results

	Q Case			S Case		
Elevation ft	$\phi°$	γ (pcf)	c (psf)	$\phi°$	γ (pcf)	c (psf)
10.0 to 0.0	0	110	400	23	110	0
0.0 to -15.0	0	48*	600	23	48*	0
-15.0 to -20.0	0	42*	650	23	42*	0
-20.0 to -30.0	0	40*	800	23	40*	0
-30.0 to -60.0	0	38*	900	23	38*	0

*The unit weight below the water table at elevation 0.0 (NGVD) is the submerged weight.

(1) Example computation for soft clay in the "Q" case for a single tip elevation of -30.0 using a timber pile having butt diameter of 12 inches and tip diameter of 7 inches. This will be the computation for a single point on a pile capacity vs. tip elevation curve. It is based upon the data above which therefore means that the pile length is 40 ft.

(a) Compute pile skin friction "Q" case. Computations will be by layer due to property variation computed as follows:

*All elevations (el) cited herein are in feet referred to National Geodetic Vertical Datum (NGVD) of 1929.

$$Q_s = \sum_{i=1 \text{ to } N} f_{s_i} A_{s_i}$$

To compute the average diameter of the tapered timber pile the following equation is used.

$$d_{i_A} = d_t + \frac{L(d_B - d_t)}{B}$$

where:

d_{i_A} = diameter at the midpoint of the layer being computed

d_t = diameter of pile tip

d_B = diameter of pile butt

L = length from pile tip to midpoint of layer

L_t = total length of pile

Layer from elevation +10.0 to elevation 0.0

$$\text{Average pile diameter} = 7 + \frac{35(5)}{40} = 11.375 \text{ inches}$$

$$\Delta Q_s = \pi \cdot \text{Avg. Diameter} \cdot \text{Length} \cdot \text{Cohesion} \cdot \text{Adhesion reduction factor}$$

obtained from Figure 4-3

Increment of skin friction

$$\Delta Q_s = \pi \frac{11.375}{12} (10)(400)(1) = 11{,}911 \text{ pounds}$$

Layer from elevation 0.0 to elevation -15.0

Average pile diameter

$$d = 7 + \frac{22.5(5)}{40} = 9.813 \text{ inches}$$

α from Figure 4-3 is 0.95

Increment of skin friction

$$\Delta Q_s = \pi \frac{9.813}{12} (15')(600)(0.95) = 21{,}965 \text{ pounds}$$

Layer from elevation -15.0 to elevation -20.0

Average pile diameter

$$d = 7 + \frac{12.5(5)}{40} = 8.563 \text{ inches}$$

Increment of skin friction

$$\Delta Q_s = \pi \frac{8.563}{12} (5)(650)(1.9) = 6{,}556 \text{ pounds}$$

Layer from elevation -20.0 to elevation -30.0

Average pile diameter

$$d = 7 + \frac{5(5)}{40} = 7.625 \text{ inches}$$

Increment of skin friction

$$\Delta Q_s = \pi \frac{7.625}{12} (10)(800)(.8) = 12{,}712 \text{ pounds}$$

$$Q_s = \sum_{1-4} \Delta Q_s = 54{,}295 \text{ lb} = 27.15 \text{ tons}$$

$$Q_{s_{Allow}} = \frac{Q_s}{FS} = \frac{27.15 \text{ tons}}{2.0} = 13.57 \text{ tons}$$

(b) Compute end bearing "Q" case with pile tip at elevation -30.0 using the equations:

$$q = 9C$$

$$Q_T = A_T q$$

where:

C = shear strength

A_T = tip area

$$Q_T = 9.0(800) \frac{\pi(7/12)^2}{4} = 1,924.23 \text{ lb} = 0.962 \text{ tons}$$

$$Q_{T_{Allow}} = \frac{Q_T}{FS} = \frac{0.962}{2.0} = 0.48 \text{ tons}$$

The allowable "Q" case Compression soil/pile load with the pile tip at elevation -30.0 using a safety factor of 2.0 in the "Q" case is computed as follows:

$$Q_{A_{-30}} = Q_{S_A} + Q_{T_A} = 14 \text{ tons}$$

The allowable "Q" case tension soil/pile load with the pile tip at elevation -30.0 using a safety factor of 2.0 in the "Q" case is computed as follows:

$$Q_{A_{-30}} = Q_{S_A} \times k_T = 13.57 \text{ tons} \times 1.0 = 14 \text{ tons}$$

(2) Example computation for the "S" case capacity with all factors as in (1). This will compute a single point upon the "S" case portion of the curve pile capacity vs. tip elevation. The effective overburden pressure at any point has to be computed at any point in the soil profile, this is presented herein on page D-21, using the soil properties presented in the table above.

(a) Compute Skin Friction "S" case. Computations will be by the layer due to property variations as follows:

$$Q_s = \sum_{i=1 \text{ to } N} f_{s_i} A_{s_i}$$

where:

$f_s = ks_u$

$s_u = \gamma' D \tan \phi + C$

Layer from elevation +10.0 to elevation 0.0

Average pile diameter d = 11.375 inches (see previous computation)

Average strength (Note a reduction factor to the angle-of-internal friction ϕ is normally considered necessary to obtain δ). See Table 4-2 for values of δ to use. A reduction factor value of 1.0 is used herein. The engineer has to use judgement and load test results to find the range of δ for the area in which the work is being performed.

$$s_u = \frac{1{,}100 \tan 23°}{2} + 0 = 233.46 \text{ psf}$$

$s_u = 233.46$, $f_s = k\sigma' v = 233.46$ psf

Increment of skin friction

$$\Delta Q_s = \pi \frac{11.375}{12} (10)(233.46) = 6{,}952.4 \text{ pounds}$$

Layer from elevation 0.0 to elevation -15.0

Average pile diameter d = 9.813 inches

Average strength

$$s_u = \frac{1{,}100 + 1{,}820}{2} \tan 23° = 619.73$$

$f_s = k\sigma' v = 619.73$

Increment of skin friction

$$\Delta Q_s = \pi \frac{9.813}{12} (15)(619.73) = 23,880.43 \text{ pounds}$$

Layer from elevation -15.0 to elevation -20.0

Average pile diameter d = 8.563 inches

Average strength

$$s_u = \frac{1,820 + 2,030}{2} \tan 23° = 817.11 \text{ psf}$$

$$f_s = 817.11 \text{ psf}$$

Increment of skin friction

$$\Delta Q_s = \pi \frac{8.563}{12} (5)(817.11) = 9,158.94 \text{ pounds}$$

Layer from elevation -20.0 to elevation -30.0

Average pile diameter d = 7.625 inches

Average strength

$$s_u = \frac{2,030 + 2,430}{2} \tan 23° = 946.58 \text{ psf}$$

$$f_s = 946.58 \text{ psf}$$

Increment of skin friction

$$\Delta Q_s = \pi \frac{7.625}{12} (10)(946.58) = 18,895.82 \text{ pounds}$$

$$Q_s = \sum_{i=1 \text{ to } N} \Delta Q_s = 58{,}887.6 \text{ lb} = 29.44 \text{ tons}$$

$$Q_{s_{Allowable}} = \frac{Q_s}{FS} = 14.72 \text{ tons}$$

(b) Compute end bearing in the "S" case with the pile tip at elevation -30.0 using the equations:

$$q = \sigma'_v N_q$$

$$Q_T = A_T q$$

where:

N_q = Terzaghi's bearing factor for $\phi = 23°$

N_q = 10 (from "Terzaghi and Peck," Figure 4-2)

$$\text{Area of tip} = A_T = \pi \frac{7/12^2}{4} = 0.267 \text{ sq ft}$$

$$Q_T = (0.267)(2430)(10) = 6{,}488.1 \text{ lb} = 3.24 \text{ tons}$$

$$Q_{s_{Allowable}} = \frac{Q_s}{FS} = 1.62 \text{ tons}$$

The allowable "S" case compression soil/pile load with the pile tip at elevation -30.0 using a safety factor of 2.0 in the "S" case is computed as follows:

$$Q_{A_{-30}} = Q_{S_A} + Q_{T_A} = 16.34 \text{ tons}$$

The allowable "S" case tension soil/pile load at elevation -30.0 tip, using a safety factor of 2.0 in the "S" case is as follows:

$$Q_{A_{-30}} = Q_{S_A} \times k_T = 14.72 \times 0.7 = 10.3 \text{ tons}$$

(3) Negative skin friction is directly addressed in other areas of this text and should be accounted for in any actual computation. Negative skin friction may occur, especially in the long-term, drained shear strength case. The soils engineer will estimate this load and furnish it to the structural engineer to be included into the applied loads.

e. Uniform Medium Density Sand Profile. This example was also developed for a bottom slab/ground line elevation of +10.0 feet, using the shear strengths from laboratory testing on a sand classified SP-F the shear strength trends shown below were developed.

Average Laboratory Test Results

Elevation (ft)	ϕ (degrees)	γ' (pcf)	c (psf)
10.0 to 0.0	30	122	0
0.0 to -60.0	30	60*	0

*The unit weight below the water table at el 0.0 is submerged weight.

(1) Example computation for sand using a single-pile tip elevation of -30.0 and a timber pile having butt diameter of 12 inches and tip diameter of 7 inches. This is a single point computation in a series to form a curve of pile tip elevation vs. pile capacity. This computation requires a 40 ft pile from elevation +10.0 to elevation -30.0.

(a) Compute the overburden pressure at the pile $\sigma'_v = \gamma D$ as shown in the computer example on Page D-24. Applying the critical depth limiting value criterion of $D/B = 15$, the critical depth is 15 feet, taking B to be the butt diameter. Therefore, σ'_v is zero at the surface, 1,220 psf at elevation 0.0, and 1,520 psf at limit depth.

The angle of internal friction ϕ is reduced in some cases by δ shown in Table 4-3. In this example δ is taken as 1.0, which is based upon engineering judgement, the pile material and pile load tests in this area.

(b) Compute pile skin friction. Computations will be by layer due to property variations, as follows:

$$Q_s = \sum_{i=1 \text{ to } N} f_{s_i} A_{s_i}$$

where:

$$f_{s_i} = k s_u$$

$$s_u = \gamma' D \tan \phi + c$$

Layer from elevation +10.0 to elevation 0.0

$$\text{Average pile diameter} \quad d = 7 + \frac{35(5)}{40} = 11.375 \text{ inches}$$

Average strength of sand s_u

$$s_u = \frac{0 + 1,220}{2} \tan 30° + 0 = 352.18 \text{ psf}$$

$$f_s = ks_u = 352.18 \text{ psf}$$

Increment of skin friction

$$\Delta Q_s = \pi \frac{11.375}{12} 10(352.18) = 10,487.83 \text{ pounds}$$

Layer from elevation 0.0 to elevation -5.0

Average pile diameter $d = 7 + \frac{27.5(5)}{40} = 10.438$ inches

Average strength of sand s_u

$$s_u = \frac{1,220 + 1,520}{2} \tan 30° = 790.97 \text{ psf}$$

$$f_s = ks_u = 790.97 \text{ psf}$$

Increment of skin friction

$$\Delta Q_s = \pi \frac{10.438}{12} 5(790.97) = 10,806.78 \text{ pounds}$$

Layer from elevation -5.0 to elevation -30.0

Average pile diameter $d = 7 + \frac{12.5(5)}{40} = 8.563$ inches

Average strength of sand s_u

$$s_u = 1,520 \tan 30° = 877.57$$

$$f_s = ks_u = 877.57$$

$$\Delta Q_s = \pi \frac{8.563}{12} (25)(877.57) = 49{,}108.04 \text{ pounds}$$

$$Q_s = \sum_{i=1 \text{ to } N} \Delta Q_{s_i} = 70{,}475.0 \text{ pounds}$$

$$Q_s = \quad \Delta Q_{s_i} = 70{,}475.0 \text{ pounds}$$
$$i=1 \text{ to } N$$

(c) Compute end bearing with the tip at elevation -30.0 using the following equations:

$$q = \sigma'_v N_q$$

$$Q_T = A_T q$$

where:

N_q = Terzaghi's bearing factor for $\phi = 30°$

$N_q = 18$

Compute:

σ'_v = 1,520 (limit value at D/B =15)

$$A_T = \pi \frac{7/12^2}{4} = 0.2672 \text{ sq ft}$$

$$Q_T = 7{,}311.24 \text{ pounds}$$

The allowable compression soil/pile load with the pile tip at elevation -30.0 using a safety factor of 2.0 will be:

$$Q_{A_{-30}} = \frac{Q_s + Q_T}{FS} = \frac{70{,}475.00 + 7{,}311.24}{2(2{,}000 \text{ lb/ton})} = 19.45 \text{ tons}$$

The allowable tension soil/pile load with the pile tip at elevation -30.0 using a safety factor of 2.0 will be:

$$Q_{A_{-30}} = \frac{Q_s \times k_T}{FS} = \frac{70,475(0.7)}{2(2,000 \text{ lb/ton})} = 12.33 \text{ tons}$$

c. Uniform Silt Subgrade. This example is developed for a bottom of slab/ground line_elevation of +10.0 feet, using the shear strengths developed from laboratory R testing on a silt (ML). The "Q" values are from the envelope to the total stress circles, where the "S" values are from the effective stress circles. The silt used in this example was "dirty" with some clay included. The shear strength trends are as shown:

Average Laboratory Test Results

	"Q" Case			"S" Case		
Elevation, ft	ϕ (deg)	γ (pcf)	c (psf)	ϕ (deg)	γ (pcf)	c (psf)
10.0 to 0.0	15	117	200	28	117	0
0.0 to -60.0	15	55*	200	28	55*	0

*The unit weight (?) below the watertable at elevation 0.0 ft is the submerged unit weight.

(1) Example computation for silt in the "Q" case using a pile tip at elevation -30.0 and a timber pile having a butt diameter of 12 inches and a tip diameter of 7 inches. This is a single point computation in a series to form a curve of pile tip elevation vs. pile capacity. This computation will use a 40 foot pile to extend from elevation +10.0 to elevation -30.0.

(a) Compute the overburden pressure at the pile as $\sigma_v' = \gamma D$ as shown in the computer example on page D-27/28. Applying the critical depth limiting value criterion of $D/B = 15$ we find the critical depth to be 15 feet. Therefore, σ_v' at the surface in zero, at elevation 0.0, it is 1,170 psf, and at the limit depth elevation of -5.0, it is 1,445 psf.

(b) The angle of internal friction ϕ is reduced by a factor given in Table 4-3 to obtain δ . In this example δ is taken as 1.0 for the "Q" case and 0.9 for the "S" case. The use of reduction factor to obtain δ depends upon engineering judgement, the pile material, and the results of pile load tests in the area.

(c) Compute skin friction "Q" case. Computations will be by layer due to property variations as follows:

$$Q_s = \sum_{i=1 \text{ to } N} f_{s_i} A_{s_i}$$

where:

$$f_{s_i} = k s_u$$

$s_u = \gamma' D \tan \phi + c$

Layer from elevation +10.0 to elevation 0.0

Average pile diameter $d = 7 + \frac{35(5)}{40} = 11.375$ inches

Average strength of silt s_u

$$s_u = \frac{0 + 1{,}170}{2} \tan 15° + 200 = 356.72 \text{ psf}$$

$$f_s = ks_u = 356.72 \text{ psf}$$

Increment of skin friction

$$\Delta Q_s = \pi \frac{11.375}{12} (10)(356.72) = 63{,}738.19 \text{ pounds}$$

Layer from elevation 0.0 to elevation -5.0

Average pile diameter $d = 7 + \frac{27.5(5)}{40} = 10.438$ inches

Average strength of silt s_u

$$s_u = \frac{1{,}170 + 1{,}445}{2} \tan 15° + 200 = 550.34 \text{ psf}$$

$$f_s = ks_u = 550.34 \text{ psf}$$

Increment of skin friction

$$\Delta Q_s = \pi \frac{10.483}{12} (5)(550.34) = 7{,}519.48 \text{ pounds}$$

Layer from elevation -5.0 to elevation -30.0

Average pile diameter $d = 7 + \frac{12.5(5)}{40} = 8.563$ inches

Average strength of silt s_u

$s_u = 1{,}445 \tan 15° + 200 = 587.19$ psf

$f_s = ks_u = 587.19$ psf

Increment of skin friction

$\Delta Q_s = \pi \frac{8.563}{12} (25)(587.19) = 32{,}908.97$ pounds

$Q_s = \sum_{i=1 \text{ to } N} \Delta Q_{s_i} = 104{,}166.64$ pounds

(d) Compute end bearing in the "Q" case with the pile tip at elevation -30.0 using the following equations:

$q = \sigma'_v N_q$

$Q_T = A_T q$

where:

N_q = Terzaghi's bearing factor at $\phi = 15°$

$N_q = 4$

compute:

$\sigma'_v = 1{,}445$ psf (limit value at D/B =15)

$A_T = \pi \frac{7/12^2}{4} = 0.2672$ sq ft

$Q_T = 0.2672(1{,}445)(4) = 1{,}544.42$ pounds

The allowable "Q" case compression soil/pile load with the pile tip at elevation -30.0 using a safety factor of 2.0 will be:

$$Q_{A_{-30}} = \frac{Q_S + Q_T}{FS} = 26.43 \text{ tons}$$

The allowable "Q" case tension soil/pile load with the pile tip at elevation -30.0 using a safety factor of 2.0 will be:

$$Q_{A_{-30}} = \frac{Q_S \times K_T}{FS} = 18.33 \text{ tons}$$

(2) Example computation for silt in the "S" case using a single pile tip at elevation -30.0 and a timber pile having a butt diameter of 12 inches and a tip diameter of 7 inches. This is a single point computation in a series to form a curve of pile tip elevation vs. pile capacity. This computation will use a 40-foot pile to extend from elevation +10.0 to elevation -30.0.

(a) The overburden pressure and limit values from the "Q" case example are valid; i.e., elevation +10.0, $\sigma'_v = 0.0$; elevation 0.0, $\sigma'_v = 1{,}170$ psf; elevation -5.0, $\sigma'_v = 1{,}445$ psf and $D/B_{critical} = 15$ feet.

(b) Compute skin friction "S" case. Computations will be by layer due to property variations as follows:

$$Q_s = \sum_{i=1 \text{ to } N} f_{s_i} A_{s_i}$$

where:

$$f_{s_i} = k s_u$$

$$s_u = \gamma' D \tan \phi + c$$

Layer from elevation +10.0 to elevation 0.0

$$\text{Average pile diameter} \quad d = 7 + \frac{35(5)}{40} = 11.375 \text{ inches}$$

Average strength of silt s_u

$$s_u = \frac{0 + 1170}{2} \tan (28° \times .9) + 0 = 275.28 \text{ psf}$$

$$f_s = ks_u = 275.28 \text{ psf}$$

Increment of skin friction

$$\Delta Q_s = \pi \frac{11.375}{12} (10)(275.28) = 8{,}197.75 \text{ pounds}$$

Layer from elevation 0.0 to elevation -5.0

Average pile diameter $d = 7 + \frac{27.5(5)}{40} = 10.438$ inches

Average strength of silt s_u

$$s_u = \frac{1{,}170 + 1{,}445}{2} \tan (28° \times 0.9) = 615.26 \text{ psf}$$

$$f_s = ks_u = 615.26 \text{ psf}$$

Increment of skin friction

$$\Delta Q_s = \pi \frac{10.438}{12} (5)(615.26) = 8{,}406.49 \text{ pounds}$$

Layer from elevation -5.0 to elevation -30.0

Average pile diameter $d = 7 + \frac{12.5(5)}{40} = 8.563$ inches

Average strength of silt s_u

$$s_u = (1{,}445) \tan (28 \times 0.9) = 679.97 \text{ psf}$$

$f_s = ks_u = 679.97$ psf

Increment of skin friction

$$\Delta Q_s = \pi \frac{8.563}{12}(25)(679.97) = 38{,}108.71 \text{ pounds}$$

$$Q_s = \sum_{i=1 \text{ to } N} \Delta Q_s = 54{,}712.95 \text{ pounds}$$

(c) Compute end bearing in the "S" case with the tip of at elevation -30.0 using the following equations:

$$q = \sigma'_v N_q$$

$$Q_T = A_T q$$

where:

N_q = Terzaghi's bearing factor at $\phi = 28°$

$N_q = 15$

Compute:

$\sigma'_v = 1{,}445$ psf (limit value of D/B = 15)

$$A_T = \pi \frac{7/12^2}{4} = 0.2672 \text{ sq ft}$$

$$Q_T = 0.2672(1{,}445)(15) = 5{,}791.56 \text{ pounds}$$

The allowable "S" case compression soil/pile load with the pile tip at elevation -30.0, using a safety factor of 2.0, will be:

$$Q_{A_{-30}} = \frac{Q_s + Q_T}{FS} = 15.13 \text{ tons}$$

The allowable "S" case tension soil/pile load with the pile tip at elevation -30.0, using a safety factor of 2.0, will be:

$$Q_{A_{-30}} = \frac{Q_s \times K_T}{FS} = \frac{54,712.95(.7)}{2,(2,000 \text{ lb/ton})} = 9.57 \text{ tons}$$

f. Layered Clay, Silt and Sand Subgrade. This example is developed for a bottom of slab/ground line elevation of +10.0 feet, using the strengths developed from laboratory testing on the various soil types as follows:

Average Laboratory Test Results

	"Q" case			"S" case			Soil
Elevation (ft)	ϕ (deg)	γ (pcf)	c (psf)	ϕ (deg)	γ (pcf)	c (psf)	Type
+10.0 to 0.0	0	110	400	23	110	0	CH
0.0 to -12.0	15	55*	200	28	55*	0	ML
-12.0 to -20.0	0	38*	600	23	38*	0	CH
-20.0 to -60.0	30	60*	0	30	60*	0	SP

*The unit weight (γ) below the water table at elevation 0.0 feet is the submerged weight.

(1) Example computation for a multiplayered soil in the "Q" case using a single pile tip at elevation -30.0 and a timber pile having a butt diameter of 12 inches and a tip diameter of 7 inches. This is a single-point computation in a series to form a curve of pile tip elevation vs. pile capacity. This computation will use a 40-foot pile to extend from elevation +10.0 to elevation -30.0.

(a) Compute the overburden pressure at the pile as $\sigma_v' = \gamma D$ as shown on the computer example on Page D-31. It should be noted that the critical depth limit was applied from the upper surface of the granular layer and not from the ground surface.

(b) The angle of internal friction ϕ is reduced by a factor given in Table 4-3 to obtain δ . In this example, δ is taken as 1.0 for both the "Q" and "S" case. The use of reduction factor to obtain δ depends upon engineering judgement, the pile material and results of pile load test in the area.

(c) Compute Skin Friction "Q" Case. Computations will be by layer due to material variations as follows:

$$Q_s = \sum_{i=1 \text{ to } N} f_{s_i} A_{s_i}$$

where:

$f_{s_i} = ks_u$

$s_u = \gamma' D \tan \phi + c$

Layer from elevation +10.0 to 0.0 (clay)

Average pile diameter $d = 7 + \dfrac{35(5)}{40} = 11.375$

Average shear strength $c = 400$ psf $= f_s$

Increment of skin friction

$$\Delta Q_s = \pi \frac{11.375}{12} (10)(400) = 11{,}911.9 \text{ pounds}$$

Layer from elevation 0.0 to elevation -12.0 (silt)

Average pile diameter $d = 7 + \dfrac{24(5)}{40} = 10.0$ inches

σ'_v top of stratum = 10′ × 110 pcf = 1,100 psf

σ'_v bottom of stratum = 10′ × 110 pcf + 12′ × 55 pcf = 1,760 psf

Average strength in silt s_u

$$s_u = \frac{1{,}100 + 1{,}760}{2} \tan 15° + 200 = 583.17 \text{ psf}$$

$f_s = ks_u = 583.17$ psf

Increment of skin friction

$$\Delta Q_s = \pi \frac{10.0}{12} (12)(583.17) = 18{,}320.87 \text{ pounds}$$

Layer from elevation -12.0 to elevation -20.0 (clay)

Average pile diameter $d = 7 + \frac{23(5)}{40} = 9.875$ inches

Average shear strength $C = 600 \text{ psf} = f_s$

Increment of skin friction

$$\Delta Q_s = \pi \frac{9.875}{12} (8)(600)(0.95) = 11{,}788.85 \text{ pounds}$$

Layer from elevation -20.0 to elevation -30.0 (sand)

Average pile diameter $d = 7 + \frac{5(5)}{40} = 7.625$ inches

$$\sigma_v' \text{ top of stratum} = 10' \times 110 \text{ pcf} + 12' \times 55 \text{ pcf} + 8' \times 38 \text{ pcf} = 2{,}064 \text{ psf}$$

$$\sigma_v' \text{ bottom of stratum} = 10' \times 110 \text{ pcf} + 12' \times 55 \text{ pcf} + 8 \times 38 \text{ pcf} + 10' \times 60 \text{ pcf} = 2{,}664 \text{ psf}$$

Average strength of sand s_u

$$s_u = \frac{2{,}064 + 2{,}664}{2} \tan 30° = 1{,}364.86 \text{ psf}$$

$$f_s = ks_u = 1{,}364.86 \text{ psf}$$

Increment of skin friction

$$\Delta Q_s = \pi \frac{7.625}{12} (10)(1{,}364.86) = 27{,}245.68 \text{ pounds}$$

$$Q_s = \sum_{i=1 \text{ to } N} \Delta Q_s = 69{,}887.77 \text{ pounds}$$

(d) Compute end bearing in the "Q" case with the pile tip at elevation -30.0 using the following equations:

$$q = \sigma_v' N_q$$

$$Q_T = A_T q$$

where:

N_q = Terzaghi's bearing capacity factor $N_q = 18$ at $\phi = 30$

σ_v' = 2,664 psf (limit value is greater than 10 feet)
(Refer to paragraph C-2.f(1)(2))

$$A_T = \pi \frac{7/12^2}{4} = 0.2672 \text{ sq ft}$$

$$Q_T = 0.2672(2664)(18) = 12{,}812.77 \text{ pounds}$$

The allowable "Q" case compression soil/pile load with the pile tip at elevation -30.0 and a safety factor of 2.0 will be:

$$Q_{A_{-30}} = \frac{Q_S + Q_T}{FS} = 20.53 \text{ tons}$$

The allowable "Q" case tension soil/pile load with the pile tip at elevation -30.0 and a safety factor will be:

$$Q_{A_{-30}} = \frac{Q_S \times K_T}{FS} = 20.13 \text{ tons}$$

(2) Example computation for a multilayered system in the "S" case using a single pile tip elevation -30.0 and a timber pile having a butt diameter of 12 inches and a tip diameter of 7 inches. This is a single point computation in a series to form a curve of pile tip elevation vs. pile capacity. This computation will use a 40 foot pile to extend from elevation +10.0 to -30.0.

(a) Compute the overburden pressure as in Paragraph 1.a. The angle-of-internal friction (ϕ) reduction factor is reduced by a factor given in Table 4-3 to obtain δ is taken as 1.0 as discussed in Paragraph 1.b.

(b) Compute Skin Friction "S" case. Computations will be by layer due to material variations as follows:

$$Q_s = \sum_{i=1 \text{ to } N} f_{s_i} A_{s_i}$$

where:

$f_{s_i} = k s_u$

$s_u = \gamma' D \tan \phi + c$

Layer from elevation +10.0 to elevation 0.0 (clay)

Average pile diameter $d = 7 + \frac{35(5)}{40} = 11.375$ inches

σ'_v top of stratum = 0

σ'_v bottom of stratum = 10′ × 110 pcf = 1,100 psf

Average strength in clay s_u

$$s_u = \frac{0 + 1{,}100}{2} \tan 23° + 0 = 233.46 \text{ psf}$$

$f_s = k s_u = 233.46$ psf

Increment of skin friction

$$\Delta Q_s = \pi \frac{11.375}{12} (10)(233.46) = 6{,}952.38 \text{ pounds}$$

Layer from elevation 0.0 to elevation -12.0 (silt)

Average pile diameter $d = 7 + \frac{24(5)}{40} = 10.0$ inches

σ'_v top of stratum = 10′ × 110 pcf = 1,100 psf

σ_v' bottom of stratum = 10′ × 110 pcf + 12′ × 55 pcf = 1,760 psf

Average strength in silt s_u

$$s_u = \frac{1100 + 1{,}760}{2} \tan 28° = 760.34 \text{ psf}$$

$f_s = ks_u = 760.34$ psf

Increment of skin friction

$$\Delta Q_s = \pi \frac{10.0}{12} (12)(760.34) = 23{,}886.84 \text{ pounds}$$

Layer from elevation -12.0 to elevation -20.0 (clay)

Average pile diameter $d = 7 + \frac{23(5)}{40} = 9.875$ inches

σ_v' top of stratum = 10′ × 110 pcf + 12′ × 55 pcf = 1,760 psf

σ_v' bottom of stratum = 10′ × 110 pcf + 12′ × 55 pcf + 8′ × 38 pcf
= 2,064 psf

Average strength in clay s_u

$$s_u = \frac{1{,}760 + 2{,}064}{2} \tan 23° = 811.6 \text{ psf}$$

$f_s = ks_u = 811.6$ psf

Increment of skin friction

$$\Delta Q_s = \pi \frac{9.875}{12} (8)(811.6) = 16{,}785.67 \text{ pounds}$$

Layer from elevation -20.0 to elevation -30.0 (sand)

Average pile diameter $d = 7 + \frac{5(5)}{40} = 7.625$ inches

σ'_v top of stratum = 10′ × 110 pcf + 12′ × 55 pcf + 8′ × 38 pcf

= 2,064 psf

σ'_v bottom of stratum = 10′ × 110 pcf + 12′ × 55 pcf + 8′ × 38 pcf + 10′ × 60 pcf = 2,664 psf

Average strength in sand s_u

$$s_u = \frac{2{,}064 + 2{,}664}{2} \tan 30° = 1{,}364.86 \text{ psf}$$

$$f_s = ks_u = 1{,}364.86 \text{ psf}$$

Increment of skin friction

$$\Delta Q_s = \pi \frac{7.625}{12} (10)(1{,}364.86) = 27{,}245.68 \text{ pounds}$$

$$Q_s = \sum_{i=1 \text{ to } N} \Delta Q_s = 74{,}870.57 \text{ pounds}$$

(c) Compute end bearing in "S" case with the pile tip at elevation -30.0 using the following equations:

$$q = \sigma'_v N_q$$

$$Q_T = A_T q$$

where:

N_q = Terzaghi's Bearing Capacity Chart at $\phi = 30°$

$N_q = 18$

σ'_v = 2,664 psf (limit value greater than 10 feet)

$$A_T = \pi \frac{7/12^2}{4} = 0.2672 \text{ sq ft}$$

$$Q_T = 0.2672(2,664)(18) = 12,812.77 \text{ pounds}$$

The allowable "S" case compression soil/pile load with the pile tip at elevation -30.0 and a safety factor of 2.0 will be:

$$Q_{A_{-30}} = \frac{Q_S + Q_T}{FS} = 21.92 \text{ tons}$$

The allowable "S" case tension soil/pile load with the pile tip at elevation -30.0 and a safety factor of 2.0 will be:

$$Q_{A_{-30}} = \frac{Q_S \times K_T}{FS} = 13.10 \text{ tons}$$

e. Computer programs are currently available to compute pile capacity, examples similar to those computed above are shown in Tables C1 through C4.

Table D-1

Computer Output for Allowable Design Loads
for Uniform Soft Clay Subgrade

* PILE CAPACITY COMPUTATIONS *

CASE I
TIMBER PILE
CLAY SUBGRADE

****
CLASS B TIMBER PILE
****

PILE BUTT DIA. IS AT THE GROUND SURFACE FOR ALL TIP PENETRATIONS
PILE LENGTH USED IS FROM GROUND SURFACE TO TIP
TIMBER PILE DIM.: 12.0 IN.BUTT DIA., 7.0 IN.TIP DIA.
TOP SURFACE ELEV.:, 10.0 FT.

**** Q-CASE ****

STRATUM NUMBER	SOIL/SOIL FRIC.ANG DEG.	WEIGHT DENSITY LB/CU FT	TOP STRA COHESION LB/SQ FT	BOT STRA COHESION LB/SQ FT	COEF LAT EAR.PRES (KC)
1	0.00	110.00	400.00	400.00	1.00
2	0.00	48.00	400.00	400.00	1.00
3	0.00	48.00	600.00	600.00	1.00
4	0.00	42.00	650.00	650.00	1.00
5	0.00	40.00	800.00	800.00	1.00
6	0.00	38.00	900.00	900.00	1.00

STRATUM NUMBER	COEF LAT EAR.PRES (KT)	TERZAGHI BEAR.CAP. (NC)	TERZAGHI BEAR.CAP. (NQ)	BOTTOM ELEVATION FEET	SOIL/PILE FRIC.ANG. DEG.	SOIL TYPE
1	0.70	9.00	1.00	0.00		CH
2	0.70	9.00	1.00	-5.00		CH
3	0.70	9.00	1.00	-15.00		CH
4	0.70	9.00	1.00	-20.00		CH
5	0.70	9.00	1.00	-30.00		CH
6	0.70	9.00	1.00	-60.00		CH

(Continued)

Table D-1 (Continued)

STRAT *NUM *	EL.TIP (FT)	COH/ADH. RESISTAN TONS	FRICTION COMPRESS TONS	RESISTAN TENSION TONS	END BEARING TONS	PILE CAPAC IN COMPRS. TONS	PILE CAPAC IN TENSION TONS
1	5.000	2.487	0.000	0.000	0.555	3.042	2.487
1	0.000	4.974	0.000	0.000	0.628	5.602	4.974
2	0.000				0.628	5.602	4.974
2	-2.500	6.218	0.000	0.000	0.644	6.862	6.218
2	-5.000	7.461	0.000	0.000	0.660	8.121	7.461
3	-5.000				0.901	8.362	7.461
3	-10.000	10.946	0.000	0.000	0.901	11.847	10.946
3	-15.000	14.530	0.000	0.000	0.901	15.431	14.530
4	-15.000				0.961	15.491	14.530
4	-17.500	16.460	0.000	0.000	0.961	17.421	16.460
4	-20.000	18.405	0.000	0.000	0.961	19.366	18.405
5	-20.000				1.141	19.546	18.405
5	-25.000	23.050	0.000	0.000	1.141	24.191	23.050
5	-30.000	27.777	0.000	0.000	1.141	28.918	27.777
6	-30.000				1.261	29.039	27.777
6	-45.000	43.737	0.000	0.000	1.261	44.998	43.737
6	-60.000	60.051	0.000	0.000	1.261	61.313	60.051

**** MODIFIED S-CASE ****
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* * *	STRATUM NUMBER	SOIL/SOIL FRIC.ANG DEG.	WEIGHT DENSITY LB/CU FT	TOP STRA COHESION LB/SQ FT	BOT STRA COHESION LB/SQ FT	COEF LAT EAR.PRES (KC)
	1	23.00	110.00	0.00	0.00	1.00
	2	23.00	48.00	0.00	0.00	1.00
	3	23.00	48.00	0.00	0.00	1.00
	4	23.00	42.00	0.00	0.00	1.00
	5	23.00	40.00	0.00	0.00	1.00
	6	23.00	38.00	0.00	0.00	1.00

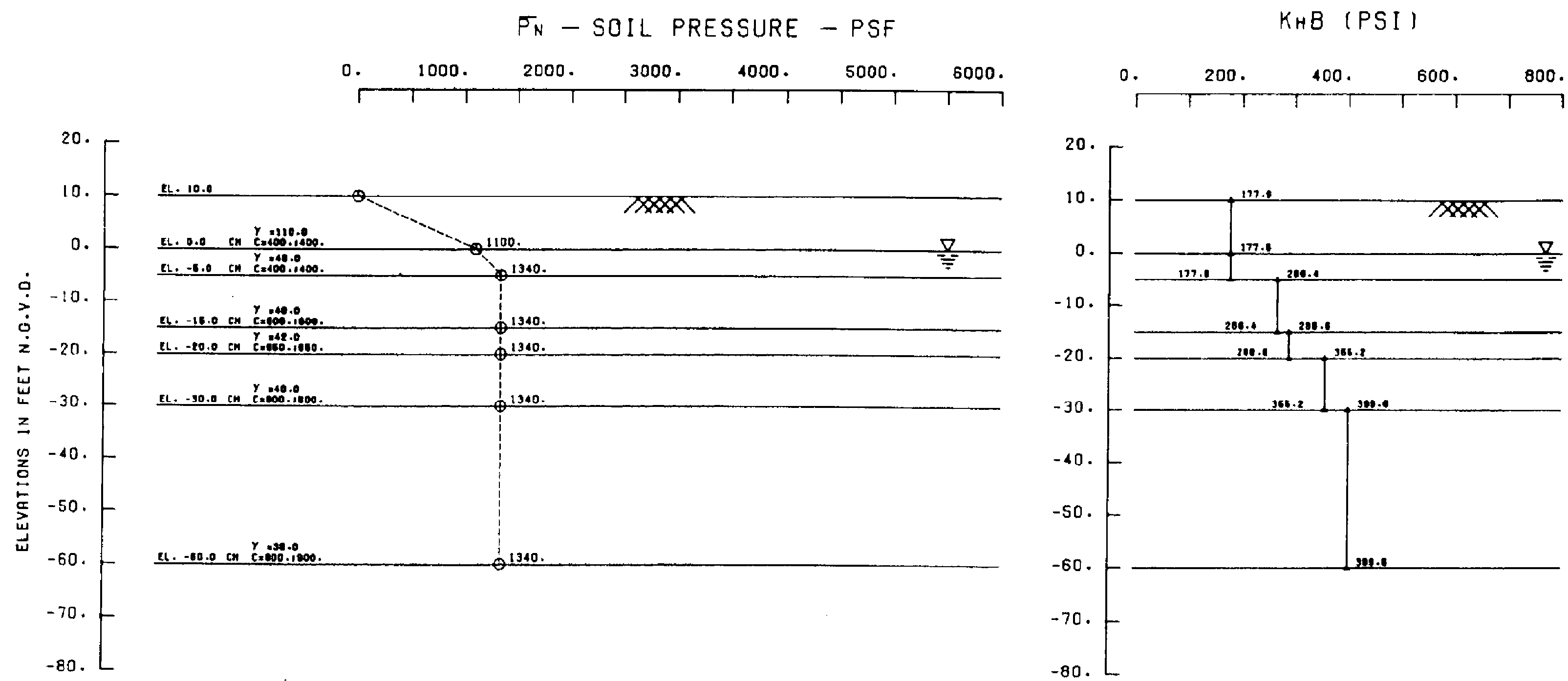
* * *	STRATUM NUMBER	COEF LAT EAR.PRES (KT)	TERZAGHI BEAR.CAP. (NC)	TERZAGHI BEAR.CAP. (NQ)	BOTTOM ELEVATION FEET	SOIL/PILE FRIC.ANG. DEG.	SOIL TYPE
	1	0.70	0.00	10.00	0.00		CH
	2	0.70	0.00	10.00	-5.00		CH
	3	0.70	0.00	10.00	-15.00		CH
	4	0.70	0.00	10.00	-20.00		CH
	5	0.70	0.00	10.00	-30.00		CH
	6	0.70	0.00	10.00	-60.00		CH

(Continued)

Table D-1 (Concluded)

STRAT *NUM *	EL.TIP (FT)	COH/ADH. RESISTAN TONS	FRICTION COMPRESS TONS	RESISTAN TENSION TONS	END BEARING TONS	PILE CAPAC IN COMPRS. TONS	PILE CAPAC IN TENSION TONS
1	5.000	0.000	0.726	0.508	0.735	1.461	0.508
1	0.000	0.000	2.903	2.032	1.470	4.373	2.032
2	0.000				1.470	4.373	2.032
2	-2.500	0.000	4.265	2.985	1.630	5.895	2.985
2	-5.000	0.000	5.813	4.069	1.791	7.603	4.069
3	-5.000				1.791	7.603	4.069
3	-10.000	0.000	9.132	6.392	1.791	10.922	6.392
3	-15.000	0.000	12.538	8.777	1.791	14.329	8.777
4	-15.000				1.791	14.329	8.777
4	-17.500	0.000	14.259	9.981	1.791	16.049	9.981
4	-20.000	0.000	15.988	11.191	1.791	17.778	11.191
5	-20.000				1.791	17.778	11.191
5	-25.000	0.000	19.462	13.623	1.791	21.253	13.623
5	-30.000	0.000	22.952	16.066	1.791	24.743	16.066
6	-30.000				1.791	24.743	16.066
6	-45.000	0.000	33.473	23.431	1.791	35.263	23.431
6	-60.000	0.000	44.032	30.822	1.791	45.822	30.822

* RUN COMPLETED * 1 TON = 2000 LBS.



S-CASE
CH,CL- Φ=23°
ML- Φ=28°
SM,SP- Φ=30°

TYPICAL SOIL PROFILE

SOIL STRATIFICATION IS BASED ON GEOLOGIC PROFILE

SHEAR STRENGTH AND WET DENSITIES SEE PLATE

SECOND ORDER STATIONS

NOTES:

K_H = $\alpha K_1/B$=(0.2222 au/B)(C)(D) COHESIVE
α = 0.4 = Factor of material properties of soil and pile
k1 = Modulus of subgrade reaction for test plate (pci)
B1 = Width or diameter of test plate (in.)
K1 = k1B1 = 80 au (psf) = 0.5556 au(psi)
au = 2 · c = Unconfined compressive strength (psf)
C = Reduction for cyclic loading—not applicable
D = Group effect reduction factor
B = Width of pile measured at right angles to the direction of displacement (in.)
K_H = (nh)(Z/B)(C)(D) COHESIONLESS
nh = Coefficient of horizontal subgrade reaction (pci)
Z = Depth below equivalent ground surface (in.)

Figure D-1. Soil pressure and allowable design loads for uniform soft clay subgrade (Continued)

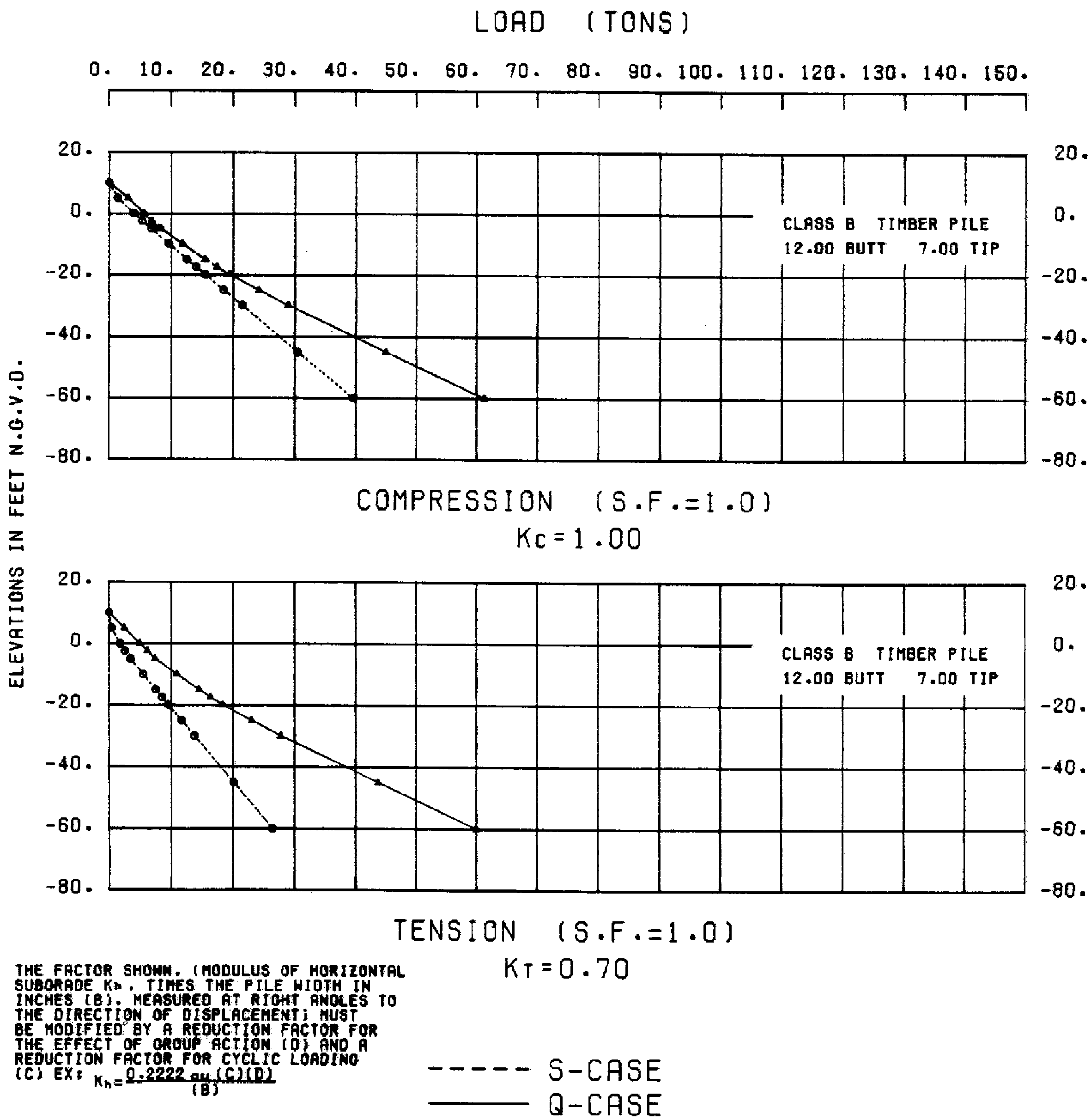


Figure D-1. (Concluded)

Table D-2

Computer Output for Allowable Design Loads for Uniform Medium Density Sand Subgrade, Run 1

* PILE CAPACITY COMPUTATIONS *

CASE II
TIMBER PILE
SAND SUBGRADE

****
CLASS B TIMBER PILE
****

PILE BUTT DIA. IS AT THE GROUND SURFACE FOR ALL TIP PENETRATIONS
PILE LENGTH USED IS FROM GROUND SURFACE TO TIP
TIMBER PILE DIM.: 12.0 IN.BUTT DIA., 7.0 IN.TIP DIA.
TOP SURFACE ELEV.:, 10.0 FT.

**** Q-CASE ****

STRATUM NUMBER	SOIL/SOIL FRIC.ANG DEG.	WEIGHT DENSITY LB/CU FT	TOP STRA COHESION LB/SQ FT	BOT STRA COHESION LB/SQ FT	COEF LAT EAR.PRES (KC)
1	30.00	122.00	0.00	0.00	1.00
2	30.00	60.00	0.00	0.00	1.00
3	30.00	60.00	0.00	0.00	1.00
4	30.00	60.00	0.00	0.00	1.00

STRATUM NUMBER	COEF LAT EAR.PRES (KT)	TERZAGHI BEAR.CAP. (NC)	TERZAGHI BEAR.CAP. (NQ)	BOTTOM ELEVATION FEET	SOIL/PILE FRIC.ANG. DEG.	SOIL TYPE
1	0.70	9.00	18.00	0.00		SP
2	0.70	9.00	18.00	-5.00		SP
3	0.70	9.00	18.00	-30.00		SP
4	0.70	9.00	18.00	-60.00		SP

(Continued)

Table D-2 (Continued)

STRAT *NUM	EL.TIP (FT)	COH/ADH. RESISTAN	FRICTION COMPRESS TONS	RESISTAN TENSION TONS	END BEARING TONS	PILE CAPAC IN COMPRS. TONS	PILE CAPAC IN TENSION * TONS
1	5.000	0.000	1.095	0.766	1.467	2.562	0.766
1	0.000	0.000	4.380	3.066	2.934	7.314	3.066
2	0.000				2.934	7.314	3.066
2	-2.500	0.000	6.445	4.512	3.295	9.740	4.512
2	-5.000	0.000	8.819	6.173	3.656	12.475	6.173
3	-5.000				3.656	12.475	6.173
3	-17.500	0.000	21.832	15.282	3.656	25.488	15.282
3	-30.000	0.000	35.238	24.666	3.656	38.894	24.666
4	-30.000				3.656	38.894	24.666
4	-45.000	0.000	51.466	36.026	3.656	55.122	36.026
4	-60.000	0.000	67.754	47.428	3.656	71.410	47.428

**** MODIFIED S-CASE ****

* STRATUM NUMBER	SOIL/SOIL FRIC.ANG DEG.	WEIGHT DENSITY LB/CU FT	TOP STRA COHESION LB/SQ FT	BOT STRA COHESION LB/SQ FT	COEF LAT EAR.PRES (KC)
1	30.00	122.00	0.00	0.00	1.00
2	30.00	60.00	0.00	0.00	1.00
3	30.00	60.00	0.00	0.00	1.00
4	30.00	60.00	0.00	0.00	1.00

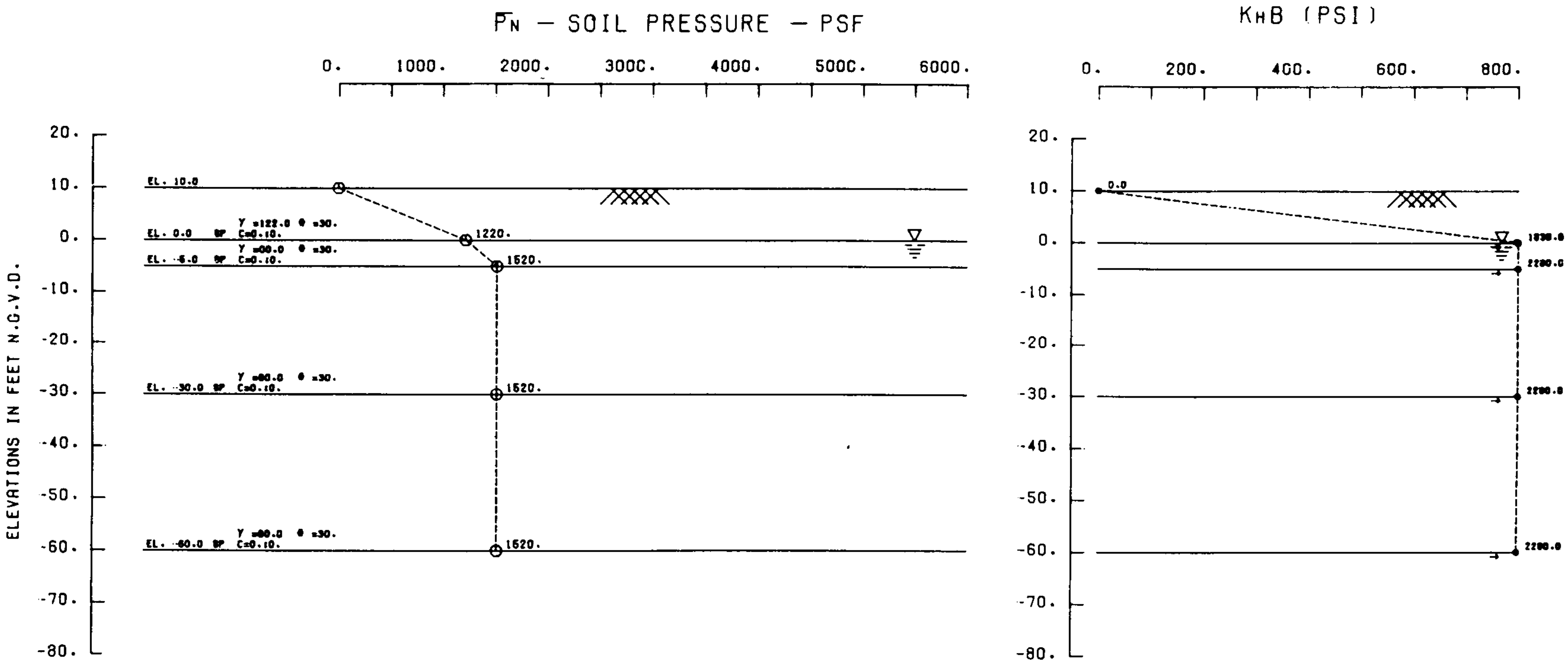
* STRATUM NUMBER	COEF LAT EAR.PRES (KT)	TERZAGHI BEAR.CAP. (NC)	TERZAGHI BEAR.CAP. (NQ)	BOTTOM ELEVATION FEET	SOIL/PILE FRIC.ANG. DEG.	SOIL TYPE
1	0.70	0.00	10.00	0.00		SP
2	0.70	0.00	10.00	-5.00		SP
3	0.70	0.00	10.00	-30.00		SP
4	0.70	0.00	10.00	-60.00		SP

(Continued)

Table D-2 (Concluded)

STRAT *NUM	EL.TIP (FT)	COH/ADH. RESISTAN	FRICTION COMPRESS TONS	RESISTAN TENSION TONS	END BEARING TONS	PILE CAPAC IN COMPRS. TONS	PILE CAPAC IN TENSION * TONS
1	5.000	0.000	1.095	0.766	0.815	1.910	0.766
1	0.000	0.000	4.380	3.066	1.630	6.010	3.066
2	0.000				1.630	6.010	3.066
2	-2.500	0.000	6.445	4.512	1.831	8.276	4.512
2	-5.000	0.000	8.819	6.173	2.031	10.850	6.173
3	-5.000				2.031	10.850	6.173
3	-17.500	0.000	21.832	15.282	2.031	23.863	15.282
3	-30.000	0.000	35.238	24.666	2.031	37.269	24.666
4	-30.000				2.031	37.269	24.666
4	-45.000	0.000	51.466	36.026	2.031	53.497	36.026
4	-60.000	0.000	67.754	47.428	2.031	69.786	47.428

* RUN COMPLETED * 1 TON = 2000 LBS.



S-CASE

CH.CL- Φ=23°
ML- Φ=28°
SM.SP- Φ=30°

TYPICAL SOIL PROFILE

SOIL STRATIFICATION IS BASED ON GEOLOGIC PROFILE

SHEAR STRENGTH AND WET DENSITIES SEE PLATE

SECOND ORDER STATIONS

NOTES:

KH = αK1/B=(0.2222 au/B)(C)(D) COHESIVE
α = 0.4 = Factor of material properties of soil and pile
k1 = Modulus of subgrade reaction for test plate (pci)
B1 = Width or diameter of test plate (in.)
K1 = k1B1 = 80 au (psf) = 0.5556 au(psi)
au = 2 · c = Unconfined compressive strength (psf)
C = Reduction for cyclic loading—not applicable
D = Group effect reduction factor
B = Width of pile measured at right angles to the direction of displacement (in.)
KH = (nh)(Z/B)(C)(D) COHESIONLESS
nh = Coefficient of horizontal subgrade reaction (pci)
Z = Depth below equivalent ground surface (in.)

Figure D-2. Soil pressure and allowable design loads for uniform medium density sand subgrade (Continued)

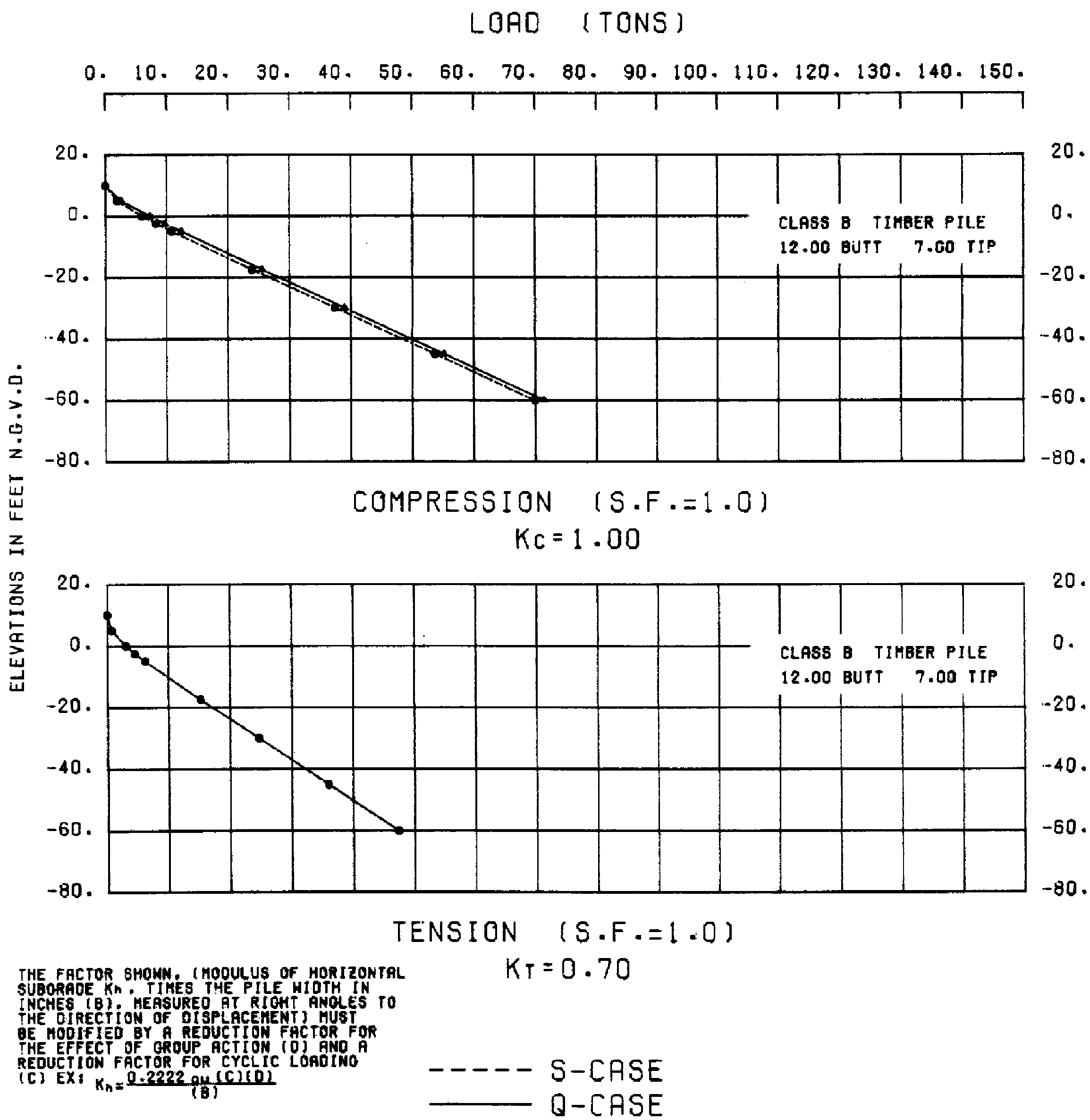


Figure D-2. (Concluded)

Table D-3

Computer Output for Allowable Design Loads
for Uniform Silt Subgrade, Run 2

* PILE CAPACITY COMPUTATIONS *

CASE III
TIMBER PILE

****
CLASS B TIMBER PILE
****

PILE BUTT DIA. IS AT THE GROUND SURFACE FOR ALL TIP PENETRATIONS
PILE LENGTH USED IS FROM GROUND SURFACE TO TIP
TIMBER PILE DIM.: 12.0 IN.BUTT DIA., 7.0 IN.TIP DIA.
TOP SURFACE ELEV.:, 10.0 FT.

**** Q-CASE ****

* STRATUM NUMBER	SOIL/SOIL FRIC.ANG DEG.	WEIGHT DENSITY LB/CU FT	TOP STRA COHESION LB/SQ FT	BOT STRA COHESION LB/SQ FT	COEF LAT EAR.PRES (KC)
1	15.00	117.00	200.00	200.00	1.00
2	15.00	55.00	200.00	200.00	1.00
3	15.00	55.00	200.00	200.00	1.00
4	15.00	55.00	200.00	200.00	1.00

* STRATUM NUMBER	COEF LAT EAR.PRES (KT)	TERZAGHI BEAR.CAP. (NC)	TERZAGHI BEAR.CAP. (NQ)	BOTTOM ELEVATION FEET	SOIL/PILE FRIC.ANG. DEG.	SOIL TYPE
1	0.70	9.00	4.00	0.00		ML
2	0.70	9.00	4.00	-5.00		ML
3	0.70	9.00	4.00	-30.00		ML
4	0.70	9.00	4.00	-60.00		ML

STRAT *NUM *	EL.TIP (FT)	COH/ADH. RESISTAN TONS	FRICTION COMPRESS TONS	RESISTAN TENSION TONS	END BEARING TONS	PILE CAPAC IN COMPRS. TONS	PILE CAPAC IN TENSION TONS
1	5.000	1.244	0.487	0.341	0.553	2.284	1.585
1	0.000	2.487	1.949	1.364	0.866	5.302	3.852
2	0.000				0.866	5.302	3.852
2	-2.500	3.109	2.867	2.007	0.939	6.915	5.115
2	-5.000	3.731	3.916	2.742	1.013	8.660	6.472
3	-5.000				1.013	8.660	6.472
3	-17.500	6.840	9.661	6.763	1.013	17.513	13.602
3	-30.000	9.948	15.577	10.904	1.013	26.538	20.852
4	-30.000				1.013	26.538	20.852
4	-45.000	13.679	22.737	15.916	1.013	37.429	29.595
4	-60.000	17.410	29.924	20.947	1.013	48.347	38.357

(Continued)

Table D-3 (Concluded)

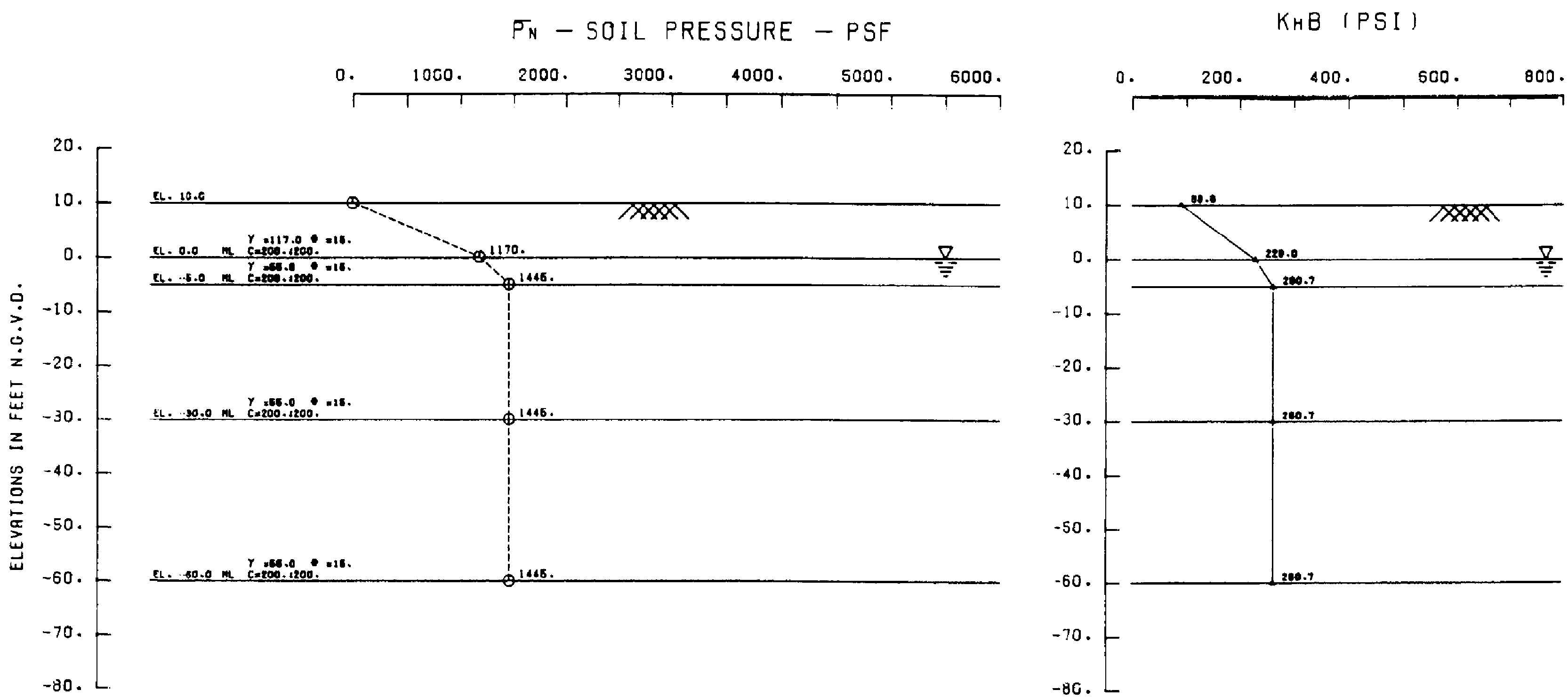
**** MODIFIED S-CASE ****

* STRATUM NUMBER	SOIL/SOIL FRIC.ANG DEG.	WEIGHT DENSITY LB/CU FT	TOP STRA COHESION LB/SQ FT	BOT STRA COHESION LB/SQ FT	COEF LAT EAR.PRES (KC)
1	28.00	117.00	0.00	0.00	1.00
2	28.00	55.00	0.00	0.00	1.00
3	28.00	55.00	0.00	0.00	1.00
4	28.00	55.00	0.00	0.00	1.00

* STRATUM NUMBER	COEF LAT EAR.PRES (KT)	TERZAGHI BEAR.CAP. (NC)	TERZAGHI BEAR.CAP. (NQ)	BOTTOM ELEVATION FEET	SOIL/PILE FRIC.ANG. DEG.	SOIL TYPE
1	0.70	0.00	10.00	0.00		ML
2	0.70	0.00	10.00	-5.00		ML
3	0.70	0.00	10.00	-30.00		ML
4	0.70	0.00	10.00	-60.00		ML

STRAT *NUM *	EL.TIP (FT)	COH/ADH. RESISTAN TONS	FRICTION COMPRESS TONS	RESISTAN TENSION TONS	END BEARING TONS	PILE CAPAC IN COMPRS. TONS	PILE CAPAC IN TENSION TONS
1	5.000	0.000	0.967	0.677	0.782	1.749	0.677
1	0.000	0.000	3.868	2.708	1.563	5.431	2.708
2	0.000				1.563	5.431	2.708
2	-2.500	0.000	5.688	3.982	1.747	7.435	3.982
2	-5.000	0.000	7.772	5.440	1.931	9.703	5.440
3	-5.000				1.931	9.703	5.440
3	-17.500	0.000	19.171	13.419	1.931	21.101	13.419
3	-30.000	0.000	30.910	21.637	1.931	32.840	21.637
4	-30.000				1.931	32.840	21.637
4	-45.000	0.000	45.119	31.583	1.931	47.050	31.583
4	-60.000	0.000	59.380	41.566	1.931	61.311	41.566

* RUN COMPLETED * 1 TON = 2000 LBS.



S-CASE
CH.CL- Φ=23°
ML- Φ=28°
SM.SP- Φ=30°

TYPICAL SOIL PROFILE

SOIL STRATIFICATION IS BASED ON GEOLOGIC PROFILE
SHEAR STRENGTH AND WET DENSITIES SEE PLATE
SECOND ORDER STATIONS

NOTES:
K_H = $\alpha K1/B$=(0.2222 au/B)(C)(D) COHESIVE
α = 0.4 = Factor of material properties of soil and pile
k1 = Modulus of subgrade reaction for test plate (pci)
B1 = Width or diameter of test plate (in.)
K1 = k1B1 = 80 au (psf) = 0.5556 au(psi)
au = 2 · c = Unconfined compressive strength (psf)
C = Reduction for cyclic loading—not applicable
D = Group effect reduction factor
B = Width of pile measured at right angles to the direction of displacement (in.)
K_H = (nh)(Z/B)(C)(D) COHESIONLESS
nh = Coefficient of horizontal subgrade reaction (pci)
Z = Depth below equivalent ground surface (in.)

Figure D-3. Soil pressure and allowable design loads for uniform silt subgrade (Continued)

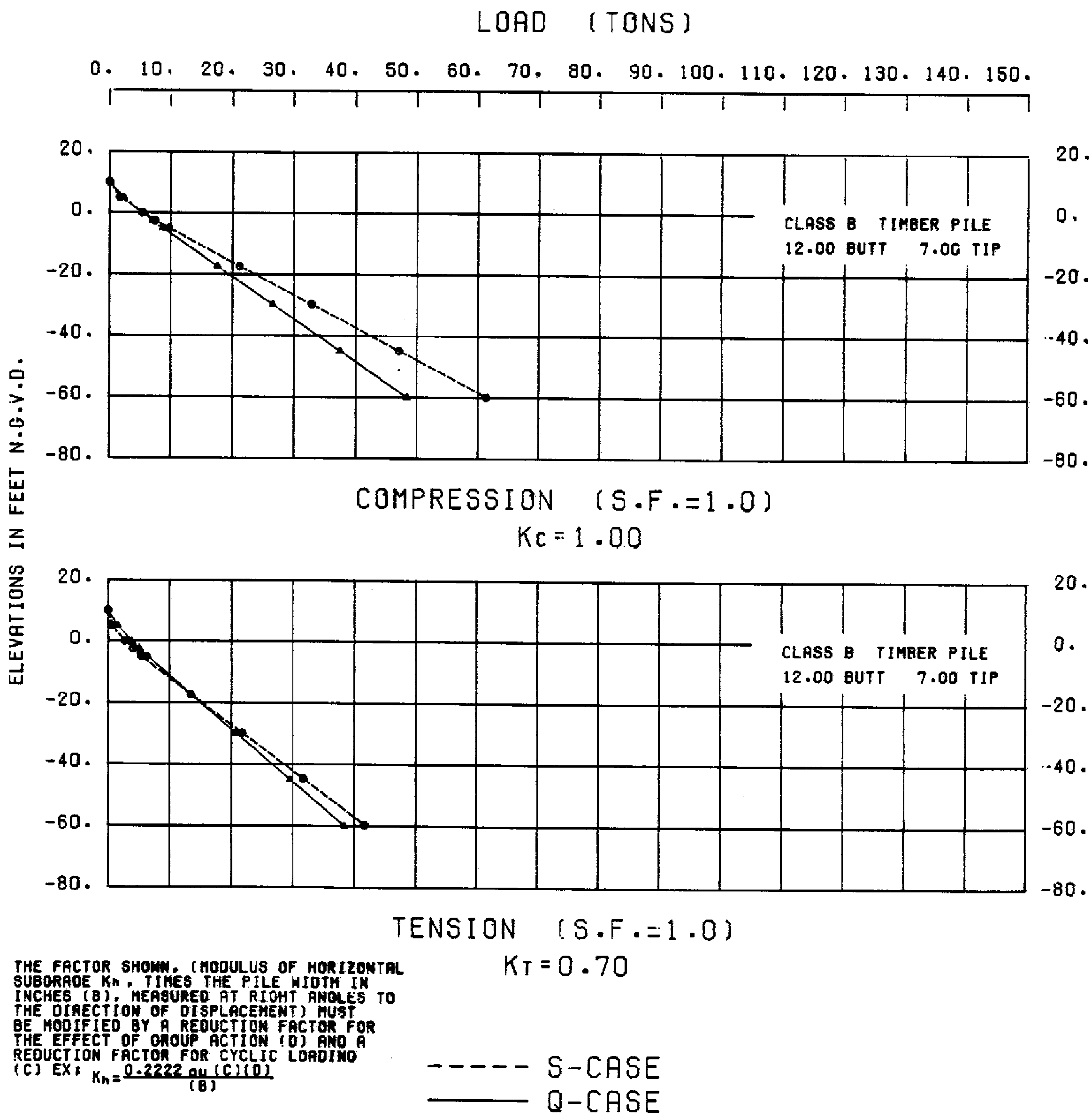


Figure D-3. (Concluded)

Table D-4

Computer Output for Allowable Design Loads for
Layered Clay, Silt, and Sand Subgrade, Run 3

* PILE CAPACITY COMPUTATIONS *

CASE IV
TIMBER PILE
INTERBEDDED SOILS

****
CLASS B TIMBER PILE
****

PILE BUTT DIA. IS AT THE GROUND SURFACE FOR ALL TIP PENETRATIONS
PILE LENGTH USED IS FROM GROUND SURFACE TO TIP
TIMBER PILE DIM.: 12.0 IN.BUTT DIA., 7.0 IN.TIP DIA.
TOP SURFACE ELEV.:, 10.0 FT.

**** Q-CASE ****

* STRATUM NUMBER	SOIL/SOIL FRIC.ANG DEG.	WEIGHT DENSITY LB/CU FT	TOP STRA COHESION LB/SQ FT	BOT STRA COHESION LB/SQ FT	COEF LAT EAR.PRES (KC)
1	0.00	110.00	400.00	400.00	1.00
2	15.00	55.00	200.00	200.00	1.00
3	15.00	55.00	200.00	200.00	1.00
4	0.00	38.00	600.00	600.00	1.00
5	30.00	60.00	0.00	0.00	1.00

* STRATUM NUMBER	COEF LAT EAR.PRES (KT)	TERZAGHI BEAR.CAP. (NC)	TERZAGHI BEAR.CAP. (NQ)	BOTTOM ELEVATION FEET	SOIL/PILE FRIC.ANG. DEG.	SOIL TYPE
1	0.70	9.00	1.00	0.00		CH
2	0.70	9.00	4.00	-5.00		ML
3	0.70	9.00	4.00	-12.00		ML
4	0.70	9.00	1.00	-20.00		CH
5	0.70	9.00	18.00	-60.00		SP

(Continued)

Table D-4 (Continued)

STRAT *NUM	EL.TIP (FT)	COH/ADH. RESISTAN	FRICTION COMPRESS TONS	RESISTAN TENSION TONS	END BEARING TONS	PILE CAPAC IN COMPRS. TONS	PILE CAPAC IN TENSION * TONS
1	5.000	2.487	0.000	0.000	0.555	3.042	2.487
1	0.000	4.974	0.000	0.000	0.628	5.602	4.974
2	0.000				0.828	5.803	4.974
2	-2.500	5.727	0.769	0.538	0.902	7.397	6.265
2	-5.000	6.436	1.700	1.190	0.975	9.111	7.626
3	-5.000				0.975	9.111	7.626
3	-8.500	7.389	3.132	2.193	0.975	11.497	9.582
3	-12.000	8.316	4.619	3.234	0.975	13.911	11.549
4	-12.000				0.905	13.840	11.549
4	-16.000	10.903	4.933	3.453	0.905	16.741	14.356
4	-20.000	13.596	5.162	3.614	0.905	19.664	17.210
5	-20.000				3.307	22.066	17.210
5	-40.000	15.195	22.386	15.670	3.307	40.888	30.865
5	-60.000	15.880	41.050	28.735	3.307	60.237	44.615

**** MODIFIED S-CASE ****

* STRATUM NUMBER	SOIL/SOIL FRIC.ANG DEG.	WEIGHT DENSITY LB/CU FT	TOP STRA COHESION LB/SQ FT	BOT STRA COHESION LB/SQ FT	COEF LAT EAR.PRES (KC)
1	23.00	110.00	0.00	0.00	1.00
2	28.00	55.00	0.00	0.00	1.00
3	28.00	55.00	0.00	0.00	1.00
4	23.00	38.00	0.00	0.00	1.00
5	30.00	60.00	0.00	0.00	1.00

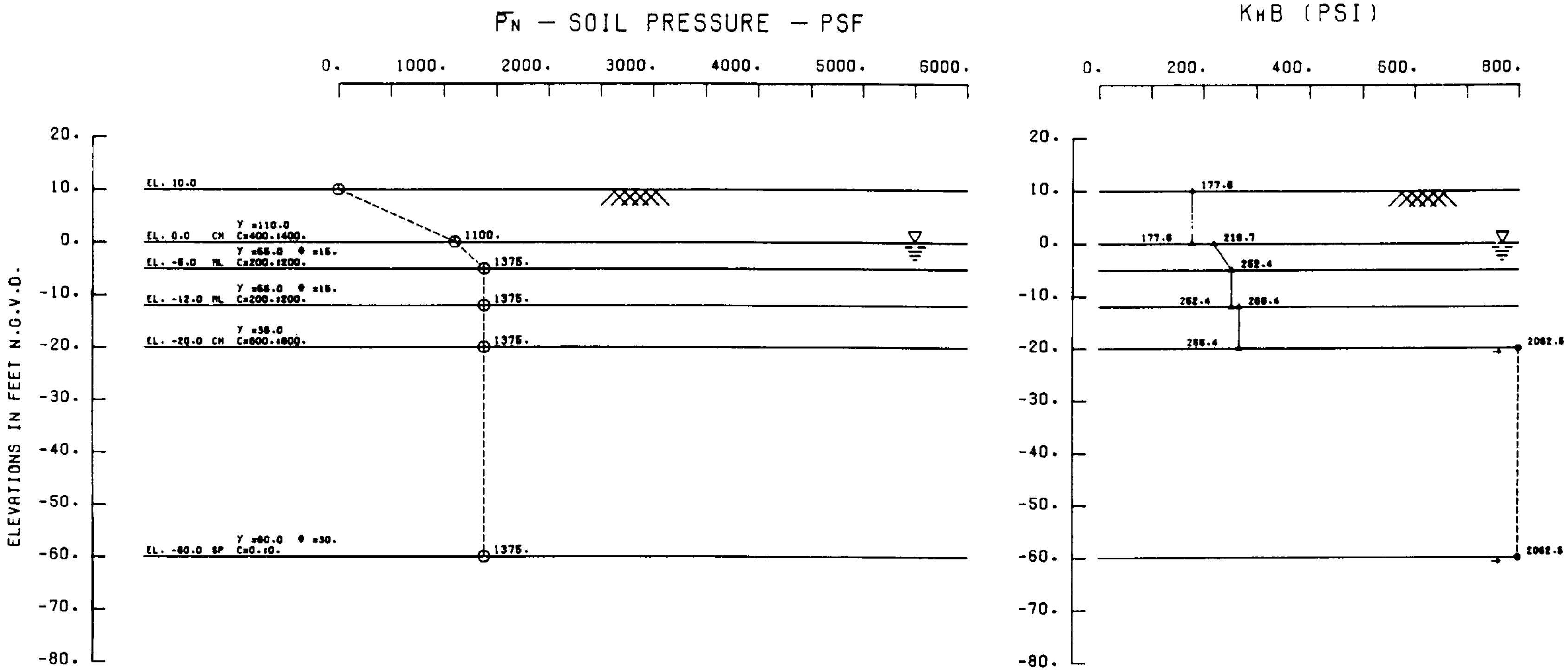
* STRATUM NUMBER	COEF LAT EAR.PRES (KT)	TERZAGHI BEAR.CAP. (NC)	TERZAGHI BEAR.CAP. (NQ)	BOTTOM ELEVATION FEET	SOIL/PILE FRIC.ANG. DEG.	SOIL TYPE
1	0.70	0.00	10.00	0.00		CH
2	0.70	0.00	10.00	-5.00		ML
3	0.70	0.00	10.00	-12.00		ML
4	0.70	0.00	10.00	-20.00		CH
5	0.70	0.00	10.00	-60.00		SP

(Continued)

Table D-4 (Concluded)

STRAT *NUM	EL.TIP (FT)	COH/ADH. RESISTAN	FRICTION COMPRESS TONS	RESISTAN TENSION TONS	END BEARING TONS	PILE CAPAC IN COMPRS. TONS	PILE CAPAC IN TENSION * TONS
1	5.000	0.000	0.726	0.508	0.735	1.461	0.508
1	0.000	0.000	2.903	2.032	1.470	4.373	2.032
2	0.000				1.470	4.373	2.032
2	-2.500	0.000	4.581	3.207	1.654	6.235	3.207
2	-5.000	0.000	6.531	4.572	1.837	8.369	4.572
3	-5.000				1.837	8.369	4.572
3	-8.500	0.000	9.470	6.629	1.837	11.308	6.629
3	-12.000	0.000	12.487	8.741	1.837	14.324	8.741
4	-12.000				1.837	14.324	8.741
4	-16.000	0.000	15.418	10.793	1.837	17.256	10.793
4	-20.000	0.000	18.342	12.840	1.837	20.180	12.840
5	-20.000				1.837	20.180	12.840
5	-40.000	0.000	37.315	26.121	1.837	39.153	26.121
5	-60.000	0.000	56.729	39.710	1.837	58.566	39.710

* RUN COMPLETED * 1 TON = 2000 LBS.



S-CASE
CH,CL- Φ=23°
ML- Φ=28°
SM,SP- Φ=30°

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NOTES:
- K_H = $\alpha K_1/B$=(0.2222 au/B)(C)(D) COHESIVE
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- B = Width of pile measured at right angles to the direction of displacement (in.)
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- nh = Coefficient of horizontal subgrade reaction (pci)
- Z = Depth below equivalent ground surface (in.)

Figure D-4. Soil pressure and allowable design loads for layered clay, silt, and sand subgrade (Continued)

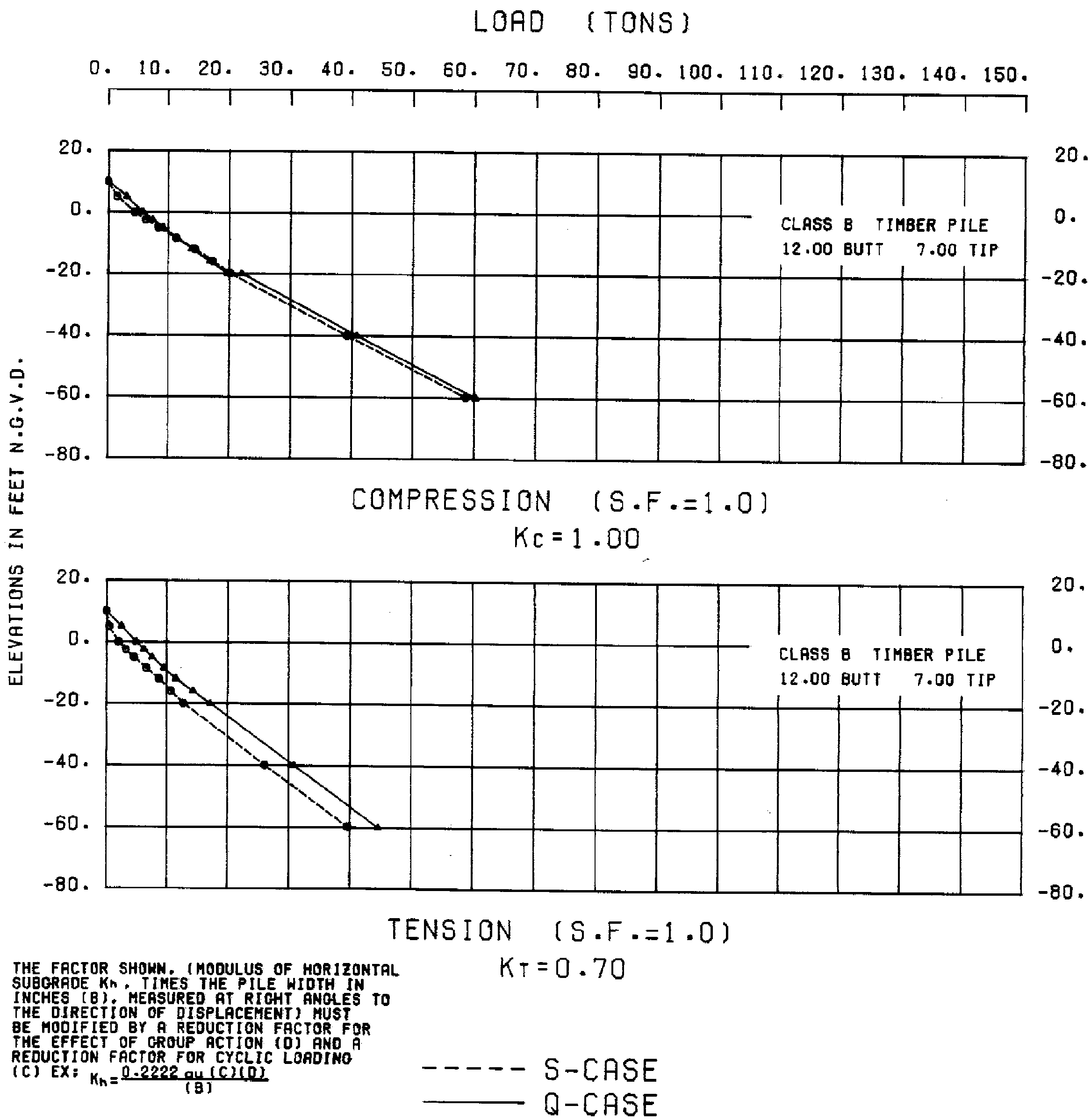

Figure D-4. (Concluded)