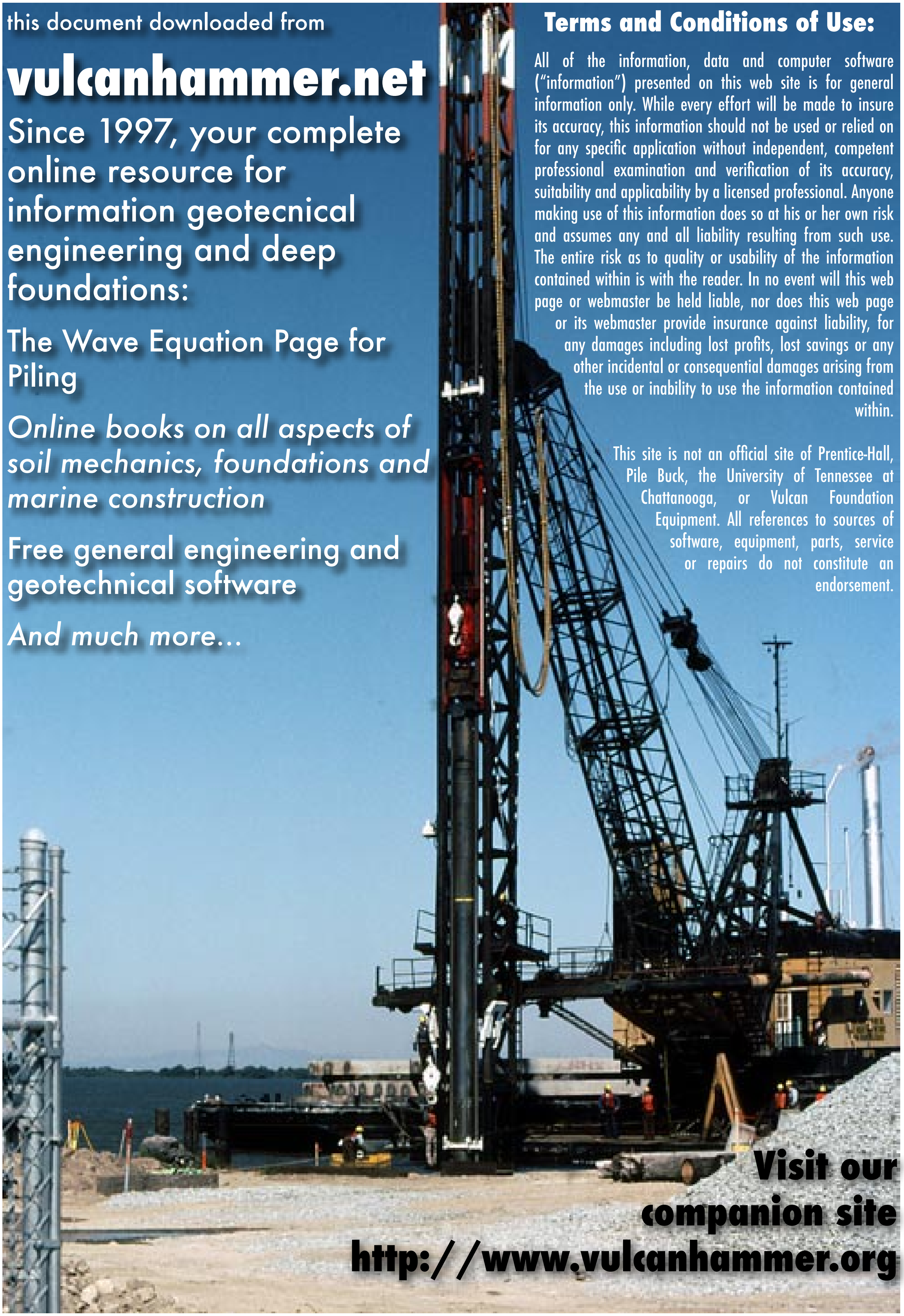


with depth, or the D'Appolonia (1968, 1970) method, which takes into account the effect of preconsolidation. Both methods provide equally suitable results. Schmertmann's modified method is presented in Chapter 8 (Shallow Foundations).

7.4.1 Modified Hough Method for Estimating Immediate Settlements of Embankments

The following steps are used in Modified Hough method to estimate immediate settlement:

Step 1. Determine the bearing capacity index (C′) by entering Figure 7-7 with $N1_{60}$ value and the visual description of the soil.

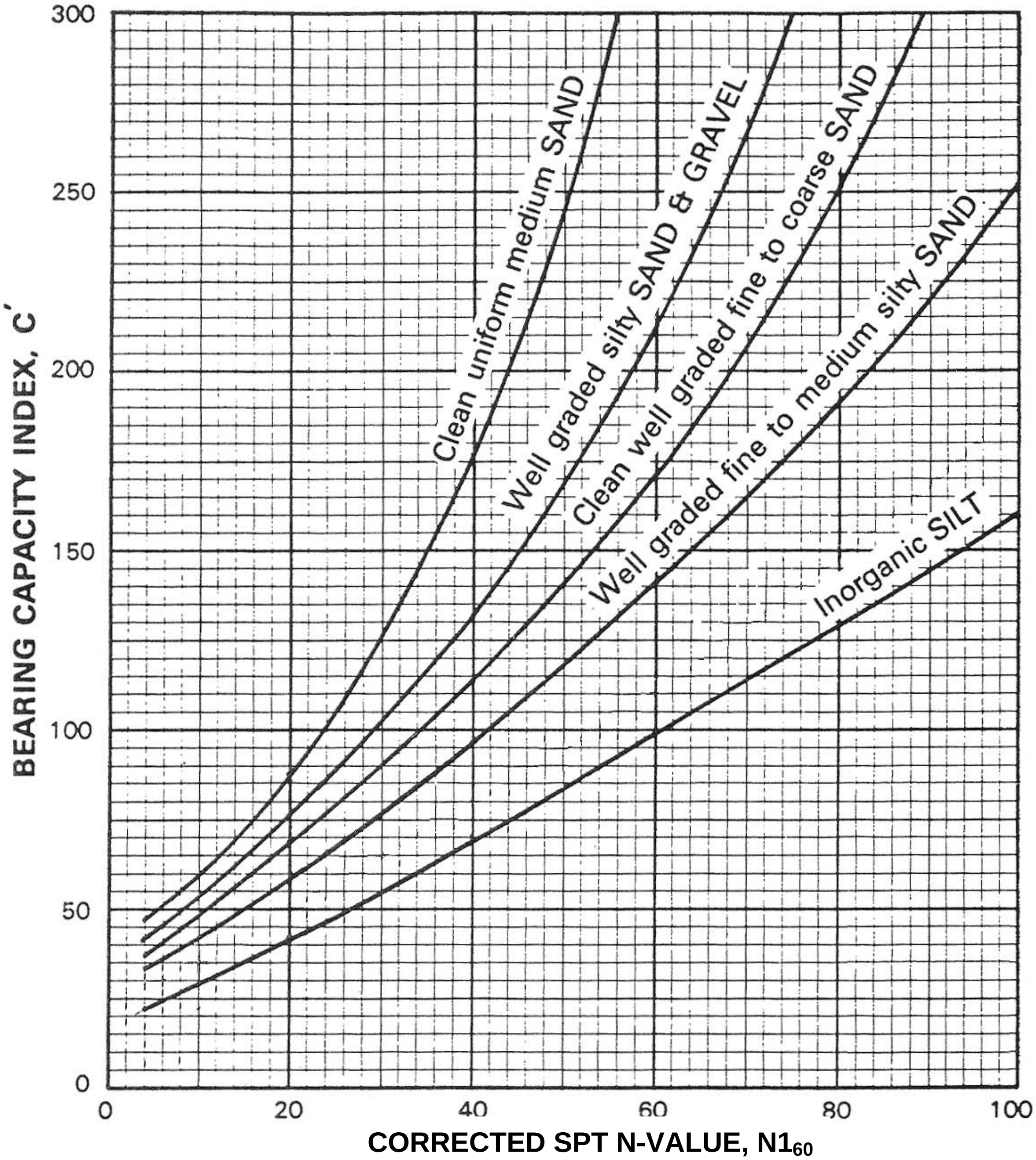
Step 2. Compute settlement by using the following equation. Subdivide the total thickness of the layer impacted by the applied loads into 10 ft ± (3 m ±) increments and sum the incremental solutions:

$$\Delta H = H\left(\frac{1}{C'}\right)\log_{10}\frac{p_o + \Delta p}{p_o} \qquad \text{7-1}$$

where:
- ΔH = settlement of subdivided layer (ft)
- H = thickness of subdivided soil layer considered (ft)
- C' = bearing capacity index (Figure 7-7)
- p_o = existing effective overburden pressure (psf) at center of the subdivided layer being considered. For shallow surface deposits, a minimum value of 200 psf should be used to prevent unrealistic settlement predictions.
- Δp = distributed embankment pressure (psf) at center of the subdivided layer being considered

Note that the term $p_o + \Delta p$ represents the final pressure applied to the foundation subsoil, p_f.

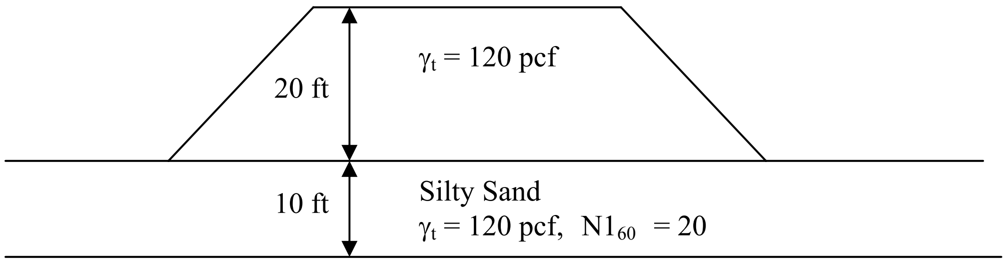
A key point is that the logarithm term in Equation 7-1 incorporates the fundamental feature of dissipation of applied stress with depth. The use of Modified Hough method is illustrated numerically in Example 7-2.



(Note: The "Inorganic SILT" curve should generally not be applied to soils that exhibit plasticity because N-values in such soils are unreliable)

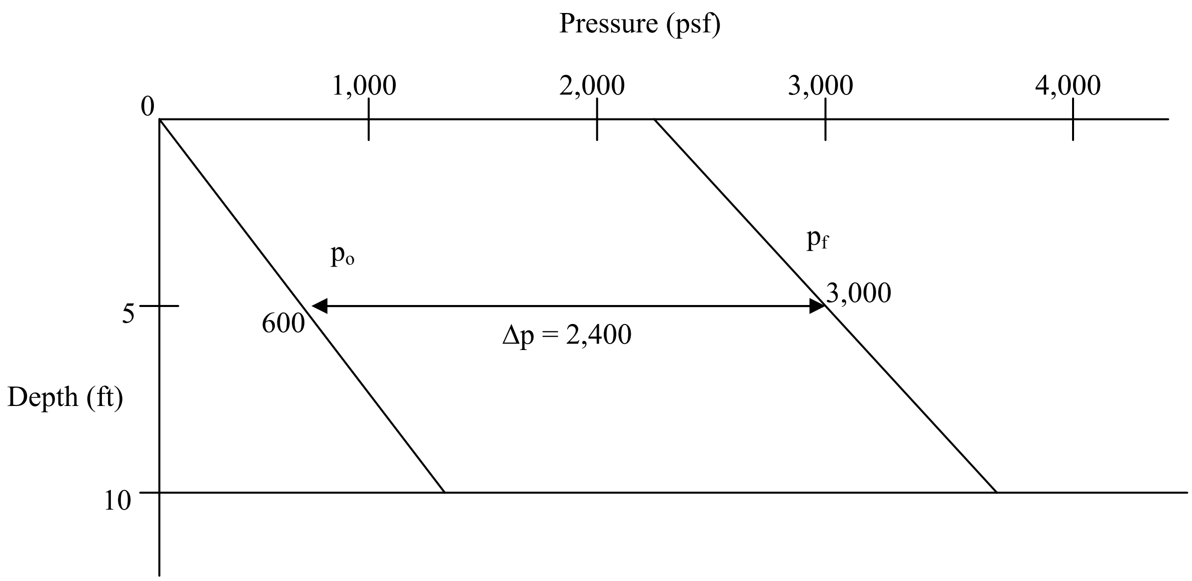
Figure 7-7. Bearing capacity index (C') values used in Modified Hough method for computing immediate settlements of embankments (AASHTO, 2004 with 2006 Interims; modified after Hough, 1959).

Example 7-2: For the geometry shown in the following figure, determine the settlement at the center of a wide embankment placed on a silty sand layer by using Modified Hough method and the p_o diagram.



Solution:

The original overburden pressure at the center of the 10 ft thick silty sand deposit can be computed as p_o = (10 ft/2) (120 pcf) = 600 psf. Since, the embankment is "wide" the stress does not practically dissipate with depth. Therefore, increase in the stress at this depth due to the 20 ft high wide embankment can be computed as Δp = (20 ft) (120 pcf) = 2,400 psf. The p_o diagram based on these values of p_o and Δp is shown below.



From Figure 7-7, find C′ for "silty sand." Using $N1_{60}$ = 20 and the "silty sand" curve, C′ ≈ 58. Find immediate settlement using Equation 7-1 as follows:

$$\Delta H = H\left(\frac{1}{C'}\right)\log_{10}\frac{p_o + \Delta p}{p_o}$$

$$\Delta H = 10\text{ ft}\left(\frac{1}{58}\right)\log_{10}\frac{600\text{ psf} + 2{,}400\text{ psf}}{600\text{ psf}} = 0.12\text{ ft} = 1.44\text{ in}$$

7.4.1.1 Comments on the Computed Settlement of Embankments

The implication of the amount of embankment settlement is that when the embankment is completed, additional fill will be required to bring the top of the embankment to the design grade. For example, a 1 in (25 mm) settlement on a 60-ft (18 m) wide, 1-mile (5,280 ft or 1,610 m) long embankment will result in a need for approximately 1,000 yd^3 (~750 m^3) of additional fill. Some state agencies refer to such settlement estimates as the "compaction factor" and note it in the contract plans so that the contractor can make appropriate allowances in the bid price to accommodate the additional embankment fill material needed to achieve the required design grades. It is in this regard the conservative estimate of the settlement resulting from the Modified Hough method may be acceptable and may even be preferable to prevent construction change orders.

7.5 COMPUTATION OF CONSOLIDATION (LONG-TERM) SETTLEMENTS

Unless the geomaterial is friable, consolidation settlements in fine-grained saturated soils occur over a period of time as a function of the permeability of the soils. This concept was introduced in discussed in Chapter 2 by using the spring-piston analogy. The features of the laboratory consolidation test were discussed in Chapter 5. In this chapter the data obtained from the consolidation test are used to demonstrate the computation of long-term settlements due to the consolidation phenomena, i.e., primary consolidation and secondary compression.

Theoretically, a necessary condition for consolidation settlement is that the soil must be saturated, i.e., degree of saturation, S = 100%. While the laboratory test for moisture content of a soil is inexpensive and relatively straightforward to perform and generally yields reliable, reproducible results, there are a number of parameters in consolidation analysis that cannot be determined with confidence as indicated by the data in Table 5-25. Therefore, depending on the magnitude and configuration of the load with respect to the size and moisture content of the compressible soil layer, it is possible that consolidation settlements may occur in soils that are judged to be "nearly saturated" but not "fully saturated." This is because such nearly saturated soils may approach full saturation after application of a load of sufficient magnitude to cause the pore spaces filled with air to compress (immediate settlement) to the extent that the degree of saturation is virtually 100%. Therefore, the geotechnical specialist should carefully evaluate the in-situ degree of saturation with respect to the degree of saturation of the soil sample at the beginning and end of the consolidation test. The geotechnical specialist should also carefully evaluate the reliability of other parameters determined during the performance of the consolidation test to make an informed judgment regarding the potential for consolidation settlements to occur. Unnecessarily