Settlement on Sand

- almost always controls design
- get parameters from in situ tests
- dependent on Dr and OCR
- OCR: - difficult to estimate for sands
  - can not use lab test
  - need knowledge of geologic or recent history

Schmertmann's Method

Based on a physical model of settlement, which has been calibrated using empirical data.

$$\delta = C_1 C_2 C_3 q' \sum \frac{I_\varepsilon \Delta z}{E_s} \tag{1}$$

where

C_1 = depth factor

C_2 = secondary creep factor

C_3 = shape factor

q' = net bearing pressure

I_ε = strain influence factor at midpoint of soil layer

Δz = thickness of soil layer

E_s = equivalent modulus of elasticity in soil layer

Empirical correction for depth of embedment, secondary creep, and footing shape:

$$C_1 = 1 - 0.5\left(\frac{\sigma'_{zD}}{q'}\right) \tag{2a}$$

$$C_2 = 1 + 0.2\log\left(\frac{t}{0.1}\right) \tag{2b}$$

$$C_3 = 1.03 - 0.03L/B \geq 0.73 \tag{2c}$$

where

σ'_{zD} = effective vertical stress at a depth D (overburden at the level of foundation)

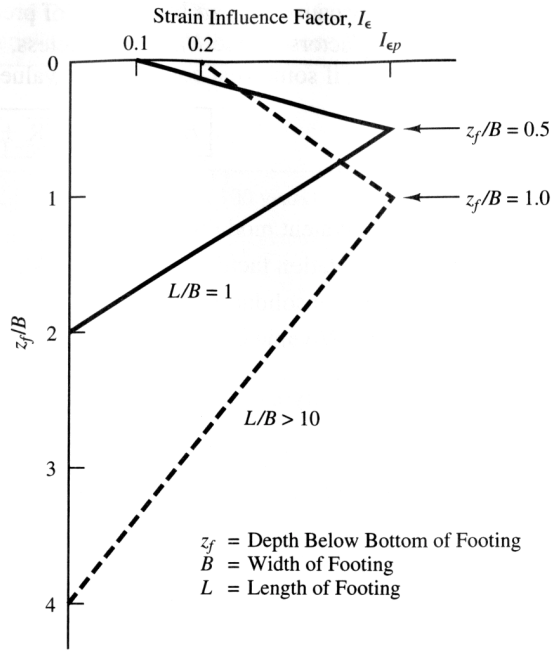
t = time since application of load (yr) ($t \geq 0.1$ yr)

L = foundation length

B = foundation width

Strain influence factor I_ε:

Figure 1



For values of L/B between 1 and 10, necessary interpolations can be made. The peak value of the strain influence factor, $I_{\varepsilon p}$ is:

$$I_{\varepsilon p} = 0.5 + 0.1\sqrt{\frac{q'}{\sigma'_{zp}}} \qquad (3)$$

where

σ'_{zp} = initial vertical effective stress at depth of peak strain influence factor

Equivalent modulus of elasticity:

Empirical correlations between E_s and cone resistance (more reliable) or SPT data can be used to estimate E_s.

Table 1.

E_S-VALUES FROM CPT RESULTS [Adapted from Schmertmann, et al. (1978), Robertson and Campanella (1989), and other sources.]

Soil Type	USCS Group Symbol	E_s/q_c
Young, normally consolidated clean silica sands (age < 100 years)	SW or SP	2.5–3.5
Aged, normally consolidated clean silica sands (age > 3000 years)	SW or SP	3.5–6.0
Overconsolidated clean silica sands	SW or SP	6.0–10.0
Normally consolidated silty or clayey sands	SM or SC	1.5
Overconsolidated silty or clayey sands	SM or SC	3

From SPT data:

$$E_s = 766N_{60}(kPa),\ \ 16N_{60}(ksf) \tag{4a}$$

or

$$E_s = \beta_0\sqrt{OCR} + \beta_1 N_{60} \tag{4b}$$

Table 2.

Soil Type	β_0 (lb/ft^2)	β_0 (kPa)	β_1 (lb/ft^2)	β_1 (kPa)
Clean sands (SW and SP)	100,000	5,000	24,000	1,200
Silty sands and clayey sands (SM and SC)	50,000	2,500	12,000	600

Most analysis should use OCR=1.0 unless there is a clear evidence of over-consolidation.

Analysis Procedure:

1. Perform appropriate in-situ tests to define the subsurface conditions.
2. Consider the soil from the base of the foundation to the depth of influence below the base. Divide this zone into layers and assign the thickness of each layer depend on the variations in the E vs. depth profile. Typically 5 to 10 layers are appropriate.
3. Compute the peak strain influence factor, $I_{\varepsilon p}$, using Equation (3).
4. Compute the strain influence factor, I_ε, at midpoint of each layer using Figure 1.
5. Compute the correction factors, C_1, C_2, and C_3, using Equation (2).
6. Compute the settlement using Equation (1).