Robertson’s Remarks

- Settlement Calculations using the CPT-

Traditionally the CPT has not been used extensively for the calculation of vertical settlements due to foundations loads. Partly this has been due to the somewhat poor correlation between CPT results and soil modulus. However, significant recent improvements have been made that provide much better estimates of soil modulus from CPT results. This recent work was based on over 20 years of experience measuring shear wave velocity with the CPT (i.e. SCPT). It is now possible to make good estimates of soil modulus from CPT results over a wide range of uncemented soils, from soft clay to dense sands.

It is common practice in many parts of the world to estimate vertical settlement under footings using the simple one-dimensional formula:

\[ S_1 = \sum \frac{\Delta \sigma_v \Delta z}{M} \]

Where \( \Delta \sigma_v \) is the change in vertical stress due to the loading and is generally calculated according to Boussinesq and \( M \) is the 1-D constrained modulus that can be estimated from the CPT. The settlement calculation is therefore a summation over the depth range where \( \Delta z \) is the interval between CPT readings. It should be noted that the above formula is based on linear elasticity and provides a settlement proportional to the load, and is unable to provide a non-linear prediction. The predicted settlement is meant to be the settlement under 'working conditions' (i.e. for a safety factor FS = 2.5 to 3.5).

The 1-D constrained modulus, \( M \) can be estimated from the CPT using the following:

\[ M = \alpha_M (q_t - \sigma_{vo}) \]

When \( Ic > 2.2 \) (i.e fine-grained soils) use:

\[ \alpha_M = Qtn \quad \text{when } Qtn < 14 \]
\[ \alpha_M = 14 \quad \text{when } Qtn > 14 \]

When \( Ic < 2.2 \) (i.e. coarse-grained soils) use:

\[ \alpha_M = 0.0188 \left[ 10^{0.55Ic + 1.68} \right] \]

The above 1-D formula can be applied to all soils. For clays the calculated settlement is only due to primary consolidation. Where secondary (creep) settlements can be large (i.e. soft clays and organic soils) it is important to add an estimate of the secondary settlement using:

\[ S_s = C_s \Delta z \log (t) \]

Where \( C_s \) is the coefficient of secondary consolidation and \( \Delta z \) is the depth interval between CPT readings. It is important to select \( C_s \) carefully. The coefficient can be estimated from the CPT using:

\[ C_s = 0.04 \left[ \frac{C_c}{1+e_o} \right] = 0.1 \left( \sigma'_v / M \right) \]

The software program CPeT-IT (www.geologismiki.gr) performs the above settlement calculation within a sub-module of the program. The above simplified approach provides excellent prediction of settlement when compared with a number of case histories.