Robertson's Remarks #5
Estimating shear wave velocity, V_s from CPT

The shear wave velocity (V_s) is a very useful parameter since it links directly to the small strain shear stiffness of the soil (G_0). Although direct measurement of V_s is preferred over estimates, relationships with cone resistance, q_t can be useful for smaller low risk projects, where V_s measurements are not always taken. There are many existing relationships between q_t and V_s (or G_0), but most were developed for either sands or clays and generally relatively young deposits. Although strong relationships between V_s and q_t exist, some variability should be expected due to factors such as age and cementation. The accumulated 20 years of experience with seismic CPT results has produced an updated relationship between cone resistance and V_s for a wide range of soils, using the CPT Normalized Soil Behavior Charts (SBT), based on Q_{tn} and F.

Based on over 100 SCPT profiles from 22 sites in California combined with published data, a set of contours of normalized shear wave velocity, V_{s1} was developed on the normalized SBT Q_{tn} – F_r chart, as shown in the attached Figure**,** where;

$$V_{s1} = V_s \, (p_a / \sigma'_{vo})^{0.25} \qquad [1]$$

Since the CPT measurements are normalized in terms of Q_{tn} and F_r, the resulting shear wave velocity values are also normalized. The data used to develop the relationship were from deposits that ranged from Holocene to Pleistocene age and were predominately uncemented. Most Holocene age deposits have V_{s1} values less than 250 m/s (820 ft/s). In general, the Holocene age data tends to plot in the center-lower left portion of the SBTn chart, whereas the Pleistocene age data tends to plot in the center-upper right portion of the chart.

Based on the contours shown in the Figure, V_s can be estimated using:

$$V_s = [\alpha_{vs} \, (q_t - \sigma_v)/p_a]^{0.5} \qquad [2]$$

Where: p_a is atmospheric pressure in the same units as q_t and σ_v to make $(q_t - \sigma_v)/p_a$ dimensionless. Since the shape of the contours for α_{vs} is similar to those of the SBT index I_c, α_{vs} can be estimated using:

$$\alpha_{vs} = 10^{(0.55\, Ic + 1.68)} \quad \text{in units of } (m/s)^2 \qquad [3]$$

or

$$\alpha_{vs} = [10.76]\, 10^{(0.55\, Ic + 1.68)} \quad \text{in units of } (ft/s)^2 \qquad [4]$$

Knowledge of soil age would improve the correlations but often the age of the deposit is not always known in advance for most small low risk projects. Hence, the general relationship shown in the Figure and equation 2 is recommended for most Holocene to Pleistocene age deposits. The predicted shear wave velocity using equation 2 in Pleistocene age deposits may be somewhat under estimated.