Robertson's Remarks

- How Accurate is the CPT?-

Occasionally I am asked "How accurate is the CPT?" In short – generally it's more accurate than most other in-situ and laboratory tests for a wide range of soils. What do I mean by that? The other primary in-situ test for soils is the SPT, which (as we know) is not very accurate. There are many variables that influence the SPT (e.g. borehole disturbance, variable hammer/anvil energy, non-standard sampler, loose rod connections). For example, you may measure an SPT N value of 12, but if the energy ratio of the hammer/anvil system was 80%, the corrected N_{60} is 16. However, if the test were at shallow depth (< 10 feet) with an old hammer, the energy ratio could be as low as 20% resulting in a corrected N_{60} of 4. Hence, you measured 12, but you are not sure if the correct N_{60} is either 4 or 16! In soft clay the SPT has zero accuracy when you measure N = 0.

The main advantage of the modern electronic CPT is that the test is operator independent. In essence, different testing companies can test the same ground and should measure the same CPT tip resistance (q_c) profile to within the tolerances set by the electronic transducers, about $\pm$ 0.1% of the full-scale output (FSO) using available commercial equipment (e.g. ASTM Standard D5778). Most commercial cones have a maximum capacity or full-scale output (FSO) of about 1,000 tsf for the tip resistance (q_c). These cones are designed to survive pushing through very hard ground (including soft rock). Hence, they have an accuracy of $\pm$ 1 tsf for q_c. In most soils, this is an excellent level of accuracy that is often better than ***$\pm$ 1% of the measured values***, especially in sands where q_c > 100 tsf. Research has shown that even university research laboratories cannot achieve this level of repeatability in simple triaxial compression testing of reconstituted samples.

When testing soft, fine-grained soils the accuracy will decrease as the measured CPT q_c decreases. To improve the accuracy of the CPT in soft soils, it is recommended to use lower capacity cones (i.e. cones with lower FSO). In soft, normally consolidated clay (such as Young Bay Mud soils near San Francisco), the measured q_c can be less than 5 tsf at shallow depth. In these very soft soils, a cone with a lower FSO (i.e. < 500 tsf for q_c) is required to obtain an accuracy of better than $\pm$ 10%. Caution is required when using lower capacity cones, since they can be overloaded if a hard/stiff soil layer is encountered. What is recommended at sites where the soils are soft and a high level of accuracy is required is to first push a standard high capacity cone to determine soil stratigraphy and to ensure that no hard layers exist over the depth of interest, then perform a small number of CPT's using a lower capacity cone to more accurately determine the shear strength of the soft soils.

Experience, has shown that the CPT friction sleeve resistance (f_s) is less repeatable ($\pm$ 0.5% of FSO) than tip resistance (q_c), due to differences in cone design and tolerances. Fortunately, f_s is not used to estimate many soil parameters other than soil behavior type (SBT) and the remolded undrained shear strength in fine-grained soils. Robertson (2009) discussed how to improve the accuracy of f_s measurements and that variations in f_s generally have a small influence on the estimated SBT for most soils.

Hence, the answer to the question, "How accurate is the CPT?" is that generally it's more accurate than most other in-situ and laboratory tests for a wide range of soils, but the user should be aware of the capacity of the cone relative to the strength of the soil tested. In general, the tip resistance accuracy is $\pm$ 0.1% of the cone capacity (FSO).