Project Summary

Texas Department of Transportation

0-4862: Correlation of Texas Cone Penetrometer Test Values and Shear Strength of Texas Soils

Background

The TCP test is a standardized test procedure currently used by the Texas Department of Transportation (TxDOT) for geotechnical studies to indirectly estimate undrained shear strength of soils (TxDOT Geotechnical Manual, 2000). Texas Cone penetrometer (TCP) is a sounding test similar to the Standard Penetration Test (SPT) and the Cone Penetration Test (CPT) used to determine the soil parameters for foundation design. In the case of the TCP test, the potential energy resulting from hammer impacts is similar to the SPT. The cone shape and apex angle are similar to CPT, but it has a larger diameter. Therefore, it can be stated that the TCP is a hybrid of SPT and CPT, and can be used in all soil types. Correlations based on the test values could be very useful to engineers to determine the shear strength of the soil. Limited research was done in the mid 1970s to correlate the TCP blow count (N_{TCP}) to the undrained shear strength of soil (S_u). These studies were performed in the upper Gulf Coast region with limited number of data. Over the decades, TxDOT has collected data on (N_{TCP}) and (S_u) which can be used in verifying the current correlations for various soils from different parts of Texas. Hence a research study was initiated at three universities – University of Houston, Lamar University, and The University of Texas at Arlington – to verify the current correlations between (N_{TCP}) and (S_u) based on the soil type and if necessary develop correlations based on the least square fit of the data.

What the Researchers Did

Texas was divided into three sectors to collect and analyze the data from TxDOT projects over the past decade (1994 - 2004). The parameters investigated were soil types, undrained shear strength (S_u), TCP blow count (N_{TCP}), and depth and locations. Over 4,000 sets of data on TCP blow count (N_{TCP}) and undrained shear strength (S_u) were collected, mainly from Houston, Beaumont, Dallas, and Fort Worth districts. Of the over 4,000 data collected, 2,100 data was on CH soils, 1,852 data was on CL soils, 29 data was on SC soils, and 42 data was on “other” soils.

Collected data was compared to the current TxDOT (S_u) versus (N_{TCP}) relationship for each soil type for the entire state and a few TxDOT districts. Also, data was analyzed based on statistical methods and using theoretical concepts. Limited control tests were performed to validate the data. The relationship between (N_1) and(N_2) was also investigated. The data collected over a decade from TxDOT projects was analyzed using three different approaches to develop new correlations and compare the data to the current linear relationships used by TxDOT. The first approach was to investigate the relationship between (S_u) versus (N_{TCP}) for each type of soil with no averaging. In the second approach, the relationship between average strength (S_u) (for each TCP blow count (N_{TCP})) and (N_{TCP}) was investigated.

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In the third approach, the depth effect (also influenced by geology and active zone) on the mean (N_{TCP}) ($\bar{N}_{TCP}$) and mean (S_u) ($\bar{S}_u$) was investigated. Based on the three different approaches, linear and nonlinear relationships between TCP blow count and undrained shear strength were developed.

What They Found

For the CH soil with 2100 data set, the undrained shear strength (S_u) varied from 0.5 to 89 psi with a mean of 16.8 psi. The COV was 67%, which was the highest for the soils investigated in this study. The probability distribution function (PDF) for the undrained shear strength (S_u) was lognormal. The TCP blow count (N_{TCP}) varied from 2 to 100 with a mean of 31. The COV was 70%, which was the highest for the soils investigated in this study. The PDF for the TCP blow count (N_{TCP}) was lognormal, which was similar to what was observed for the undrained shear strength (S_u). The current TxDOT relationship overpredicted 59% of the data.

For the CL soil with 1852 data set, the undrained shear strength (S_u) varied from 1 to 114.6 psi with a mean of 12.9 psi. The COV was 54%, which was the lowest for the soils investigated in this study. The PDF for the undrained shear strength (S_u) was lognormal. The TCP blow count (N_{TCP}) varied from 2 to 100 with a mean of 35. The COV was 58%. The PDF for the TCP blow count (N_{TCP}) was lognormal, which was similar to what was observed for the undrained shear strength (S_u).

For the SC soil with 29 data set, the undrained shear strength (S_u) varied from 3.5 to 38.6 psi with a mean of 10.8 psi. The COV was 60%. The PDF for the undrained shear strength (S_u) was lognormal. The TCP blow count (N_{TCP}) varied from 7 to 87 with a mean of 30. The COV was 66%. The PDF for the TCP blow count (N_{TCP}) was Weibull.

For the “other” soil with 42 data set, the undrained shear strength (S_u) varied from 1.4 to 69.3 psi with a mean of 16.8 psi. The COV was 66%. The PDF for the undrained shear strength (S_u) was Weibull. The TCP blow count (N_{TCP}) varied from 10 to 93 with a mean of 45. The COV was 45%, which was the lowest for the soils investigated in this study. The PDF for the TCP blow count (N_{TCP}) was normal.

All the correlations developed in this study were based on soil type. Based on the analyses of data and average values, linear and nonlinear relationships were developed using three approaches in this study. Analyses showed that the current TxDOT design relationships overestimated the undrained shear strength (S_u) and that the TCP blow count (N_{TCP}) was dependent on the depth for all the types of soils investigated. The depth dependency also varied from location to location. The correlations developed between undrained shear strength and TCP blow count were also influenced by the locations.

What This Means

Linear and nonlinear correlations developed between undrained shear strength (S_u) and TCP blow count (N_{TCP}) based on over 4,000 sets of data can be used to better predict the shear strength of various types of soil in Texas. Relationships have been developed for local areas to better correlate the shear strength of soil. It is recommended that depth effect on TCP blow count be considered in future studies on improving the correlations used by TxDOT.

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