LTRC Technical Summary Report 439

LTRC Proj. No. 06-6GT ~ State Proj. No. 736-99-1406

December 2009

Louisiana Transportation Research Center

4101 Gourrier Ave., Baton Rouge, LA 70808

# Update of Correlations between Cone Penetration and Boring Log Data

## Objective

The main objective of this project is to update the correlations that are currently used to interpret Cone Penetration Test (CPT) data for engineering design purposes and to assess the reliability of using CPT data to predict soil shear strength. The results of laboratory soil testing were retrieved from borehole logs and were used as reference measurements in this study.

## Methodology

The research team collected project data files in the form of paper printouts from the Louisiana Department of Transportation and Development (LADOTD) and soil testing engineers. A total of 752 CPT points were documented of which 503 were matched with adjacent boreholes and 249 did not have adjacent borehole data available. The CPT data was used to predict soil undrained shear strength, bulk density, and classification according to Robertson (Robertson, 1990) and Zhang and Tumay (Zhang and Tumay, 1999) methods. The CPT data was then used to develop a database of undrained shear strength estimates with corresponding results from boreholes.

The results in the database were preprocessed to apply constraints on data points included in the calibration study, such as setting a maximum threshold on the distance between CPT and borehole locations and a minimum and maximum threshold on undrained shear strength values to represent realistic soil properties. The resulting database included results from 251 CPT locations with borehole results in their vicinity that meet the aforementioned constraints. From these CPT locations, 862 unique undrained shear strength data points were obtained at various depths.

The dataset was analyzed for general and specific trends in order to identify appropriate parameters to be included in the study. Soil classification was clearly the most plausible parameter based on which the CPT undrained shear strength estimates should be calibrated for.

## Conclusions

1. A single $N_{kt}$ value that is valid for all soil types is unwarranted as it will lead to acceptable results for some soil conditions and unacceptable results for others, which can be unconservative.
2. Two approaches for the calibration of the CPT coefficient, $N_{kt}$, were presented in this study. The first approach is a direct correlation between undrained shear strength results in the assembled database from both CPT and boring data. The second approach utilizes the First Order Reliability Method (FORM) and accounts for all sources of uncertainty (soil properties, device measurement, and transformation model) as compared to the first approach, which only accounts for uncertainties in the transformation model (see Figure 1).
    - Based on the first approach, a value of 25 should be used for the CPT coefficient, $N_{kt}$, to achieve a 50 percent probability of exceedance, i.e., $\beta_T$ = 0.0. Safer designs will need higher probability of exceedance values— higher $\beta_T$ that results in equal to 27 and 32 for target $\beta_T$ values equal to 0.1257 (55%) and 0.4308 (66.7%), respectively.

**LTRC Report 439**

**Principal Investigators:**
Khalid Alshibli, Ph.D., P.E.
Ayman M. Okeil, Ph.D., P.E.
Bashar Alramahi, Ph.D.

**LTRC Contact:**
Zhongjie "Doc" Zhang, Ph.D., P.E.
Phone (225) 767-9162

**Louisiana Transportation Research Center**

*Sponsored jointly by the Louisiana Department of Transportation and Development and Louisiana State University*

4101 Gourrier Avenue
Baton Rouge, LA 70808-4443
www.ltrc.lsu.edu

Cont'd on Back

- The second approach yielded $N_{kt}$ values equal to 27.5, 31.0, and 42.0 for target $\beta_T$ values equal to 0 (0%), 0.1257 (55%), and 0.4308 (66.7%), respectively. The difference in $N_{kt}$ values obtained from both methods is attributed to the fact that the first approach does not account for the uncertainties inherent in soil properties and the measuring device. Both uncertainties add to the overall confidence in the soil property, which was captured by the FORM analysis (2nd approach) but cannot be captured using the first approach.

3. The $N_{kt}$ results presented above are based on the entire dataset compiled for this study. The dataset was further analyzed by grouping data points in subgroups based on different parameters associated with each point. The parameters considered in this study for grouping the data are: (1) depth, (2) soil classification (three different methods), and (3) CPT readings. It was determined that the soil classification is the only parameter showing clear trends that affect CPT estimates of the undrained shear strength. Therefore, further calibrations were warranted considering the soil type. $N_{kt}$ values for each soil type based on the Robertson (Robertson, 1990) classification and the Zhang and Tumay (Zhang and Tumay, 1999) classification were obtained. The recommended $N_{kt}$ values obtained from this study indicate that the coefficient for soils with higher clay content is lower than those with less clay content.
4. Results obtained from this study also showed that the unit weight estimates from CPT readings are in good agreement with borehole results. The CPT predictions slightly underestimate the unit weight on average by 2 percent. The scatter of the results is also limited (COV = 12.4 percent) compared to the undrained shear strength discussed earlier.
5. A procedure for classifying projects based on the site variability was proposed. The procedure builds on the results from the repeatability study conducted in this project. It can be used to obtain a non-subjective classification for site variability of a certain project (e.g., low, medium, or high) by studying the coefficient of variation of the CPT undrained shear strength estimates from multiple soundings at the project site. This classification can then be used in conjunction with the AASHTO-LRFD design code to use appropriate design coefficients.

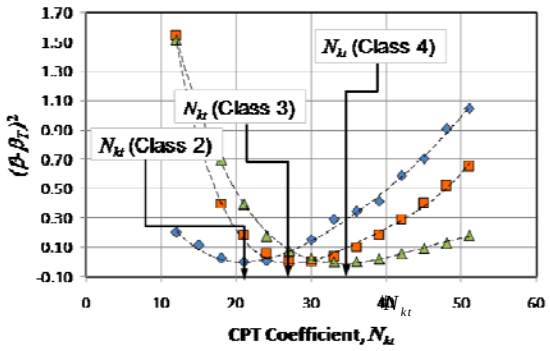


**Figure 1**

**Determining optimum $N_{kt}$ –values [ $\beta_T$ = 0.1257, = $\sigma_{vo}/q_c$ 0.05]**

# Recommendations

1. It is recommended that LADOTD design engineers consider the information provided in this study when selecting $N_{kt}$ values for their designs.
2. The research team also recommends that the LADOTD staff utilize the developed database before sending the drilling crew to the field.
3. Based on the statistical studies performed in this research effort, it is recommended that LADOTD starts adopting the updated CPT coefficient in conjunction with borehole results for a transition period until the proposed values are validated. Updates of the CPT coefficient are also prudent; as more CPT data becomes available, they should be added to the developed database.