Field Testing of CIGMAT Downhole Penetrometer During Drilled Shaft Construction

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Abstract: In this study, CIGMAT Down-Hole Penetrometer was field tested during the construction of drilled shafts, in clay shale, clay and silty clay at six locations in the Houston and Dallas districts. Based on the field test results correlation between undrained shear strength and penetrometer deflection have been developed.

1 Introduction

In order to support high loads on bridges and other transportation structures and/or based on the near surface geological conditions, more and more drilled shafts are being socketed to soft rocks and clay. During the construction of drilled shafts in soft rock or hard clay, it is critical to identify the soil stratum during the drilling process so that the drilled shaft could be correctly socketed in the soft-rock or hard clay.

Both static and dynamic penetrometers are being used to determine the in-situ soil properties for designing deep foundations and slope stability analysis. However, these devices cannot be used to characterize the soil in the drilled shaft borehole due to the difficulty of incorporating the operations during the construction phase. In order to overcome this difficulty the CIGMAT Down-Hole Penetrometer (DHP-CIGMAT) (Vipulanandan and Usluogullari 2008) developed at the University of Houston, Houston, Texas. It must be noted that there is no other commercially available tool to characterize the clay and soft-rock strength at the bottom of the borehole of a drilled shaft.

Correlations based on the test values could be very useful to engineers to determine the undrained shear strength of the soil/rock in the borehole. In order to correlate the DHP-CIGMAT measurements (deflections) to soil/rock strength and Texas Cone Penetrometer (TCP) values, limited field tests were performed in the Houston district and Dallas district.

2 Objective

In this study, DHP-CIGMAT was tested to determine its effectiveness in measuring the strength of soil/soft rock at the bottom of the borehole. Based on limited field tests, correlations between geomaterial strength and DHP-CIGMAT deflection have been developed.

3 Field Test Locations

To investigate the relationship between deflection obtained from DHP-CIGMAT and undrained shear strength of soil/soft rock, field tests were performed on the drilled shaft construction sites in Houston and Dallas, Texas. At all the soil sites, boreholes were filled with/without drilling mud and DHP-CIGMAT tests were performed at various stages construction to determine the bottom of the borehole based on design values. In Dallas, tests were performed on clay shale, soft rock, the bore holes were dry. The depth of the boreholes varied from 15 to 30 m (50 to 100 ft). In these test sites CH, CL and clay shale were the major soil formations.

Clay samples were obtained using the DHP-CIGMAT from four boreholes in various locations in Houston, Texas and DHP-CIGMAT tests were performed in these boreholes.

Details of the four drilled shafts at the test sites and material properties of the clay samples obtained from that four locations are summarized at Table 1.

Table 1. Summary of Field Test Results

Location	Length of Borehole (ft.)	Slurry	Plastic Limit (%)	Liquid Limit (%)	Plasticity Index (%)	Soil Classification
B1	50	Yes	21	53	32	CH
B2	63	No	20	59	39	CH
B3	53	No	22	42	20	CL
B4	54	Yes	27	72	45	CH

4 Results

The main focus of this study was to investigate the relationship between the undrained shear strength of soil/soft rock and the deflection obtained from DHP-CIGMAT with various stiffness to cover the various strength of the geomaterials. Unconfined compression tests were performed to measure the undrained shear strength of samples which were collected at the same borehole at the same elevation with DHO-CIGMAT tests.

After the tests, DHP-CIGMAT deflections were recorded immediately by measuring the displacement of the ring using a digital caliper with 0.001 in resolution. Because of relatively higher strength for soft rocks and hard soils, stiffer DHP-CIGMAT was used at Dallas field tests. Based on limited field test data, the relationship between unconfined compressive strength of soft rock and hard clay and penetrometer displacement readings showed good agreement. Based on the analysis of the data, the following correlation was obtained for DHP-CIGMAT-1800 deflection and undrained shear strength of soil from Dallas area:

$$S_u = 62.8\,\delta \qquad \text{(15 data)} \qquad (1)$$

Less stiff DHP-CIGMAT was used for clay soils, in the Houston area. Based on the analysis of the data, the following correlation was obtained for DHP-CIGMAT-1100 deflection and undrained shear strength of soil:

$$S_u = 26.6\,\delta \qquad \text{(8 data)} \qquad (2)$$

5 Conclusion

A new device to measure the undrained shear strength of soils and soft rocks during the drilled shaft constructions has been developed. This device can be easily attached to the Kelly Bar during the construction to determine the undrained shear strength of geomaterials at the bottom of the borehole. Based on the limited field data, linear correlations between the undrained shear strength of the geomaterials and deflection of various DHP-CIGMAT have been developed.

6 Acknowledgements

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7. References

1. Vipulanandan, C., and Usluogullari, O. (2008) "Development and Verification of a Down-Hole Penetrometer ", TxDOT Project Report 5-4372-01-1.