0-6146: Design of Short, Laterally Loaded Drilled Shafts in High-Plasticity Clay

Background

The Texas Department of Transportation (TxDOT) uses three-cable barrier systems to prevent cross-over collisions by capturing and maintaining errant vehicles in their direction of travel. However, in 2007, a cable barrier system located east of Dallas experienced problems due to its location in an expansive soil environment. It was determined that when the expansive clayey soil was hydrated and the cables were subjected to cold temperature induced tension conditions, the short drilled shafts used to anchor the barrier system were lifted in an angular direction along the three cables due to an increase in inclined loading.

This research project investigated ways to enhance and improve drilled shaft designs and behavior. Researchers sought to:

- provide failure mechanisms of shafts in high PI clay areas,
- design appropriate and various dimensions of drilled shafts subjected to the same type of loading in order to prevent the failures,
- develop a new and modified foundation system, and
- develop a design chart for different settlement criteria by accounting for various deflection criteria.

What the Researchers Did

To achieve their goals, the researchers did the following:

- **Literature Review:** Conducted a comprehensive literature review on cable median barriers used, factors affecting the failures, such as high PI clay conditions, temperature effects, lateral loads from inclined cable loads, and uplift capacities due to inclined loads and expansive soils. Additionally, lateral load analysis methods were reviewed.
- **Site Selection and Laboratory Studies:** The selected site was located on IH 20 and Rose Hill Road in Kaufman County. Samples from the site tested 59 for plasticity in the soil, which indicated a high potential of swelling in the foundation soil. Geotechnical studies including Atterberg Limits, linear shrinkage, standard Proctor compaction, three dimensional free swell and shrinkage, swell pressure, soil suction measurement, direct shear strength and unconsolidated-undrained tests were performed. Test results were used for the modeling analysis.
- **Construction of Drilled Shafts and Lateral Load Tests:** The static inclined load testing on drilled shafts was designed to simulate the load-acting characteristics of drilled shafts used at the end of cable barrier systems.
- **Load Tests and Analysis of Test Results:** 12 drilled shafts were tested by applying tensile load at an angle of 16.1 degrees with the ground surface through a high tension steel bar (Dywidag Bar) and the tests were performed in both summer and winter simulating dry and wet seasons. Strain gages were attached on the Dywidag bar to measure the actual loads acting to the test shafts. Deflections of drilled shafts were measured by using both an inclinometer and MEMS-SAA system. Surrounding soil movements in the influence zone were also collected by inclinometer surveys. At ground level, digital dial gauges were used to measure horizontal and vertical movement of test shafts.

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Project Completed: 8-31-10

- **Design/Construction Guidelines of Shafts in High PI Clays:** The design charts for drilled shafts used in the cable barrier systems were developed by using the field test results and analytical models. Applicable models for lateral load and vertical uplift load predictions, such as Broms, CLM, p-y methods, Das and Seely, and O'Neill and Poormoayed models were analyzed and compared with the field results. Calibration factors for lateral load and vertical uplift from the most appropriate (best-fit) models were established. A design chart for the inclined load at the 16.1 degree angle was developed based on the calibration factors obtained from previous steps.

What They Found

Based on the research performed in the past two years, the following major findings are established:

- The designed test setup was successfully constructed and able to apply inclined load acting to the different sizes of test shafts. Also, this field load testing was successful in simulating the inclined loading mechanisms that transpired in the original distressed shafts.
- Comparison analyses of field results in summer and winter showed major variations in their loads versus displacement behaviors. The major differences in wet and dry conditions were the nature of the high-PI clay creating the uplift forces due to soil expansion as the moisture content was increased. In addition, the load-displacement pattern of test shafts in the winter condition showed semi-brittle response whereas the same displacements in the summer condition were close to rigid brittle type pattern.
- The equipment, MEMS-SAA, used to measure the data showed very good agreement with those recorded with the inclinometer system. The major advantage of the MEMS-SAA system was that it provided a complete load displacement data collection process. This was possible due to the use of the in-place and flexible MEMS-SAA probe which was able to provide a complete loading profile at the same time allowing users to retrieve back the unit after the completion of the test.
- Many models were used to compare vertical and horizontal load components with data collected in the field. The appropriate model for uplift capacity developed by Das and Seely provided reasonable results with an average ratio between the field test and the predicted results at 37% and the 'p-y' method using the LPILE program provided the best-fit results for lateral component with overpredictions by 21%.
- Design charts were developed based on the validated models for estimating inclined tensile forces. The load was estimated at the same angle as the cable barrier from lateral and uplift results for various drilled shaft dimensions. Steps were developed for future designing of shafts for cable barriers. These charts can be used for various deflection criteria.

What This Means

- Drilled shafts of various dimensions to resist various lateral deflections can be designed from the developed design charts for different inclined loads that can come from temperature and soil conditions at a given site.
- Expansive soils show the potential of volume change which can impact the performance of drilled shafts. In summer, losing contact between soil and the surface of the shaft from soil shrinkage leads to less skin friction though strength properties are higher in dry conditions. In winter, water can go into cracks between the shaft and soil, which increases the active depth of the soils around the shaft. Therefore, a concrete pad is recommended for reducing swelling and shrinking around the shafts.

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