LOUISIANA TRANSPORTATION RESEARCH CENTER

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Estimating Setup of Piles Driven into Louisiana Clayey Soils

INTRODUCTION

Geotechnical engineers and researchers (Seed and Reese 1955, Long et al. 1999, and Bullock et al. 2005) have reported for many years that the axial capacity of a driven pile may increase over time, which is usually referred to as pile setup or freeze. A recent example was reported by Tsai and Zhang (2008). For instance, shaft resistances of some driven piles at the LA-1 relocation project gained as much as 30 to 100 percent of the initial resistance during the first week of driving. Resistances of some piles in this project had significant growth even after 3 to 7 months (LADOTD 2008). As such, it is prudent to incorporate pile setup into the pile design.

Due to the relatively weak soils in the state, the Louisiana Department of Transportation and Development (LADOTD) has spent millions of dollars annually on pile foundations. The current LADOTD design practice is based on the 14-day resistance, ignoring any long term gain in resistance due to a lack of a systematic approach to handle this issue. As such, the pile design may be too conservative. Therefore, there is a need for developing a reliable design methodology that will account for the benefit of pile setup, so a more cost-effective pile design may be used in the future.

OBJECTIVE AND SCOPE

The objective of this research was to provide LADOTD engineers with a simple, rational, and accurate method for predicting the capacities of piles over time after driving in various soil conditions and to identify the factors governing the setup, relate the setup magnitude, and rate pile and soil types. Prediction of the ultimate pile capacity was to make pile foundation designers quantitatively aware of the potential benefit of pile setup and the setup time after the end of driving (EOD) for any expected pile capacity. The research work was done in an effort to provide some fundamentals for guideline-establishment in the future to economically design pile foundation by accounting for pile setup.

METHODOLOGY

The approach selected to solve the problem was based on a combination of a review of existing knowledge, collection of field testing data, a survey of pile setup practice in pile foundation design in different states, development of pile setup model, verification of the newly established models against available pile testing data, the application of the models to LADOTD pile foundation design, and the application of the load and resistance factor design (LRFD) method incorporating pile setup to pile foundation design. The semi-logarithmic pile setup equation of the Skov-Denver model to Louisiana soils was achieved based mainly on the pile restrike data of the production and test piles and static load testing data of the test piles at the LA-1 relocation project, which were driven into typical Louisiana soft clays. The pile capacity growth rate-based model was established as well to predict the ultimate pile capacity and the elapsed time after EOD until desired pile capacity was reached. In the case of the absence of pile restrike data at the reference time (e.g., 24 hour after EOD), empirical equations between the 24-hour restrike pile capacity and the calculated CPT log-based static pile capacity were provided to make pile setup prediction possible.

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CONCLUSIONS

The Skov-Denver model was established from the dynamic and static pile load test data collected at the LA-1 project site, and two synthetic prediction equations were developed. Distribution of the setup parameters A was analyzed and studied. Effects of various reference times were investigated on the test piles. A new growth rate-based pile capacity prediction model was proposed by estimating, analyzing, and examining the growth rate of the pile resistances. The model can provide the ultimate pile capacity.

The pile setup parameters A of the Skov-Denver model, with the reference time of 24 hours, mostly range between 0.5 and 0.7 from different data sources for the precast, prestressed concrete (PPC) piles driven into the typical south Louisiana clayey soils at the LA-1 relocation project. Selection of the reference time does not cause a large statistical variation of A values. The growth rate-based model offers the capability of predicting the ultimate pile resistances. The ultimate shaft capacities of the piles were about twice the measured shaft capacities at the 24-hour restrike. In general, the piles at the LA-1 relocation project reached about 90~95 percent of the ultimate shaft capacities at two weeks after installation. It should be noted that the prediction was made from the model that was established without a significant amount of long-term restrike data. There were only 24 restrike and load testing records acquired at or longer than 336 hours (two weeks) after the end of driving.
Empirical equations were established between measured skin friction at 24-hour restrike and the calculated cone penetration test (CPT) data-based skin friction, with the methods of the Laboratoire Central des Ponts et Chausees (LCPC), Schmertmann, and de Ruiter and Beringen, respectively. The relationship between the measured 24-hour skin friction and the calculated skin friction were presented as the measured skin friction versus the calculated skin friction, and the quad root of the ratio of the measured skin friction to the calculated skin friction versus the calculated skin friction, which gives a better correlation.

LRFD calibration was done to incorporate pile setup effect in pile foundation design. The resistance factors were calculated using the Mean Value First Order Second Moment (MVFOSM) method. The research employed the load statistics and the load factors from NCHRP Report 507 (Paikowsky et al. 2004), and the corresponding resistance factors for the Skov-Denver model and the rate-based model were very close, between 0.5 and 0.6 for the specified target reliability indices and the dead to live load ratios.

RECOMMENDATIONS

It is recommended that the developed prediction models be used to consider pile setup by pile foundation engineers in their design and construction work in different ways. The beneficial use of the predicted pile setup could avoid the unnecessary increase in pile length if the measured pile capacity does not meet the design requirement during dynamic testing for construction quality control. Pile setup predictions need to be constantly validated from field measurements. These models will continue to be modified and improved.

In order to implement the pile setup prediction in engineering practice, a detailed step-by-step implementation manual will help engineers become familiar with pile setup prediction procedures using the mathematical models. A one- or two-day workshop is suggested to be held for job training. A window-based software program, similar to the DRIVEN and the PileConeAnalysis, is developed to make pile setup computations simple and easy.

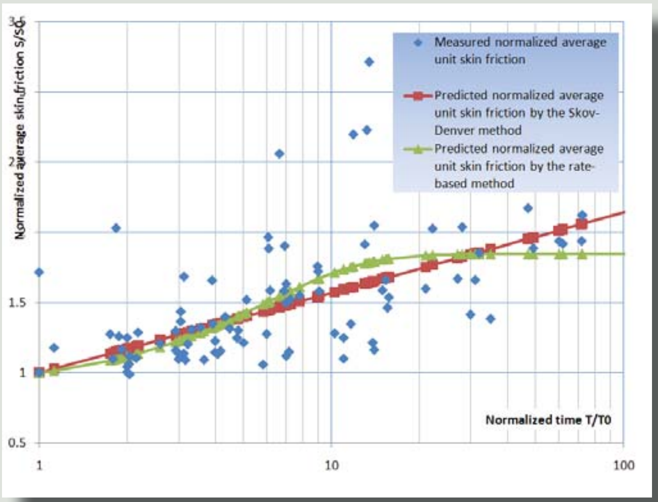

Figure 1
Normalized measured unit skin frictions and their predictions