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Executive Summary Report

Prediction of Pile Set-Up for Ohio Soils

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Project Background

ODOT typically uses small diameter driven pipe piles for bridge foundations. When a pile is driven into the subsurface, it disturbs and displaces the soil. As the soil surrounding the pile recovers from the installation disturbance, a time dependant increase in pile capacity often occurs. This phenomenon is referred to as "set-up" or "pile freeze". A significant increase in pile capacity could occur due to the set-up phenomenon. For optimization of the pile foundations, it is desirable to incorporate set-up in the design phase or predict the strength gain resulting from set-up so that piles could be installed at a lower *End of Initial Driving* (EOID) capacity. This project was undertaken to compile and evaluate the pile set-up data available for Ohio soils.

Study Objectives

Set-up is frequently observed in driven piles constructed in Ohio. ODOT has been collecting set-up information at different sites throughout Ohio. The proposed research was undertaken to characterize the set-up phenomena of piles in Ohio soils in terms of field parameters measured during pile installation. Alternatively, if it was determined that no significant change in strength occurred following pile installation in a particular strata, the objective was to provide all documentation to identify such conditions during the design phase.

Description of Work

The initial task was to identify published work related to pile set-up. A thorough literature search was conducted and the equations proposed for predicting set-up were identified. In order to address the set-up phenomena in Ohio geology, pile driving data in Ohio soils were obtained from ODOT and GRL, an engineering company dedicated to dynamic pile load testing, located in Cleveland, Ohio. The set-up data of twenty three piles was compiled along with time, pile length, pile diameter. The liquid limit, plastic limit, average clay and silt content, average SPT value were compiled along the pile length. The length and diameter of the piles varied from site to site.

In 91 % cases of the driven piles, some degree of set-up was observed. Correlations among several soil parameters and pile capacities were explored. Applicability of the Skov & Denver equation to compiled data was evaluated. The data was mostly scattered and no correlation was observed. However, the final and initial load capacities of the piles, and the time of restrike showed good correlation as a power function. An implementation protocol was developed to evaluate the parameters of the proposed correlation in the field.

Research Findings & Conclusions

The following conclusions were drawn from the analysis.

- The subsurface soil along the pile shafts at sites investigated were predominantly clay - silt mixtures, with larger silt fractions in most cases.
- Set-up occurred commonly in driven steel piles in Ohio soils. In 91% cases some degree of set-up was observed.
- Relaxation of piles occurred rarely. In about 9% cases relaxation was observed.
- The set-up primarily occurred at the pile shafts.
- The Skov & Denver 'A' parameter varied from 0.08 to 3.16 for the piles investigated. This equation was not applicable for set-up prediction of piles investigated.
- Pile set-up in general showed an increasing trend with increasing pile lengths. However, the data was too scattered for any meaningful correlation.
- There was no correlation between the 'A' values and the average clay content, LL, PI or *clay activity* along the pile shaft.
- No correlation was observed for 'A' values with the average silt content along the pile shaft.
- No set-up correlation was observed with the average SPT values along the pile shaft.
- No correlation was observed between the normalized shaft capacity increase and the restrike time.
- Effect of pile submergence on set-up not distinguishable.
- Strong correlations were observed between (Q/Qo)/t vs. t in terms of total and shaft capacities.
- The correlation for the total pile capacities was stronger than the shaft capacities.
- An equation for pile set-up in Ohio soils was developed for driven steel pipe piles, and shown to be applicable universally to all ODOT sites investigated.

- The EOID capacity of driven steel pipe piles under identical site conditions was shown to vary linearly with LD^2. However, additional research is required for further verification of this correlation.
- Based on the correlations developed, a design method for small diameter driven steel pipe piles has been proposed for the implementation of the research findings.

Implementation Recommendations

The correlation developed for pile set-up predicted the set-up of driven steel pipe piles at different ODOT sites with reasonable accuracy. An implementation plan of the research findings was developed. The proposed method requires driving of a *preconstruction test pile* at the site, and determination of EOID (*end of initial driving*) capacities at two different embedment lengths L_1 and L_2, which could be substantially shorter than the expected design lengths. Measurement of restrike capacity is also required to ensure occurrence of set-up. However, it is advisable that the developed correlation be verified at additional sites in Ohio before full implementation.