Housing Authority Research Fund

Project Title :
Study of Termination Criteria and Acceptance Criteria for Long Driven Piles including Jack Piles and Development of a Comprehensive Piled Foundation Database for Hong Kong Soils
(ref: CB20030027)

Summary of Report

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EXECUTIVE SUMMARY

Introduction

Termination criteria based on Hiley's formula may not be suitable for long piles due to some doubtful assumptions involved in the formula. This research project was dedicated to develop practical termination criteria for long driven piles based on the wave equation and for jacked piles based on results of field and centrifuge tests. The research was performed in connection with field works at five South East Kowloon Development sites. In these sites, approximately 6000 Grade 55C 305x305x223 kg/m steel H-piles were installed by driving and over 30 Grade 55C 305x305x180 kg/m steel H-piles were installed by jacking.

Use of Wave Equation Analysis

A methodology for the development of final set tables for long piles using the wave equation approach was proposed. Three major tasks were undertaken to substantiate the methodology and facilitate the implementation of the methodology. The first task was the determination of soil parameters for wave equation analysis. The second task was the validation of wave equation program GRLWEAP. The third task was the verification of performance of long driven piles final set by the wave equation approach. In this project, three preliminary piles were installed at the South East Kowloon Development sites based on final set tables derived from the wave equation and load tested. These piles passed all acceptance requirements set forth by the Housing Authority. In addition, performance data of 10 preliminary piles final set by other methods at the South East Kowloon Development sites and 12 preliminary piles at the Un Chau Street Development site were also used to verify the wave equation approach. The wave equation approach allows larger final set values than conventional driving formulas for long piles embedded in firm soil strata. It has been demonstrated that the use of the wave equation approach can resolve problems relating to final sets under such circumstances.

Hong Kong Driven Pile Database and its Applications

A Hong Kong Driven Pile Database has been developed in this project using Microsoft Access. The database contains information of over 1500 piles, with complete records of 308 static load tests, 1276 dynamic tests and 257 CAPWAP analyses. It is to date one of the largest pile databases in the world based on a literature review. The Database is equipped with search functions and includes design examples. Project teams can make use of the Database to obtain useful pile information in nearby sites or sites with similar subsoil conditions to assist them in feasibility study and pile design. Using the database, the Research Team has evaluated the reliability of pile capacity prediction by various dynamic methods as well as the accuracy of driving stress prediction by ICE (1954) and Bowles (1988), and by wave equation analysis.

Termination Criteria for Pile Jacking

Pile jacking is a piling method that introduces a noise- and vibration-free environment in the construction site. In this research project, field tests and centrifuge tests were conducted to study the termination criteria for pile jacking and understand better the behavior of jacked piles. A steel H-pile was instrumented, installed at a weathered soil site, and load tested. A set of proposed termination criteria was applied to the test pile, which included a specified final jacking force, a minimum of four loading-unloading cycles at the final jack force, and a

specified maximum rate of pile settlement at the final jacking force. The test pile passed the required acceptance criteria. Therefore the termination criteria are considered applicable to similar working piles in the site. The test results were used by the Housing Authority as a supporting document to substantiate an ICU submission on jacked piles.

Based on the results of the field tests at Southeast Kowloon, field tests in other sites in Hong Kong and Guangdong, as well as centrifuge tests in this study, a relation between the ratio of final jacking force to pile capacity, $P_J/Pult$ and the pile slenderness ratio is established. A regression equation is also established to determine the final jacking force. The recommended final jacking force can be smaller than 2.5 times the design load for very long piles, but may be larger than 2.5 times the design load for piles shorter than 42 times the pile diameter.

Centrifuge Modelling of Pile Jacking

Two series of centrifuge model tests were also carried out to investigate the effects of the pile penetration depth and the number of loading-unloading cycles on required final jacking force. These tests simulated the installation and loading behaviour of jacked piles 6.0 - 11.6 m long. The results of these tests supplement those from the files tests in which the pile lengths were in the range 34.8 – 41.1 m. Loading-unloading cycles at the maximum jacking load did not appear to cause noticeable changes in the behaviour of the long piles in the field tests, but did cause considerable pile penetration increment of the relatively short piles in the model tests.

Setup Effects of Long Piles in CDG

Setup effect in long piles driven in CDG was also studied in this project. A series of PDA restrike tests and static load tests were carried out on two preliminary piles up to 106 days after the end of driving. Setup in shaft resistance was observed while relaxation occurred at the pile toe. The setup factor A_i for completely decomposed granite was evaluated. The setup factor tends to decrease with depth. Residual stresses during and after pile installation, as well as load transfer in long driven piles were studied in detail as well.

Research Output

The output from this research project includes the Hong Kong Driven Pile Database, six technical reports, one draft ICU/BD Pre-submission Enquiry paper, nine technical papers for leading international journals or conferences in the area of foundation engineering and 4 public presentations.