

DISTRIBUTION OF SHAFT RESISTANCE FOR SINGLE DRIVEN PILE

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Abstract

This paper deals with the prediction of shaft resistance of single driven pile based on Meyerhoff formulation and empirical method based on SPT test. The accuracy of these predictions was evaluated by comparing the results with static load test (SLT) and dynamic loading test analyzed by Pile Driving Analyzer (PDA) and Case Pile Wave Analysis Program (CAPWAP) programs. The data for this study was collected from University Riau Hospital Project in Pekanbaru. The result of static and dynamic pile load test shows that only a small capacity of end resistance was mobilized due to insufficient pile deformation.

Keywords: *shaft resistance, shaft distribution, driven pile, PDA, CAPWAP.*

1. Introduction

Many methods have been developed to estimate the bearing capacity of pile. These methods can be grouped as analytical and empirical method. Analytical methods are subjected to the estimation of soil properties which rely on the quality of site investigation and the ability of engineer to interpret and select the data. Empirical method based on standard penetration test (SPT) was shown to give a better prediction on the shaft resistance of driven pile. However, there is still some uncertainties related to properties of soil as well as pile parameters, etc. Because of these difficulties, pile load test is still considered as the most

accurate method to estimate the pile resistance.

Pile bearing capacity comprises end bearing and shaft resistance. Determining the portions of end bearing and shaft resistance is a difficult task because mobilization of each resistance is subjected to different deformation. The deformation required to mobilize the shaft resistance is only 2% of pile diameter whereas deformation of 10% of pile diameter is needed to mobilize end bearing. Previous case study shows that only 2 – 5 % of the pile resistance comes from end bearings, thus shaft resistance plays an important role in bearing capacity of pile. The contribution of shaft resistance to the total bearing capacity of pile is a function of

many variables, such as the pile types, soil types and more importantly the deformation pattern of the pile itself under axial loading.

Most of the analytical approaches to predict the axial bearing capacity of piles rely on empiricism Randolph (2003), hence there is a need to verify the prediction with full scale static load test, SLT, Fellenius *et al.* (1992). Many types of static loading test have been introduced, including Maintained Load Test (MLT), Constant Rate of Penetration (CRP) and Osterberg Load Test (OLT). Many countries requires Maintained Load Test (MLT) to be performed on certain number of piles in a project site. The objective of pile testing with MLT include the determination of the load bearing capacity of the driven piles, the settlement and residual settlement of the pile under loading. Procedure for conducting the MLT on piles is presented in ASTM D-1143 – Standard Test Method for Piles under Axial Compressive Load. Previous studies proved that this test is reliable but very time consuming and expensive.

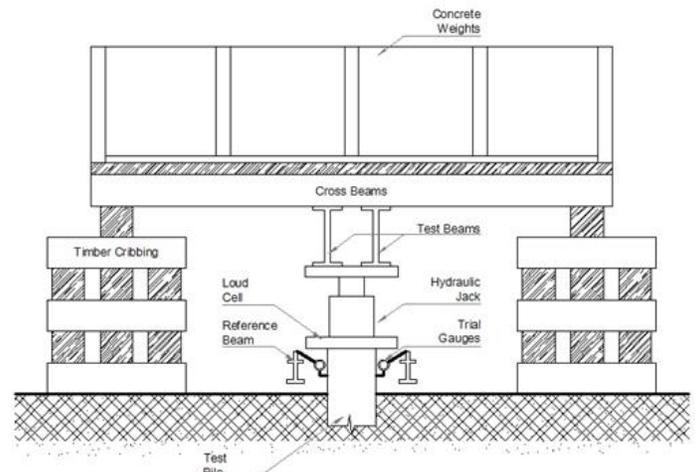


Figure 1. Schematic for Maintained Load Test. (Coduto, 2001)

A more recent development was the dynamic test which is relatively cost efficient, time saving and easy to perform. The test, provided by Pile Driving Analyzer (PDA) was developed based on wave equation analysis integrated in CAPWAP program. The PDA test is a quick test, thus; can be performed on more piles providing a bigger numbers of sample. Combination of this technique with dynamic monitoring of the pile during driving gives a significant effect on prediction of pile's bearing capacity and its distribution.

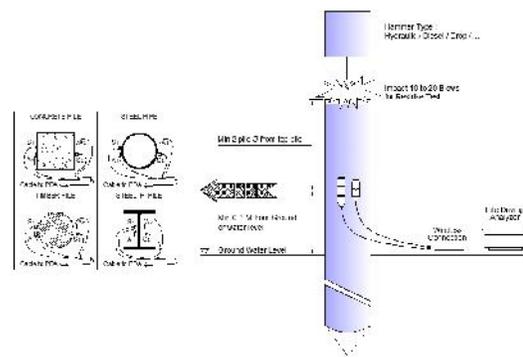


Figure 2. Schematic for PDA Test.

Dynamic testing requires measuring pile force and velocity during hammer impact and subjecting this data to a signal matching analysis to determine the soil behavior. Two types of instrument is required i.e. two sets of the strain gages, and from tests with the limited purpose of separating shaft and end bearing resistances through the tests for the purpose of detailing the shaft resistance distribution along the pile.

To obtain a reliable ultimate capacity from dynamic testing, some guideline must be followed, such as hammer weight, impact factor, etc to mobilize the full soil strength. As mention by Likins (2004), the recommended hammer weight is at least 1% of the required ultimate pile capacity to be proved for shafts installed in clay soils, and for the piles with larger expected end bearing contributions, the recommended percentage increases to at least 2% of the ultimate pile capacity to be tested. The

accuracy of data from PDA test is subjected to uncertainties with respect to the energy transmitted to the pile during testing.

This paper presents the prediction of shaft resistances and their distribution along the pile based on analytical method and SPT test. The accuracy of these predictions was evaluated by comparing with results of static load test (SLT) and dynamic loading test analyzed by Pile Dynamic Analyzer (PDA) and Case Pile Wave Analysis Program (CAPWAP) programs.

2. Methodology

The data for this study was collected from University Riau Hospital Project in Pekanbaru, Indonesia. It is an 8-story building driven pile foundation. The piles are 350mm diameter, and the piles are embedded to 12 to 14 m depth. Figure 1 and 2 shows the project location and subsurface profile respectively.



Figure 3. Project Location (Google map)

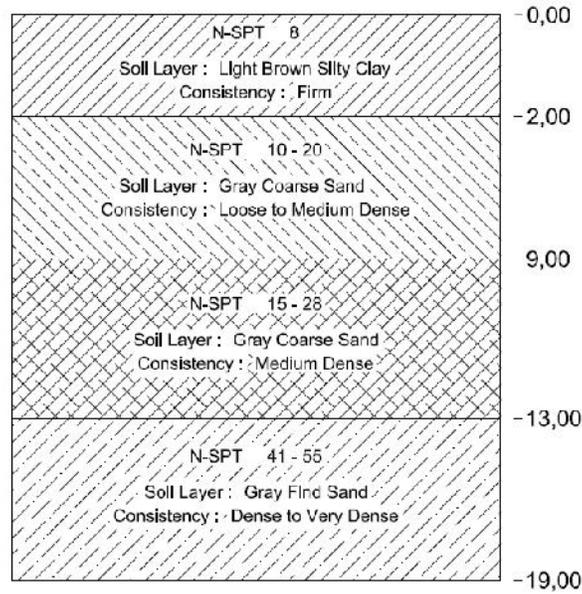


Figure 4. Soil Profile (SI Report of Hospital's Riau University)

Deep foundation transfer the axial load into the ground via two mechanisms; shaft friction and toe/end bearing. A part of the load will be transfer as a shaft/friction capacity along the pile and the rest will be transfer to the toe/end of the pile. By using the instrumentations (strain gauge and accelerometer) through the pile, we can determine the load, which is carried by the shaft at any depth, and the rest will be carried by the toe. The prediction of the end bearing(Q_2) and the shaft resistance(Q_1) along the pile from the top to the toe will be like that shown in Figure.3 below :

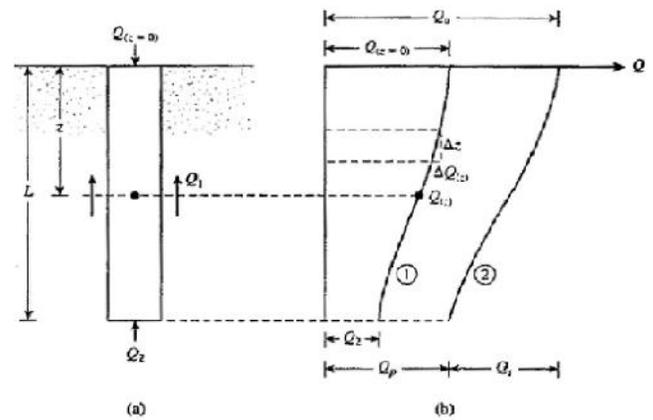


Figure 5. Typical Load Transfer (Das, 2007)

The unit shaft (f_z) resistance of the pile can be determine as the formula below :

$$f_z = \frac{\Delta Q_z}{P \times \Delta z}$$

Where :

P : perimeter of the pile

z : depth

The variation of unit frictional resistance at depth as shown in Figure 4 below :

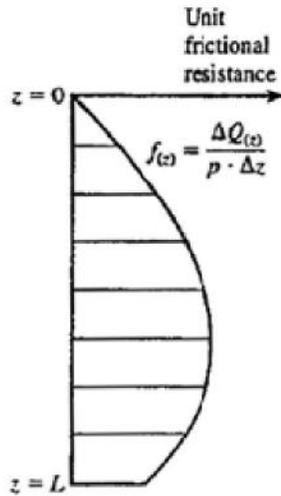


Figure 6. Variation of unit frictional resistance at depth (Das, 2007)

3. Results and Analysis

A. Comparison of Empirical Analysis (N-SPT) and PDA tests

According to Figure 5, shows the comparison of shaft resistance prediction between empirical analysis (n-spt method) and PDA tests, in general both of the predictions are reasonably consistent.

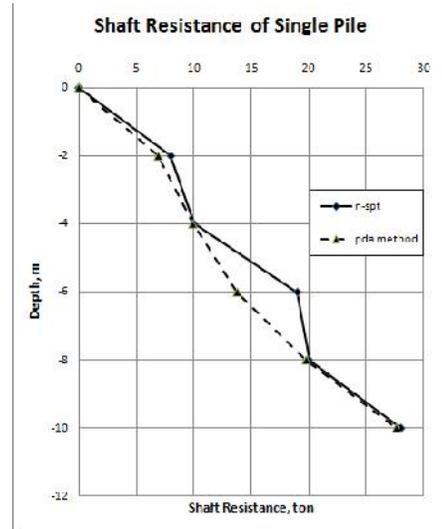


Figure 7. Shaft resistance of pile

B. Comparison between Static Load and PDA Test

There is a slight discrepancy around 5% in predicting the ultimate pile capacity between static load and PDA test, as mentioned in Figure 6. This could be attributed by non recovery of soil resistances after PDA test.

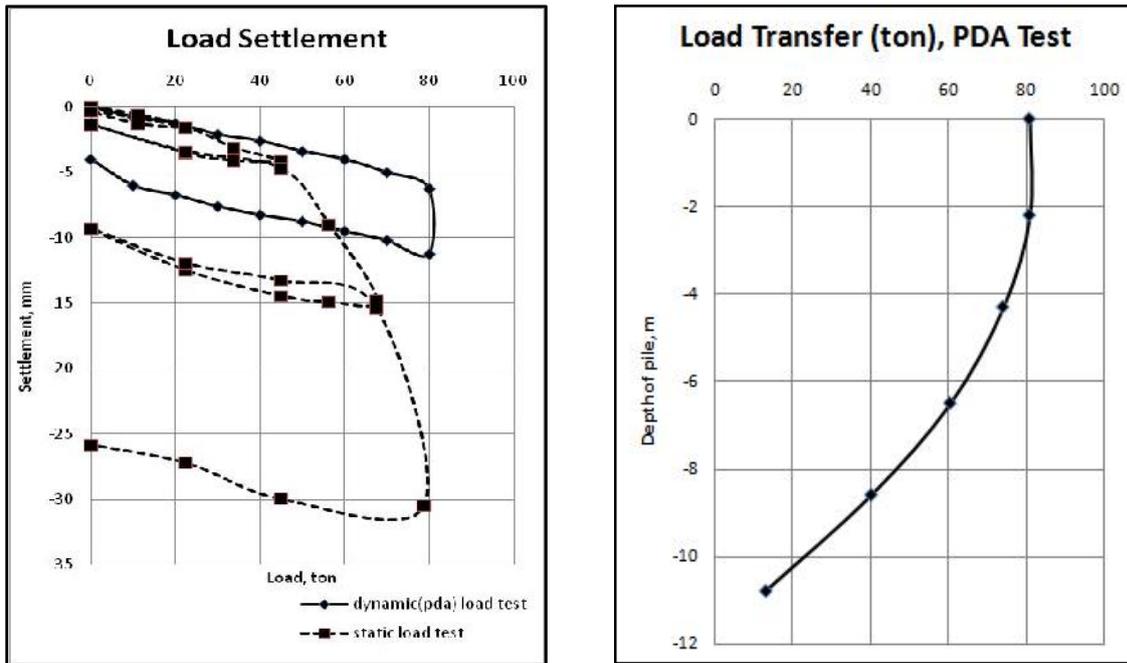


Figure 8. Load settlement and Load Transfer of pile

In figure 8, shows comparison of load settlement curves of the PDA and SLT test, where they both are reasonably comparable, except the PDA test indicates much stiffer response or less settlement at ultimate load rather than SLT test.

4. Conclusions

From the methods of calculation and types of loading test of pile, several conclusions can be made. The shaft distribution of the pile shaft resistance curve obtained from the empirical and dynamic load test are comparable and acceptance. Static Load Test and PDA Test shows that only a little capacity of end resistance was mobilized due to insufficient pile deformation

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