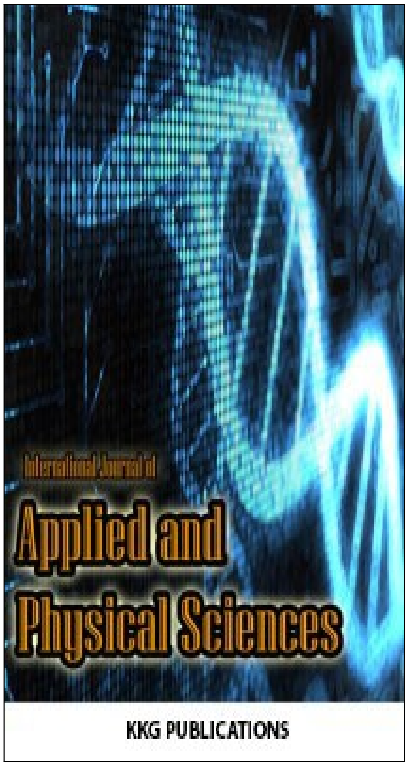

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Estimation of Pile Bearing Capacity of Single Driven Pile in Sandy Soil Using Finite Element and Artificial Neural Network Methods

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ESTIMATION OF PILE BEARING CAPACITY OF SINGLE DRIVEN PILE IN SANDY SOIL USING FINITE ELEMENT AND ARTIFICIAL NEURAL NETWORK METHODS

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Abstract. The good estimation of pile bearing capacity, derived by total axial pile bearing capacity, can be obtained through numerous empirical, analytical, and field tests. Thus, the application of the methods has been a difficult task due to the uncertainties of various factors related to the properties of soil and rock, which, unlike other engineering materials, are subject to spatial uncertainty. On the other hand, performing field tests such as static and dynamic load test is time-consuming and expensive; hence, finite element and Artificial Neural Networks (ANNs) methods are often of interest. This paper explains the finite element and ANNs methods to estimate the pile bearing capacity of sandy soil. The ANNs method is used to estimate the bearing capacity by using dynamic load test data. The outputs of finite element modeling were compared with a well-established empirical method for estimating the pile's ultimate axial bearing capacity. The results show that finite element and ANNs prediction on the percentage of the ultimate load is close to each other.

INTRODUCTION

There are numerous methods that have been developed to estimate the bearing capacity of a pile. These methods can be grouped as numerical, analytical and empirical methods. Numerical method is the most common method to analyze the complex Geotechnical construction problems. Numerical techniques are for approximation of the behavior of continua by assembly of small parts i.e. elements. The behavior of these piles acting in compression has been widely studied using numerical modeling. 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 the driven pile. The other methods proposed for development of Artificial Neural Networks (ANNs) model for prediction of the bearing capacity of a driven pile are based on the Pile Driving Analyzer (PDA) test data. However, there are still some uncertainties related to properties of soil as well as pile parameters, etc. Because of these difficulties, Static Load Test (SLT) of the pile is still considered as the most accurate method to estimate the pile resistance.

Recently, the application of Artificial Intelligence such as an Artificial Neural Network (ANN) is often used in Geotechnical engineering. Previous researchers such as [1] used ANN to predict the bearing capacity of driven pile from the PDA test result. [2] used ANN to predict pile shaft capacity from CPT and CPTu data. And many other researchers [3], [4], [5], [6], and the others) used ANN in Geotechnical engineering. Review of ANN application in Geotechnical engineering can be found elsewhere (e.g. [7]).

Most of the analytical approaches to predict the axial bearing capacity of piles rely on empiricism [8] hence there is a need to verify the prediction with full scale static load test [9]. Although SLT is reliable but this test is very expensive and time consuming, hence researchers have been trying to come up with other efficient approaches. Many studies [10], [11] have shown that PDA test result is in good agreement with SLT. On the other hand, nowadays due to developing friendly commercial software like PLAXIS, using finite element analysis for which the system is discretized into a number of meshes, to obtain axial capacity is of interest.

In this paper, the ANN will be used to predict the bearing capacity of driven pile. The ANN will be programmed in self-made program with special interface in order to make people easily operate it. The results of ANN prediction are compared with finite element method in this paper. Finally, the effectiveness of ANN and finite element method in predicting the bearing capacity of driven pile is discussed as a conclusion.

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FINITE ELEMENT METHOD

Finite Element Method (FEM) is the most common method to analyze the complex Geotechnical construction problems. FEM is a numerical technique for approximation of the behavior of continua by assembly of small parts i.e. elements. The behavior of these piles acting in compression has been widely studied using numerical modeling.

The analysis of pile bearing capacity is determined by the program software, PlAXIS-2D. PLAXIS is one of the most important software which is used in solving Geotechnical problems. This software is a finite element method based on a two-dimensional program in which the pile was modeled by axisymmetric. This software combines simple graphical input procedures, which allow the user to generate automatically finite element model with output facilities and calculation report. The problem is discredited into many meshes. The equitability and compatibility of each mesh, and the whole system will be examined.

The true advantage in using PLAXIS lies in its user friendliness. The input pre-processor and output post-processor are completely functional. The problem geometries in the PLAXIS are done easily with CAD-like drawing tools. Material properties and boundary conditions are easily assigned using dialogue boxes and a simple mouse click or drag and drop. Figure 1 shows the PLAXIS case of drawing and modeling.

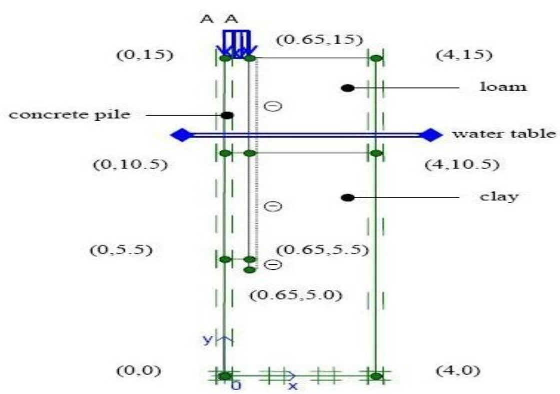

Fig. 1 . PLAXIS friendly interface for modelling

Once the geometry, material properties, and boundary conditions are set, the next step is mesh generation. Choosing the mesh generation tool in PLAXIS will fill each of the delineated polygon areas of the model with triangular finite elements. An example showing a complex mesh of finite elements is shown in Figure 2. This module allows the user to set up multiple chronological loading, excavation, or consolidation events. If the problem is a simple loading i.e. axially loaded pile, then the user would simply enter the load multiplier and the program would automatically step the load up to calculate the deformations.

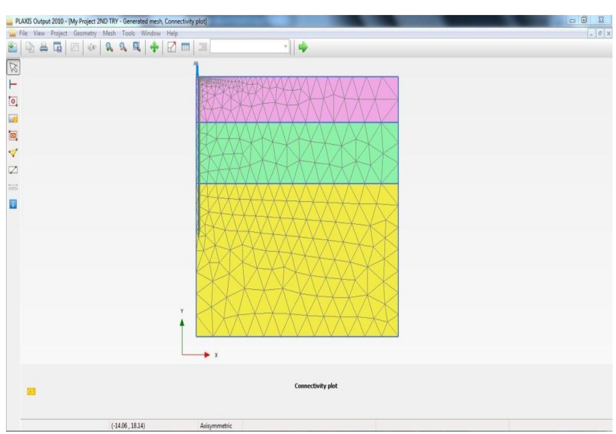

Fig. 2 . PLAXIS automatic mesh generation

Data Collection

The data used for this study were collected from various projects involving dynamic pile tests in Indonesia. The tests were performed using PDA test based on ASTM D 4945-08 and CAPWAP software for analysis of bearing capacity. Only high quality data from concrete pile were used in the study. Two hundred sets of high quality test data from the dynamic load test were selected for the subsequent study. The spun piles used in this study were circles with diameter between 300 and 500 mm and squares with sides between 200 and 400 mm. In this study, the piles were grouped into small, medium, and large diameter piles. There are 24 (12%) small (diameter less than 200mm) piles, 126 (63%) medium sized (diameter between 200mm and 400mm) piles and 50 (25%) large piles (diameter >400mm) (Table 1).

TABLE 1
GROUPING OF PILE DATA BASED ON DIAMETER

Group	Diameter	Number of piles	Percentage
Large pile	>400 mm	50	25%
Medium pile	200 - 400 mm	126	63%
Small pile	<200 mm	24	12%

The development of NN-HM model was made in order to obtain more accurate estimate of shaft resistance capacity of single Pile Driving Analyzer (PDA) test data. The architecture of the NN-HM model was developed based on the parameters as summarized in Figure 3. There are five parameters that were selected as input parameters for the subsequent study, i.e. piles equivalent diameter (D), embedment length (L), ram weight, (WH), Drop Height, (DH) and energy transferred (EMX). The target output variance for this study is total bearing capacity (Qt). These target values were obtained from the output of CAPWAP analysis.

There are two evaluation criteria for the training of the ANN model to get the reasonable and optimal results. The criteria are the correlation of Regression (R) and Mean Square Error (MSE). [4] used error back propagation neural network that was utilized to predict the ultimate bearing capacity of piles. [3] used sum of correlations and the average sum squared error to predict the axial pile bearing capacity.

In finite element method to predict the axial bearing capacity of piles, the soil profile in which the test is conducted is shown in Figure 4. In Geotechnical engineering, PLAXIS is one of the most widely used finite element software. The version 2010 of this program is capable of modelling static plane strain or two dimensional axisymmetric problems using 6 or 15 nodes triangular soil element.

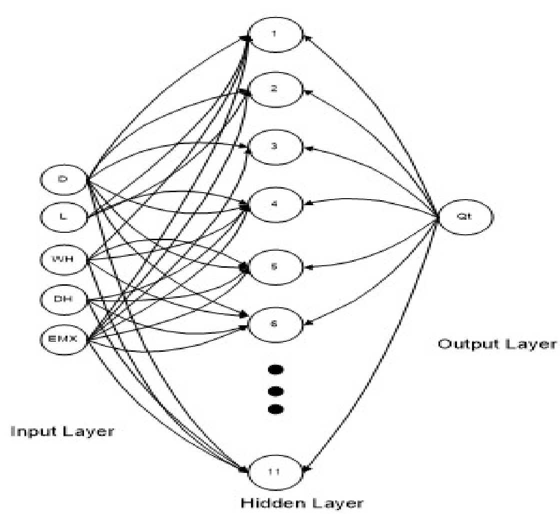

Fig. 3 . An architecture ANN model

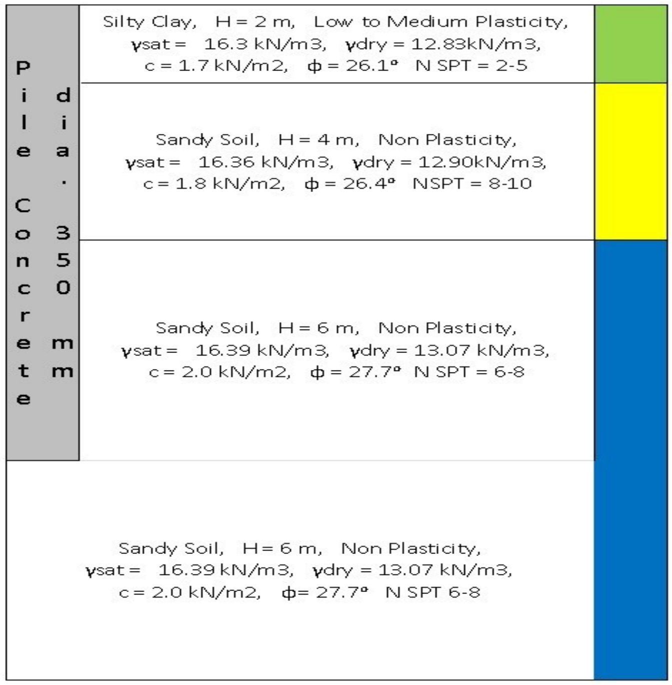

Fig. 4 . Soil profile and parameters

RESULTS AND DISCUSSION

Based on finite element method using PLAXIS Software, the analysis was performed. The maximum load obtained from Figure 5 which is 919 KN was considered for subsequent analysis.

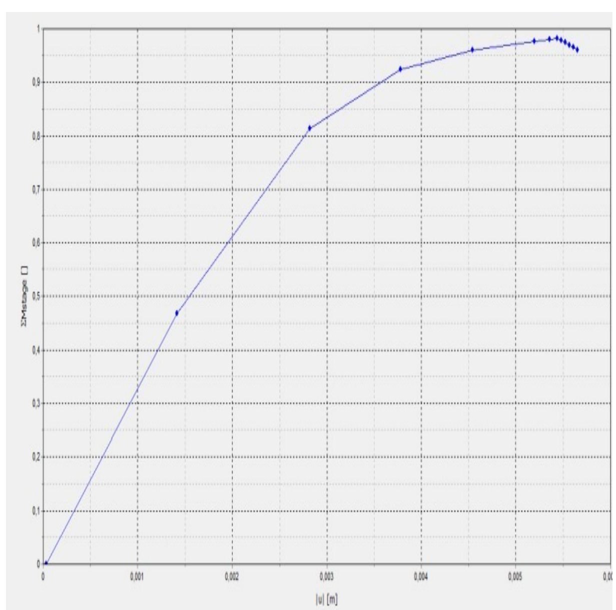

Fig. 5 . Load displacement curve of the study

Using Artificial Neural Networks (NN-HM) model, the training, testing and validation phase model of axial pile bearing capacity can be shown in Figure 6 below:

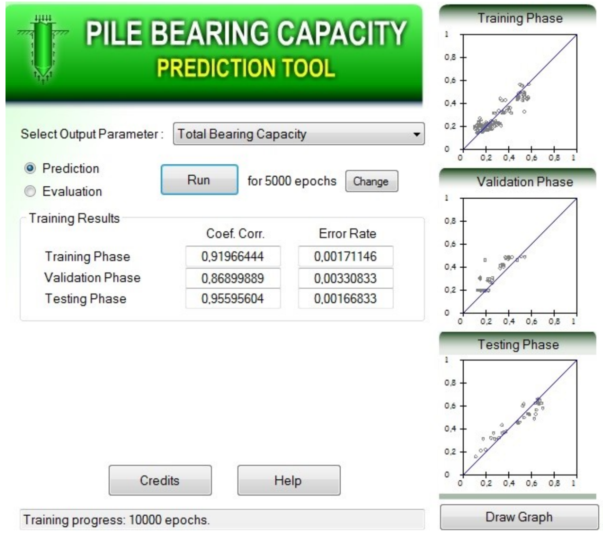

Fig. 6 . Neural network model result

Once the criteria of neural network model were achieved, such as coefficient of correlation value is about 1 (one) and error rate value is about 0 (zero), then the prediction of pile bearing capacity is shown in Figure 7 below:

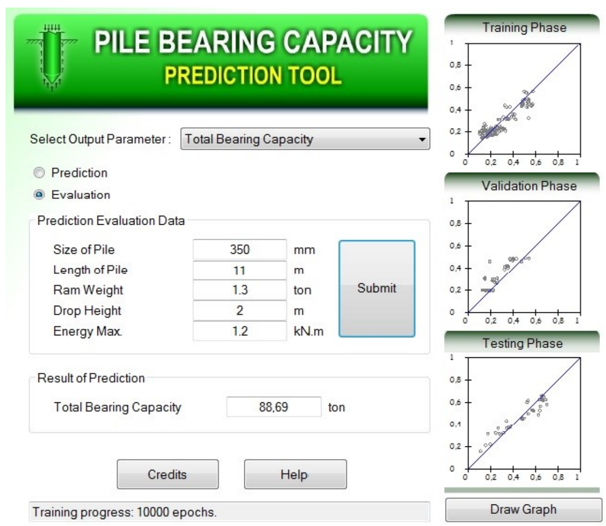

Fig. 7 . Prediction of axial bearing capacity of pile

The results of all methods are summarized in Table 2.

TABLE 2
COMPARISON OF THE PILE BEARING CAPACITY FOR PILE

Method	Total capacity, kN
PDA	919.0
Finite Element	886.9

CONCLUSION

Based on the results obtained from the analyses, the following conclusions can be drawn as follows:

- The result of finite element analysis shows that the ultimate axial capacity is in good agreement with the axial capacities obtained using other methods, such as PDA tests.
- From the PDA result, it is concluded that axial bearing capacity of piles obtained by means of the pile driving analyzer is quite variable, hence they must be validated with other reliable methods such as static load test.

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REFERENCES

[1] R. Nazir, E. Momeni, K. Marsono and H. Maizir, "An artificial neural network approach for prediction of bearing capacity of spread foundations in sand," *Jurnal Teknologi,* vol. 72, no. 3, pp. 9-14, 2015.

[2] H. Ardalan, A. Eslami and N. Nariman-Zadeh, "Piles shaft capacity from CPT and CPTu data by polynomial neural networks and genetic algorithms," *Computers and Geotechnics,* vol. 36, no. 4, pp. 616-625, 2009.

[3] W. T. Chan, Y. K. Chow and L. F. Liu, "Neural network: An alternative to pile driving formulas," *Computers and Geotechnics,* vol. 17, no. 2, pp. 135-156, 1995.

[4] I. M. Lee and J. H. Lee, "Prediction of pile bearing capacity using artificial neural networks," *Computers and Geotechnics,* vol. 18, no. 3, pp. 189-200, 1996.

[5] C. I. Teh, K. S. Wong, A. T. C. Goh and S. Jaritngam, "Prediction of pile capacity using neural networks," *Journal of Computing in Civil Engineering,* vol. 11, no. 2, pp. 129-138, 1997.

[6] E. Momeni, H. Maizir, N. Gofar and R. Nazir, "Comparative study on prediction of axial bearing capacity of driven piles in granular materials," *Jurnal Teknologi,* vol. 61, no. 3, pp. 15-20, 2013.

[7] M. A. Shahin, M. B. Jaksa and H. R. Maier, "Artificial neural network applications in geotechnical engineering," *Australian Geomechanics,* vol. 36, no. 1, pp. 49-62, 2001.

[8] M. F. Randolph, "Science and empiricism in pile foundation design," *Geotechnique,* vol. 53, no. 10, pp. 847-876, 2003.

[9] B. H. Fellenius, "The analysis of results from routine pile load tests," *Ground Engineering,* vol. 13, no. 6, pp. 19-31, 1980.

[10] G. Likins and F. Rausche, "Correlation of CAPWAP with static load test," in *Proceedings of the Seventh International Conference on the Application of Stress wave Theory to Piles 2004*, The Institute of Engineers Malaysia, Malaysia, 2004.

[11] N. Gofar and M. Angelo, "Evaluation of design capacity of bored piles based on high strain dynamic test," in *Proceedings of the 10th ISGE Annual Science Meeting*, Bandung, Indonesia, 2006.

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