VOL. 11, NO. 24, DECEMBER 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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THE MAPPING OF SOIL BEARING CAPACITY AND THE DEPTH OF HARD STRATUM FOR SUPPORTING PILE BASED ON N-SPT VALUE IN JAKARTA

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ABSTRACT

The type and the location where the stratum hold the foundation affect its bearing capacity value. This study aims to map the bearing capacity of the foundation and the distribution of the depth of the hard stratum to support it. To achieve those targets, this research uses the data in the form of soil investigation equipped with boring logs and N-SPT from several locations in Jakarta. The performed methods are: collecting, selecting, grouping and plotting the data location on Jakarta map. The data shows that the hard stratum is found about 10 meters depth in most places in Jakarta. The calculation of static empirical method are used to estimate bearing capacity of close ended-spun pile types with a diameter of 50 cm based on the data of N–SPT. The result shows that in West Jakarta has relatively larger bearing capacity compared with other regions which is about 100.04 to 194.55 tons, South Jakarta 69.36 to 177.1 tons, East Jakarta 59.16 to 188.5 tons, North Jakarta to 64.1 163.56 tons, and Central Jakarta 67.8 to 186.6 tons.

Keywords: pile foundation, bearing capacity, N-SPT, soil mapping of Jakarta.

INTRODUCTION

It is recorded in 2010, population in Jakarta reached 9.607.787 people, with the growth rate of 1.11% [1]. Increasing of population growth in Jakarta every time causes increasing of requirement in human space. Those requirements are fulfilled by the engineers with the construction of apartments, office buildings, hospitals and so on. Building projects and other civilian buildings in Jakarta are unavoidable necessities. Considering that each building requires a strong and stable foundation to carry the load the structure above [2], so that the selection of the type of foundation is clearly a critical factor in any development project. In the multi-storey building for example, the column reaction requires foundations with large bearing capacities for carrying this burden and distribute it to the hard stratum at a certain depth to produce optimum bearing capacity. The depth of the hard stratum surely affects the bearing capacity produced. The foundation of the building is generally divided into two shallow foundation and deep foundations [3]. If the hard stratum is located very deep, then the pile is an appropriate option to support the load.

Affandi, Diah, *et al.* [4] investigated that the hard stratum as a supporter of the foundation may have vary location in depth. A study by Asrurifak, M., *et al.* [5] investigated that the distribution maps of site class in Jakarta dominated by soft soil and medium soil and for North Jakarta is mostly dominated by soft ground. The dominated areas with soft soil tend to produce relatively lower bearing capacity. In addition, the engineering properties of the soil also affects its bearing capacity to support the load.

A series of investigations needs to be done in order to get clear information about engineering properties of soil so that the estimation of bearing capacity can be done better. The investigation consists of *in-situ* and laboratory test, to generate the properties of index properties and engineering properties of soil. *In-situ* tests commonly performed are DCPT (Dutch Cone Penetrometer Test) and drilling accompanied by SPT (Standard Penetration Test). The soil samples from the site were taken and brought to a laboratory to do geo-lab (for testing). The results of laboratory tests produce soil parameter values which are required in the design and analysis stage for the planning stage of foundation.

In recent years, the application of *in-situ* testing techniques has increased for geotechnical design. This is due to the rapid development of *in-situ* testing instruments, an improved understanding of the behavior of soils, and the subsequent recognition of some of the limitations and inadequacies of conventional laboratory testing [6, 7]. Although there are some problems on the explicit interpretation of the results of SPT, this test is the most frequent in-situ test in geotechnical practice because of its simplicity and affordable costs.

The objectives of this paper are to determine the distribution of soil bearing capacity on piles that are plotted on the map of Jakarta and to map of the depth of hard stratum for supporting the foundation in Jakarta based on N-SPT data taken as case studies. The mapping itself aims to facilitate the parties who need the data of bearing capacity Jakarta by giving preliminary information about soil. For the planner, the maps can be used as an initial overview prior for more detailed planning. As for the company which is executing soil investigations, the maps are also useful as an overview of the tools that might be used and carried to the site.

MATERIALS AND METHODS

In this research, several steps are taken to achieve the objectives of this study as shown in Figure-1. The flow charts shows several stages taken in this study.

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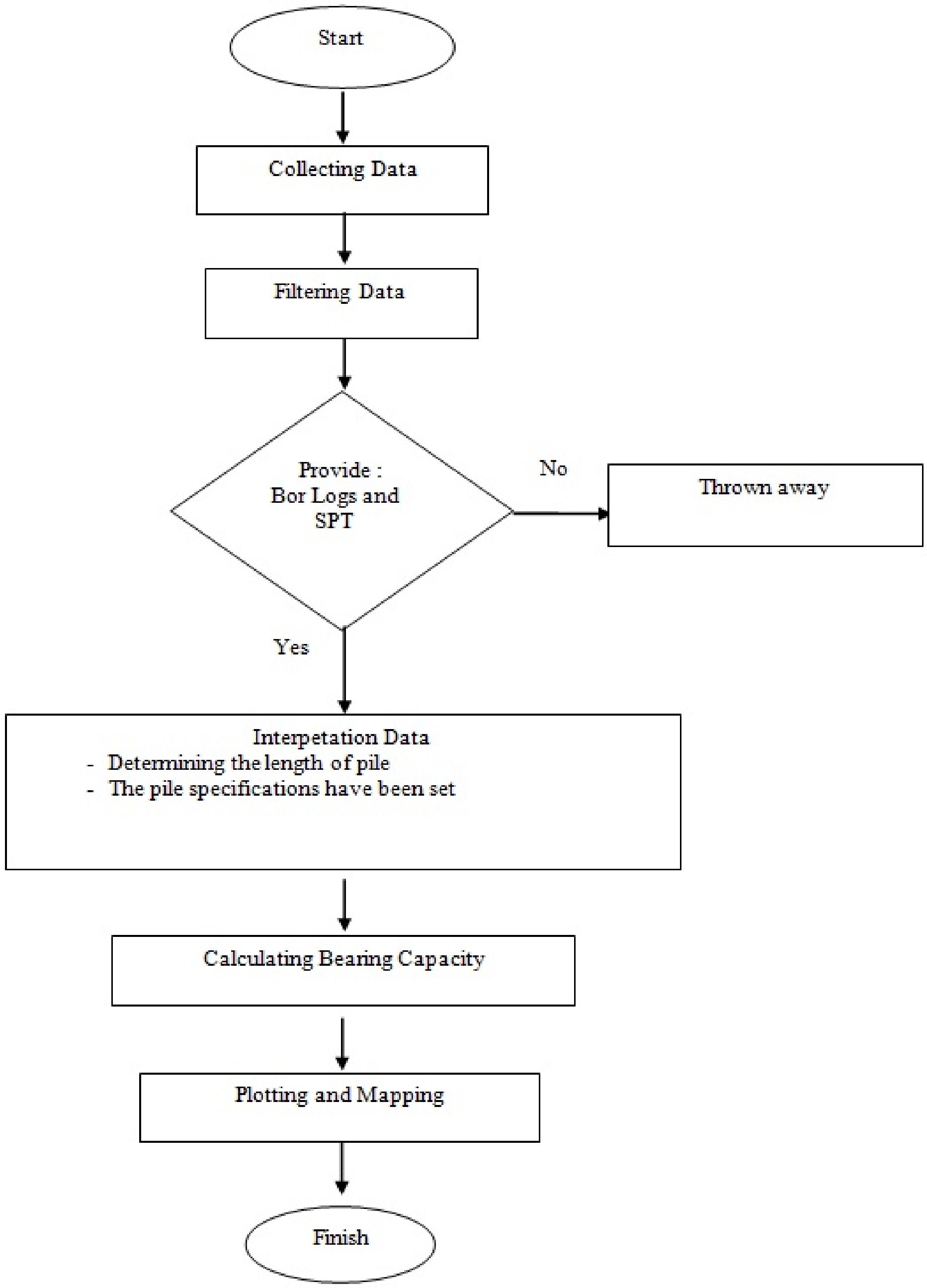

Figure-1. Flow chart of methods in this paper.

a. Collecting data: The data collected are the secondary data in the form of soil investigations from several sources which have been done before as a necessity in a construction project. The soil investigation is held before the construction process begins. It aims to get the engineering properties of soil. These properties will be used as the basis for the calculation of the bearing capacity. The soil samples taken in the field when the field tests then were brought to the laboratory for a laboratory test. The results of laboratory tests produce some quantities that determine the behavior of the soil. These quantities will be taken as consideration for estimating the bearing capacity.

b. Filtering data: The quality and completeness of the data are important in this research to support the validity of the desired results. Hence, it is necessary to do some filtering, so that the only data with good quality and completeness which can be used as the input in this research. The selection and validation of data as the filtering process are done by considering the following things:

- The soil investigation reports are located in Jakarta.

VOL. 11, NO. 24, DECEMBER 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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- The soil investigation must be equipped with the bore logs and the N-SPT, considering this study using SPT value as the basis for the calculation of the bearing capacity. The distribution data considered sufficiently representative each territory in Jakarta.
- Data without any drill assay results and the SPT can not be used (disposed) in this research.

All data which have passed the filtering stage is summarized and plotted onto the map of Jakarta. The distribution of soil investigations is shown in the Figure-2.

Figure-2. The selected soil investigation distribution in this study.

c. Interpretation data: The interpretation of soil in real conditions by observing the borehole logs is necessary to determine the presence of hard stratum to support the foundation. It is important, considering that the foundation must be driven on the hard and firm stratum. The hard stratum is indicated by the N value which is more than 30 [8]. The consistency of soil can be seen by reading of N-value in the SPT results. The correlation between the N-value and the consistency of the soil is given as follows:

Table-1. Correlation between qu-N-SPT (Terzaghi & Peck 1967).

Consistency	SPT-N	q_u (Kpa)
very soft	< 2	< 25
soft	2-4	25-50
medium	4-8	50-100
stiff	8-15	100-200
very stiff	15-30	200-400
hard	>30	>400

How depth the pile will be driven to the ground determines the length of pile used in the calculation. The length of pile may vary since the depth of pile driven depends on how depth the hard stratum is located.

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ARPN Journal of Engineering and Applied Sciences

However, the lens on the ground need to be taken as consideration in the determination of the length of the pile. The lens is a relatively thin bedrock which is located between the layers of soft soil. Therefore, the soil profile is required in decision of the pile's length needed. The determination of the pile's dimensions in this case concerns to cross-sectional shape and size of the pile that has been set, it's used Precast Concrete Reinforced Pile-Close End with a diameter of 50 cm.

Figure-3. The specification of pile used in this research.

d. Calculating bearing capacity: After determining the length of pile by observing the properties and its consistency of the soil, then the next step is to estimate the bearing capacity may bear in each location. The estimation of pile bearing capacity using static analysis method by reading the N-value attached in the soil investigation. The bearing Capacity of single pile consists of end bearing capacity and skin friction capacity. Meyerhof and Schmertmann proposed a method for estimating the value of end bearing and skin friction capacity based on N-value. The end bearing capacity is calculated just in the layer where the pile tip terminates. The equation is given as follows :

$$Q_P = Ap. \, qd \quad (1)$$

Where;
Qp = End bearing capacity (ton)
Ap = Cross-sectional area of the pile (m^2)
qd = average resistance of the pile , valid value 40.N (ton / m^2) for Sand and 20.N (ton/ m^2) for Silt / Clay .

N value is an average value of N at the tip of the pile and the value of N along 4D (four times the diameter) of pile. It is calculated from the end of the pile [9].

$$N = \frac{N_1 + \bar{N}_2}{2} \quad (2)$$

Where ;
N1 = N value at the tip of the pile
N2 = the value of N along 4D (4 times of the pile diameter from the tip)

When a pile lengthen through a number of different layers of soil with different behaviour, the skin friction capacity is calculated by simply summing the amounts of resistance each layer exerts on the pile.

$$Q_S = \Sigma \, P . \, f_i . \, L_i \quad (3)$$

Where ;
Q_s = frictional resistance (ton)
P = circumference blanket cross-section pole (m)
fi = shearing friction resistance (ton/ m^2)
Li = length of the pole segments are reviewed (m)

The value f_i is a fifth of the value of the reading N (N/5) or a maximum of 10 ton/m^2 for Sand; and equal to the reading N or a maximum of 12 ton/m^2 for Silt/Clay [9]. With N is the average value of N along the pile.

The ultimate bearing capacity is the theoretical maximum pressure which can be carried without failure. In general the ultimate bearing capacity of the pile to carry axial load can be calculated by a simple equation which is the sum of the end bearing capacity and skin friction capacity. The general form of ultimate bearing capacity can be expressed as :

$$Qu = QP + QS \quad (4)$$

Where,
Qu = ultimit bearing capacity (ton)
Qp = End bearing capacity (ton)
Qs = Skin friction capacity (ton)

By submitting the value of the safety factor, the allowable bearing capacity of single pile will be obtained. Meyerhof suggested 3 as the value of the safety factor for the end -bearing capacity and 5 for skin friction capacity. It is the maximum extra pressure (in addition to initial overburden pressure) that a foundation soil can withstand without undergoing shear failure.

$$Q_{all} = \frac{Q_p}{SF\,1} + \frac{Q_s}{SF\,2} \quad (5)$$

Where,
Qall= allowable bearing capacity (ton)
Qp = End bearing capacity (ton)
Qs = Skin friction capacity (ton)
SF1 = 3 (safety factor value of the end-bearing capacity)
SF2 = 5 (safety factor value of the skin friction capacity)

e. Plotting and mapping : after the allowable bearing capacities are obtained these values are summarized and used for mapping. The mappings are performed include: the mapping of bearing capacity and the mapping of the depth of hard soil as a support of foundation which are plotted on a map of Jakarta as shown in the figures below.

 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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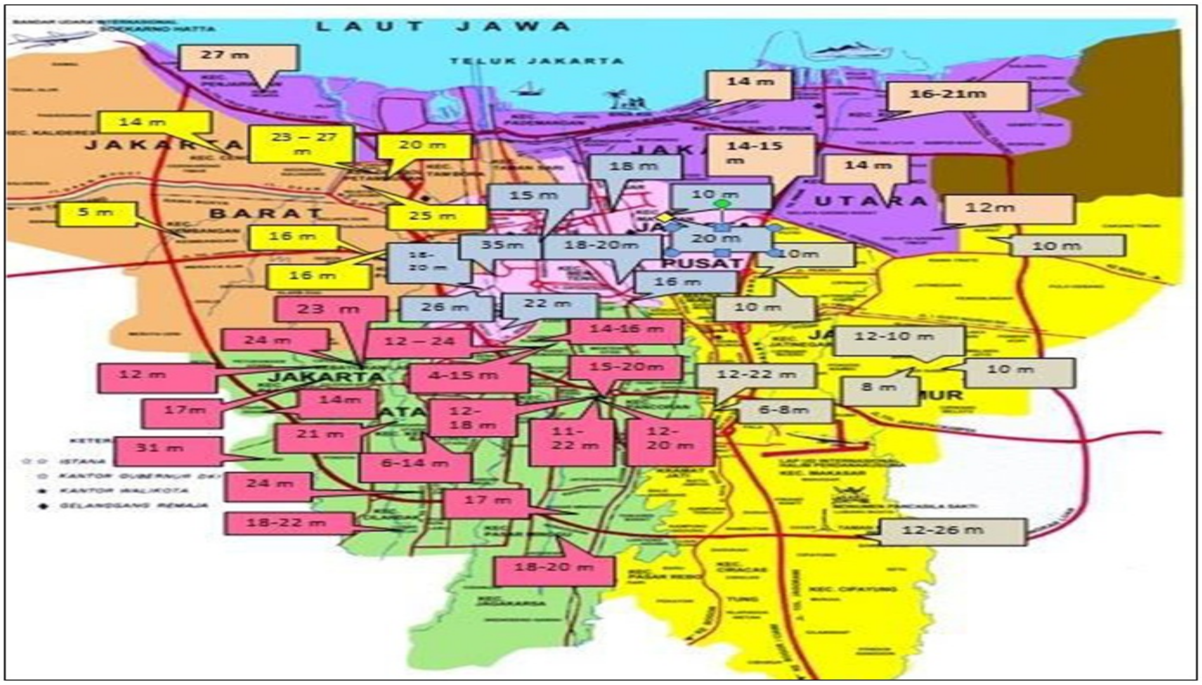

Figure-4. The depth of hard stratum to support pile based on N-value in Jakarta.

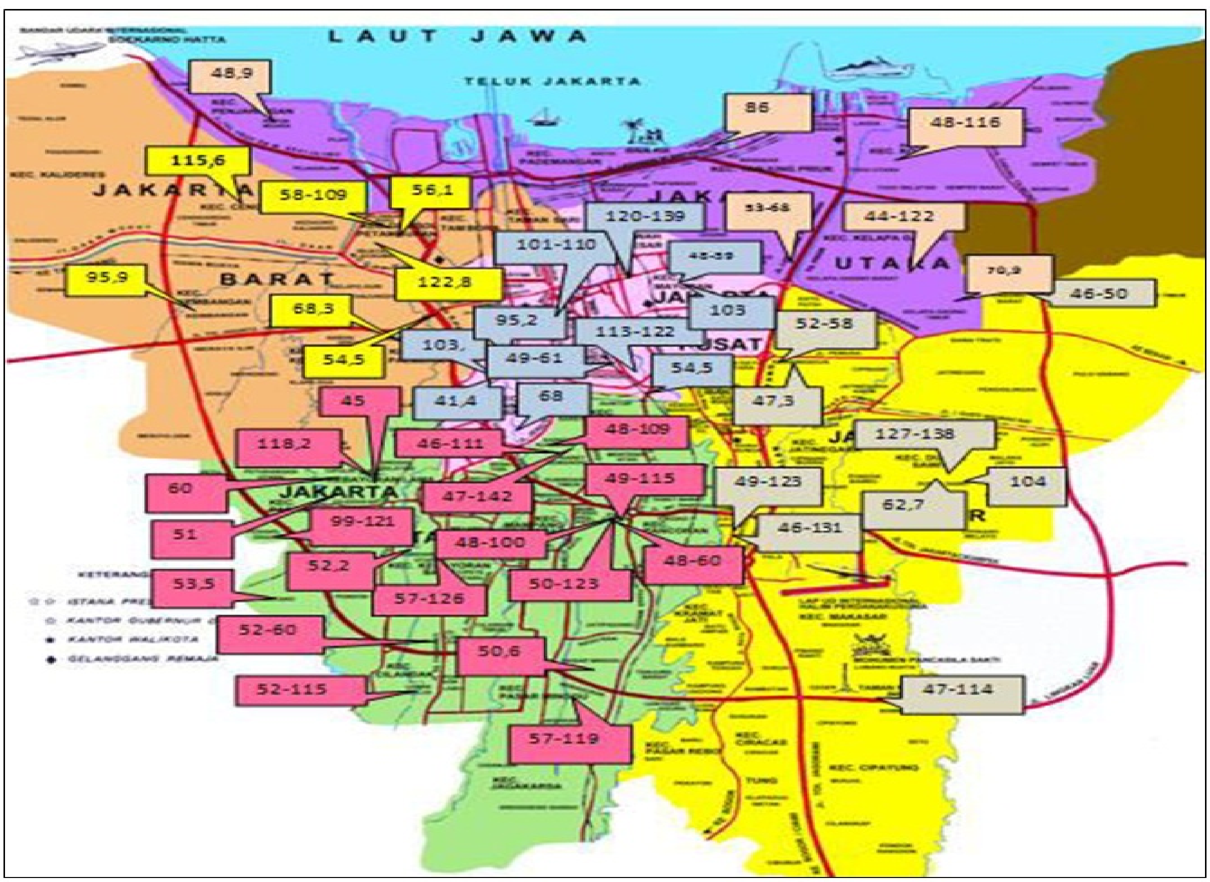

Figure-5. The distribution of end bearing capacity of single pile in Jakarta (tons).

VOL. 11, NO. 24, DECEMBER 2016 ISSN 1819-6608
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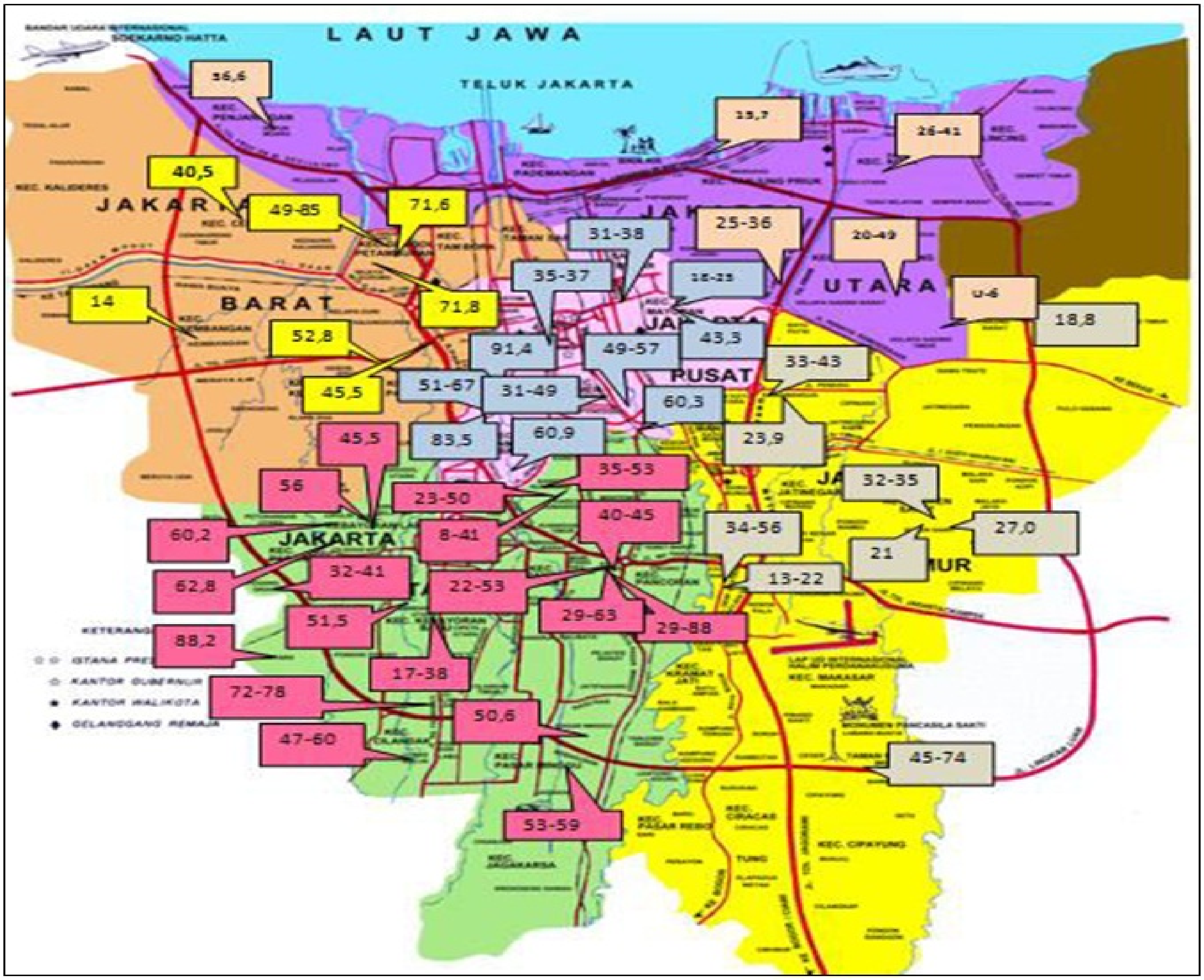

Figure-6. The distribution skin capacity of single pile in Jakarta (tons).

RESULTS AND DISCUSSIONS

The length of pile (L) is determined by the depth of the hard stratum to support the pile. By observing the soil profile, referring to the N-values and its correlation to the consistency of the soil, the depth of hard stratum required can be set. The table below presents the results of observations of the hard stratum in Jakarta by using the data in the case of N-SPT used as study.

Table-2. The range of pile penetration's depth in Jakarta.

No	Region	Min. Length (m)	Dominant Length (m)	Max. Length (m)
1	West Jakarta	5	10 - 20	27
2	South Jakarta	4,5	10 - 27	31
3	East Jakarta	6	10 - 20	26
4	North Jakarta	12	12 - 20	27
5	Central Jakarta	10	10 - 20	35

Based on the depth distribution of hard strartum, it generally can be explained as follows:

1. The hard stratum was found at a depth $L \leq 10$ meters:
   - West Jakarta: it's generally found about 10-20 meters in depth, while in Kembangan it is found that hard stratum encountered at the depth of 5 meters.
   - South Jakarta: Kebayoran Baru, Pancoran and Sudirman.
   - East Jakarta: Duren Sawit, Cakung and Rawamangun.
   - Central Jakarta: at Kemayoran.
   - North Jakarta: **-**

2. The hard stratum was found at a depth $10 \text{ m} < L \leq 20$ m:
   - West Jakarta : Mostly found in all locations, except Grogol and Petamburan
   - South Jakarta : Pancoran, Pasar Minggu, Lebak Bulus, Sudirman, Kuningan, Kebayoran Lama dan Kebayoran Baru.
   - Jakarta Timur : Cawang, Rawamangun, Pinang Ranti dan Duren Sawit.

- Jakarta Utara : Tanjung Priuk, Kelapa Gading dan Koja.
- Jakarta Pusat : Menteng, Gambir, Gunung Sahari dan Kemayoran.

3. The hard stratum was found at a depth 20 m < L ≤ 30 meters:

- West Jakarta : Petamburan.
- Soutth Jakarta: Kebayoran Lama, Kebayoran Baru, Cilandak and Pancoran.
- East Jakarta : Cawang and Pinang Ranti (about 22–26 m).
- North Jakarta : Kapuk Muara and Tanjung Priuk.
- Central Jakarta : Tanah Abang at Jalan K.S Tubun - Petamburan and at Jalan Danau Tondano – Bendungan Hilir.

4. The hard stratum was found at a depth 30 m < L ≤ 35 meters:

- South Jakarta: Bintaro.
- Jakarta Pusat : at Jalan Fachrudin – Tanah Abang.

The length of pile is not directly proportional with the bearing capacity of pile generated. In some cases, the area with shallow depth of pile penetrated generates bigger bearing capacity the area with deeper in depth. Since beside the length of pile, the bearing capacity is also affected by the type of soil and its consistency at the end of the pile and along its skin. The table below shows the estimation of allowable bearing capacity from single pile with diameter of 50 cm driven in several locations in Jakarta.

Table-3. Allowable bearing capacity of single pile in Jakarta (with diameter of 50 cm).

No	Region	Allowable Bearing Capacity [Tons]		
1	West Jakarta	100	to	195
2	South Jakarta	69,36	to	177
3	East Jakarta	59,16	to	189
4	North Jakarta	64,1	to	164
5	Central Jakarta	67,8	to	187

From the interpretation of N-values, it is indicated that the hard stratum mostly can be found at a depth of 10 m to 20 meters. However, in some areas, the depth of the hard stratum is not in that range. For example in Kembangan-West Jakarta, it is found that hard stratum encountered at a depth of 5 meters. At Petamburan, the hard stratum can only be found at a depth of 25-27 meters.

At Cawang - East Jakarta, the bedrock was found at a depth of 6,0 to 8.0 meters. In other sites the bedrock is found the depth range between 12.0 m to 18.0 meters. However, the soil with N-SPT > 30 was found at a depth of 26 meters at Pinang Ranti. Actually, at a depth of 8 meters, ground has shown very stiff, indicated by N-SPT of 37 but the deeper, N-SPT shows that its consistency becomes down to medium.

In South Jakarta, the soil investigation shows the bedrock was found at a depth of 4.5 meters at Senayan-Kebayoran Baru. Whereas at Bintaro, the hard stratum can be found after a depth of 31 meters.

While in west region of North jakarta precisely in the area of Muara Kapok, a layer of hard soil can only be found at a depth of 27 meters. Upper layer on this land consists of very soft soil shown by N-SPT < 1 with 8 meters of thickness. By analyzing the soil profile at the borhole logs in this point, it is found a lens showing by N-SPT of 49 and 1.5 meters only of thickness.

In Central Jakarta, the hard stratum can be found in the range of 10.0 m up to 22.0 meters. But there is one data showing that the bedrock at a depth of 35 meters which is located in Tanah Abang near the Central Jakarta.

CONCLUSIONS

So far, there's an assumption that the area of south Jakarta have larger ability to bear the burden of structure than others. Furthermore, it's alleged that North Jakarta have relatively lower capacity compared to other regions. However, the calculation results show that a location in South Jakarta have relatively small capacity (at Cawang-East Jakarta about 59.12 tons) while in the North Jakarta may support relatively larger capacity (at Kelapa Gading- North Jakarta about163.56 tons). The results show that even in northern areas is dominated by soft soil, but it is still possible to have a large bearing capacity.

ACKNOWLEDGEMENTS

This work was supported by Mercu Buana University, Jakarta, Indonesia. Several discussions and interviews were held with lecturers and practitioners construction. As it is impossible to list all these individuals, their assistance is gratefully acknowledged.

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