Numerical Study of Negative Skin Friction Development on Pile Constructed In Soft Clays

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Abstract— East Bandung area is in the basin area of Bandung which has a soft soil layer that is very deep and very compressible. Pile is used in one of the buildings in the development area of East Bandung. If the soft soil is deep enough and considerable decline due to consolidation, Negative Skin Friction (NSF) will occur on the pile. This paper will research the negative skin friction on pile using numerical methods. Based on the OCR, soft clay soil has degree of consolidation around 80%, this indicates that the location is underconsolidated. The neutral point is at a depth of 11 m, then as time goes by the neutral point deeper into a depth 18 m for 5 years, this indicates that the NSF's neutral point will change by time.

Index Terms— Negative Skin Friction, Soft Soil, Underconsolidated Soil, Pile

1 Introduction

INFRASTRUCTURE in Indonesia is growing rapidly. Where the distribution of soft clays in Indonesia is very widespread. One example of infrastructure development in Indonesia is the development of the East Bandung area in West Java. Where the development of the area will be made as a tourism area, education, and flood control.

The East Bandung area is located in the basin area of Bandung which occurs due to precipitation from volcanic rocks and lake sediments. However, these areas have very deep compressible layer. Therefore, the development of the East Bandung area is the background of this paper.

Pile is used in construction in one of the buildings in the development of the East Bandung area. However, issues need to be addressed in the planning and implementation of pile that are often carried out on pile. If the soft clays layer is deep enough then the pile will downdrag or called Negative Skin Friction (NSF) because of downward movement of soil relative to the pile.

Negative skin friction will occurs additional compressive force on the pile. Failure that often occurs due to negative skin friction is the detachment of the foundation from the pile cap. Thus, the calculation of negative skin friction needs to be considered in the design of the pile.

According to Poulos & Davis (1980) the magnitude of the downdrag on the pile is caused by several factors:

- Characteristics of piles, installation method, pile length, shape of cut, surface treatment.
- Soil characteristics, shear strength, compressibility, depth of soil layer, stiffness of the layer at the end of the pile.
- Causes of soil movement.
- Time of pole installation.

Johannessen & Bjerrum (1965) states that the downdrag can cause the design load to be exceeded. So that there is an additional settlement on the pile and causes the pile to crack.

According to Briaud & Tucker (1993), the criteria that need to be considered in the presence of negative skin fractions are:

- The total decrease in the soil surface is estimated to be more than 100 mm.
- Settlement at ground level after pile erection will be more than 10 mm.
- The height of the embankment that will be placed on the existing surface is more than 2 m.
- The thickness of the compressible soft soil layer is more than 10 m.
- Decreased groundwater level of more than 4 m.
- Piles over 25 m long.

Where if one of these criteria is fulfilled, then the magnitude of the negative skin expression needs to be considered.

Calculations of negative skin friction can be done by empirical or numerical methods. In this paper, studies on the development. of negative skin on piles will be carried out using numerical methods, which can be better for soil structures interaction simulation.

2 Analysis Procedure

2.1 Finite Element Method

Finite element method is based on the concept of discretization an element into smaller elements to make it easier to review. With finite element, numerical modeling can be used for various engineering field.

This paper used Plaxis (2D) for finite element software, with software can be obtained the amount of deformation and stability. Modeling uses axisymmetry, which is symmetrically modeled on an axis. The analysis stages as follow:

- Initial condition, this stage describe the existing conditions before construction.
- Fill material installation.
- Pile installation.
- Consolidation 1 year, 3 year, and 5 year after pile installation.

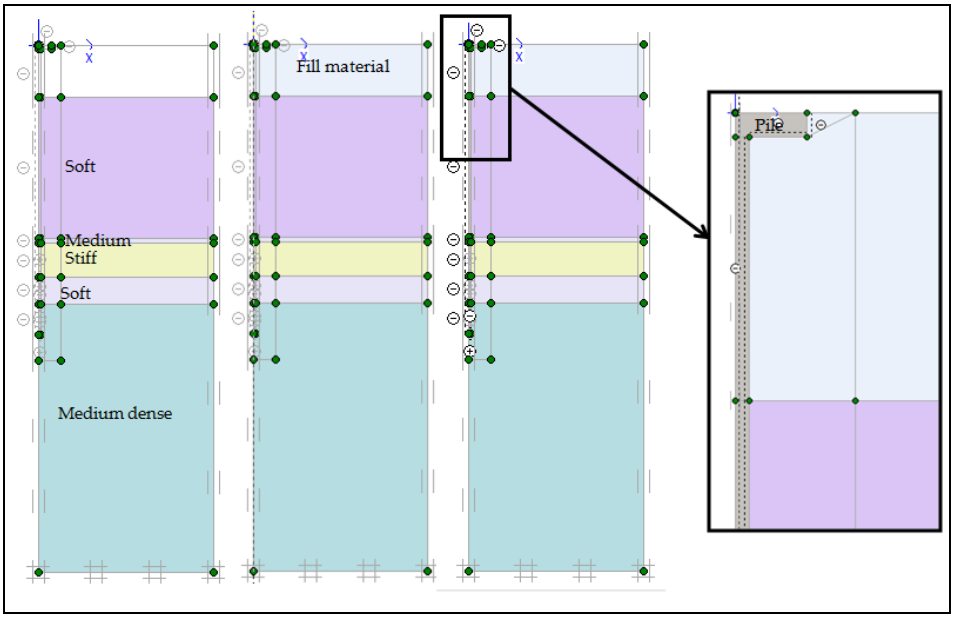

Fig. 1. Stage of Analysis

2.2 Interpretation of Data

It is necessary to determine the parameters and interpretation of the data in advance so that it can obtain analysis results that are in accordance with the actual situation. Identification of soil behavior needs to be done before determining parameters and doing calculation.

The degree of consolidation needs to be known to find out whether the soft soil layer is still consolidating. Setionegoro (2013) has done a research of the relationship between Bq to OCR. Rahardjo et al (2015) in his research has made a curve of the relationship between Bq and OCR modified from the results of Setionegoro, 2013) so that calculations can be made more easily. Equation as follow:

$$OCR=1/((1.2Bq+0.1)) \quad (1)$$

3 Data And Analysis

Based on soil investigation data, the average soil type on the surface is very soft silty clay, the average thickness of the soft soil layer is 22 meters depth, there is a sand layer under soft soil.

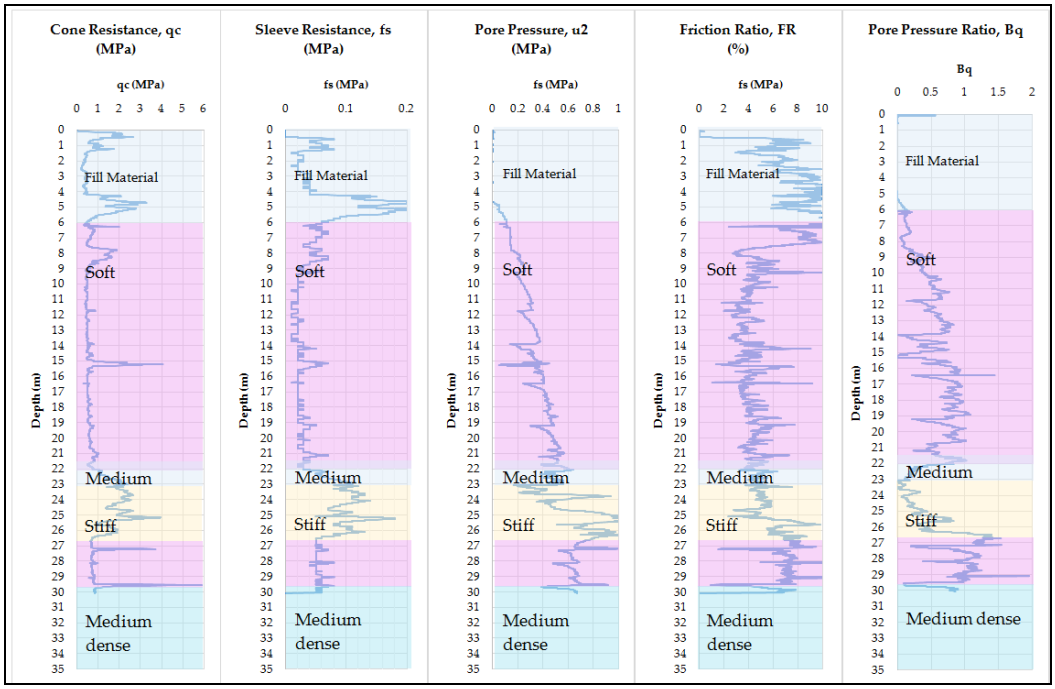

Fig. 2. Soil Layer Based On CPTu Data

Soft soil is a cohesive soil that has a low shear strength, low bearing capacity, and low permeability. Soft soil can be determined based on the NSPT value, where soft clay has an N-SPT value ≤ 4.

3.1 Degree of Consolidation

OCR values can be determined based on the Bq value so that the relationship between OCR and the depth curve can be obtained. Based on the OCR value it can be seen that the soil is underconsolidated. Therefore, in the analysis the construction begins when the soil is still consolidating 80%.

The pile installed at the location is 60x60 cm with 33 m length. Pile modeling uses axisymmetry with cluster and linear elastic model material and non-porous type material. Based on CPTu data, there was fill material installed with 6 meter depth. Therefore, the amount of settlement caused by fill material can be obtained.

3.2 Neutral Point Based On Settlement

Neutral point can be obtained based on the settlement curve of the pile intersect with settlement curve of soil. Based on the analysis of the pile, downward movement of soil relative to the pile, this condition indicates that the pile has NSF. Based on the settlement curve, it can be seen that the position of the neutral point deeper with time to 18 m depth.

At the end of construction, there was no negative skin friction. However, in the 1st, 3nd and 5rd year even though there was no additional load around the pile, up to the 5th year the magnitude of the negative skin friction was still exist.

3.3 Neutral Point Based On Shear Stress

Shear stress can be determined based on analysis, when the shear stress curve reverses which is a neutral point, then the amount of NSF can be obtained. The amount of NSF to time range 56 kN to 595 kN for 5 year, this value is an additional load on the pile. At locations above the neutral point there will be a NSF which causes additional load on the pile. At the bottom of the neutral point, skin friction resistance and end bearing resistance will occur.

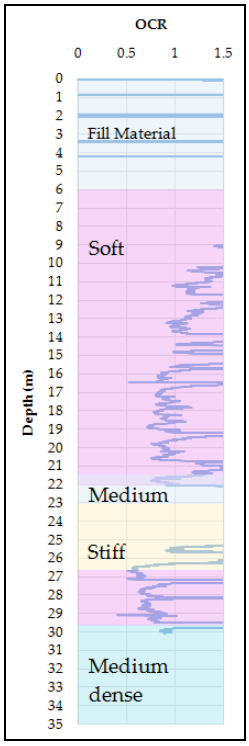

Fig. 3. Over Consolidated Ratio

3.4 Load Transfer Curve

Load transfer curves show that the bearing capacity works at depths below the neutral point, which ranges at 11 m to 18 m depth.

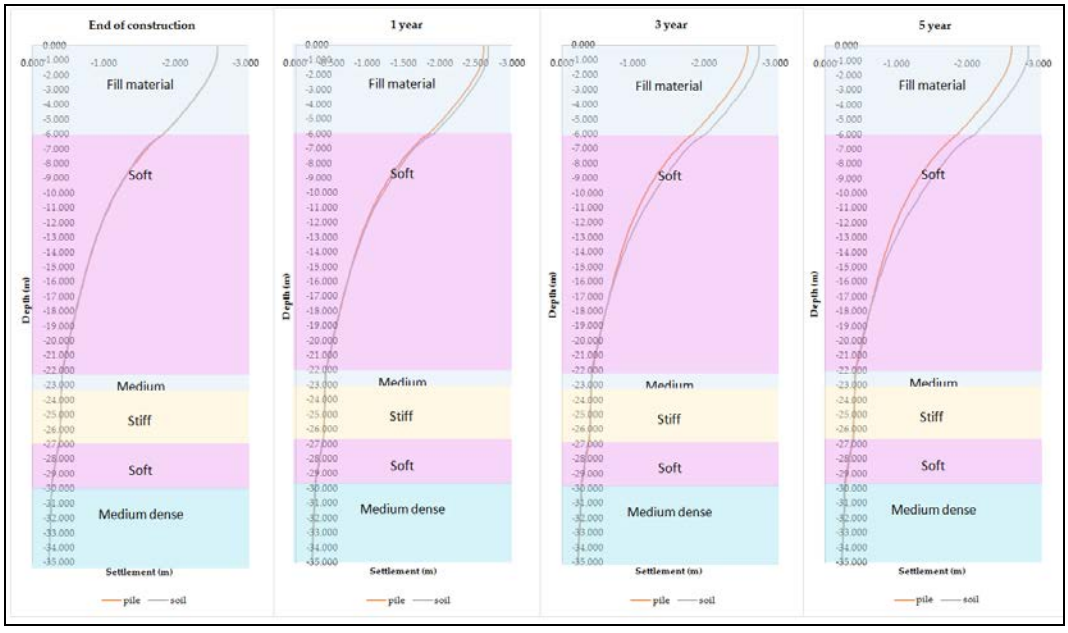

Fig. 4. Neutral Point Based On Settlement

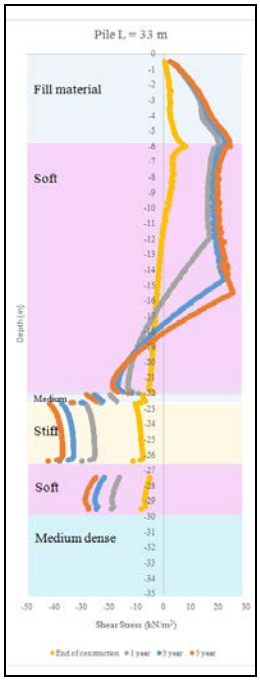

Fig. 5. Neutral Point Based On Shear Stress

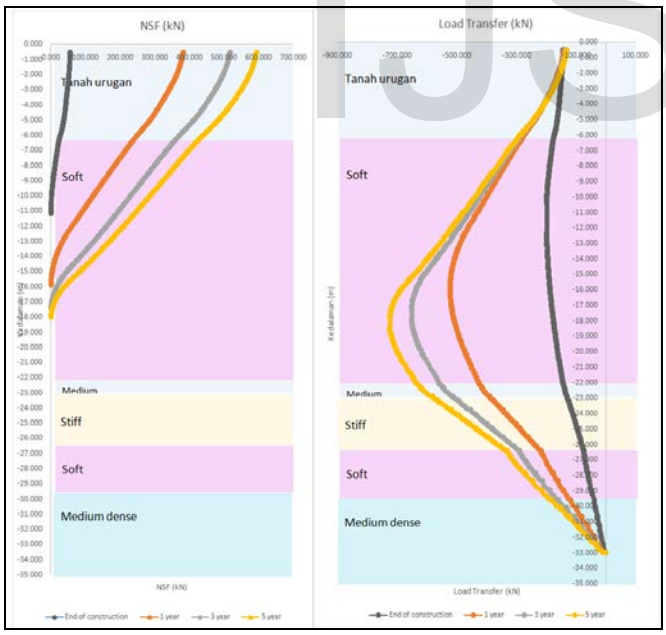

Fig. 6. NSF and Load Transfer Curve

4 Conclusion

Based on the research that has been done, the curve of the relationship between OCR to depth can be concluded that soft clay has an 80% consolidation degree, this indicates that the soil is underconsolidated. The neutral point is at a depth of 11 m, then as time goes by the neutral point deeper into a depth 18 m. This indicates that the NSF's neutral point will change by time. NSF occurs from the pile head to a neutral point of 56 kN to 595 kN for 5 years.

Based on the research that has been done, the existence and magnitude of the NSF need to be considered because as long as the subgrade is still consolidating the magnitude of the NSF will increase and deeper. In addition, when the subgrade has finished consolidating the NSF is not lost but is constant at certain values and points. Addition of load to the soil around the pile such as embankment needs to be avoided because it will increase the size of the NSF.

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