

THE EFFECT OF PILE CROSS-SECTION AREA AND STRAIGHTNESS ON FRICTION CAPACITY IN SOFT CLAY SOIL BASED ON LABORATORY MODEL SCALE

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ABSTRACT

The bearing capacity of a foundation is influenced by the diameter and straightness of the pile because the bearing capacity is highly dependent on the resistance of the pile tip and the resistance of the pile cover and the shape of the pile affects the strength of the foundation. Therefore, the purpose of this study was to determine the value of the bearing capacity of the pile foundation on the cross-sectional area and the effect of pile misalignment.

The method used in this study is the descriptive analysis method. Data were collected from laboratory tests with a comparison of the field scale. The manufacture of pile test specimens with each variation was 10%, 25%, 50%, and 75%.

From the test results, the variation in the cross-sectional area affected the bearing capacity value which increased as the variation in the cross-sectional area increased. As for the test results, the variation in the straightness of the pile affected the bearing capacity value which decreased as the variation in the pile misalignment increased.

Keywords: bearing capacity, cross-sectional area, straightness, clay soil, laboratory tests, piles.

1. INTRODUCTION

Banjarmasin is one of the cities in South Kalimantan that has many areas (swamps) with high groundwater levels. The type of soil is characterized by soft clay and peat.

Building on soft soil is a major problem in geotechnical engineering. Various methods have been developed for soil improvement. One of them is soil reinforcement as an alternative solution to the problem of land subsidence and loss of soil bearing capacity.

Galam wood pile foundations are the choice and are most often used by relying on bond or friction to support the building (Irwandy Muzaidi, 2023).

In construction, consideration of morphology and structure is required, because the risk factors associated with various types of soil vary greatly. In addition to the shape and structure of the soil, the shape of the pile also affects the strength of the foundation. The bearing capacity of a foundation is influenced by the diameter and straightness of the pile and the number of piles used. The larger the diameter of the pile foundation used, the higher the load bearing capacity. And vice versa. The load capacity of the foundation is highly dependent on the resistance of the pile tip and

the resistance of the pile cover. However, in the friction pile foundation system, the bearing capacity is only based on the friction between the side of the pile and the surrounding soil. Even though the resistance at the tip still provides bearing capacity, the value is small.

Other researchers who examined the effect of the diameter of the cerucuk galam on the carrying capacity of soft clay soil, concluded that the larger the diameter of the cerucuk as a whole provides an increase in effective carrying capacity, as well as variations in the length of the cerucuk providing effective carrying capacity. (Suroso, Harimuti 2021). This shows that the diameter affects the bearing capacity of the pile, especially the friction bearing capacity of the pile.

The study was conducted to determine the effect of pile misalignment and bearing capacity value on the cross-sectional area of pile foundation in this final project. This study is based on a scale model experiment in the laboratory. In this study, we consider field and laboratory scales and modify the commonly used bar shape according to market availability.

2. THEORETICAL BASIS

Soil Classification

The Unified Soil Classification System is a soil classification system based on the aviation classification system developed by Casa Grande during World War II. This system was later modified and adopted by US government agencies in 1942. Several additional improvements were later made to this system and it became known as ASTM D 2487-93.

Soil Friction

Water content has a significant effect on soil cohesion. When water content increases, soil cohesion decreases. Increasing water content can change the distance between particles and reduce the bond strength between particles. This reduced bond strength causes a reduction in the cohesion and shear strength of the soil itself. Dry and wet conditions have a significant effect on the friction capacity of pile foundations in the active zone area.

Foundation

A foundation is an architectural structure that functions as a support for a building and transfers the loads of the building above it (upper structure) to the load-bearing soil layer. The structure used as a foundation can also be divided into two types, namely shallow foundations and deep foundations.

Ultimate Bearing Capacity of Pile Foundation

The bearing capacity of a pile is the ability or capacity of a pile to support a load. (Hardiyatmo, 2011)

UCT (Unconfined Compression Test)

Unconfined Compression Test is a method carried out in the laboratory to measure how much the soil's bearing strength receives the given compressive strength until the soil is separated from its grains and also the soil strain due to the pressure. During the test, the test object is given vertical stress, while the cell stress is equal to zero.

3. METHOD

The form of the flow diagram in this study is shown in Figure 3. 1

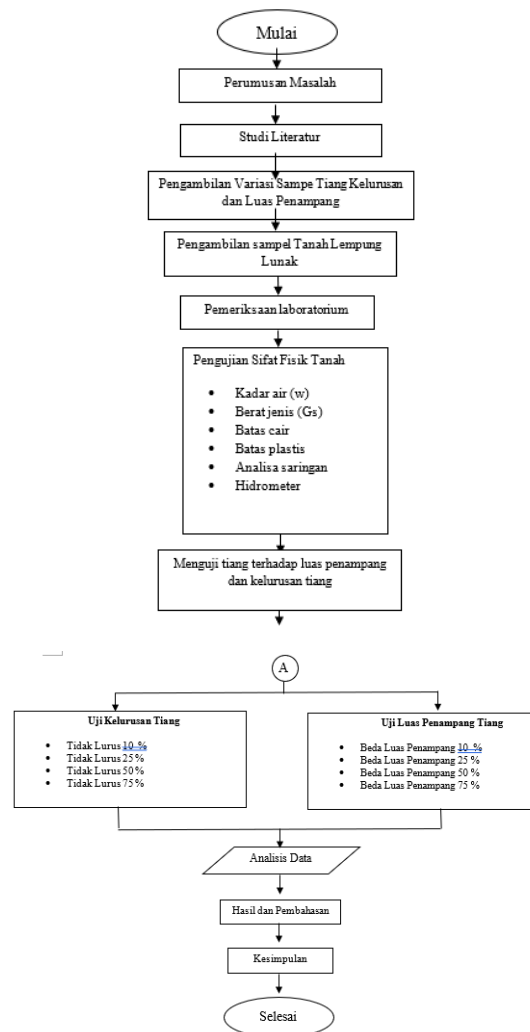


Figure 3. 1 Research Flow Chart

Preparation of Tools and Materials

1. Equipment

In this study, several testing tools were used, including:

- a.) PVC Pipe
- b.) Pole Friction Model Test Equipment in the Laboratory

2. Material

The location for taking the soft clay soil that was tested came from Sungai Tabuk sub-district, Banjar district, South Kalimantan and is located at the coordinates 3°21'26"S 114°41'59"E.

In this study, 3 tests were carried out, including:

1. Property Index and Mechanical Index Testing for Soft Clay Soil

The soil material used is soft clay. To determine the water content, volumetric gravity test, specific gravity test, Van Shear test and UCST.

2. Clay Soil Testing with Pile Variations with Different Cross-Section Areas

In this test, variations of different cross-sectional areas of piles were given with variations of 10%, 25%, 50% and 75%. Unconfined Compression Test (UCT) was carried out by pressing the pile test object until there was no resistance or loss of adhesion (friction). The test objects were modeled in 3 types in each variation, namely 1 pile, 2 piles and 4 piles.

3. Testing of Pile Variations with Different Straightness

In this test, variations of different straightness poles were given with variations of 10%, 25%, 50% and 75%. Unconfined Compression Test (UCT) was carried out by pressing the pole test object until there was no resistance or loss of adhesion (friction). The test objects were modeled in 3 types in each variation, namely 1 pole, 2 poles and 4 poles.

4. RESULTS AND DISCUSSION

Properties Index Test Results

The results of the property index test on soft clay soil can be seen in Table 4.1 below.

Depth			: -0,00 s.d -4,00 m
Specific Gravity			2.68
Water content	%		49.18
Volumetric weight	gr/cm ³		1.51
Grain Distribution			
Gravel (> 2 mm)	%		0.00
Course sand (0.6-2.0 mm)	%		0.42
Medium sand (0.2-0.6 mm)	%		1.29
Fine sand (0.05-0.2 mm)	%		7.76
Silt and Clay (0.002-0.05)	%		42.72
Clay (<0.002mm)	%		47.81
Atterberg Limits			
Liquid limit	%		45.43
Plastic limit	%		22.81
Plasticity Index	%		22.61
Classification	%		CL

Table 4.1 Properties Index Test Results

Based on the results of laboratory tests, the water content of soft clay soil was 49.18%. The volume weight value of soft clay soil was 1.51 gr/cm³. The specific gravity value of soft clay soil was 2.68.

The results of the sieve and hydrometer analysis tests in the Laboratory obtained grain distribution values, namely, Gravel of 0%, Coarse Sand of 0.42%, Medium Sand of 1.29%, Fine Sand of 7.76%, Silt and Clay of 42.72% and Clay 47.81%.

The results of the Atterberg limits test obtained a value from the Liquid Limit test of 45.43% and a Plastic Limit of 22.81% and a Plasticity Index value of 22.61%. Based on the USCS classification system, namely CL, this soil is included in the Inorganic clay of low to medium plasticity group or soft clay with low plasticity. The test results can be seen in Figure 4.1 below.

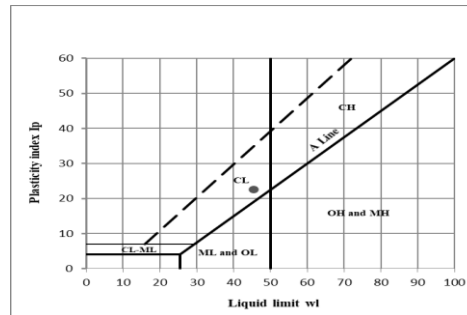


Figure 4.1 Plasticity Diagram of USCS Soil Classification Method

Mechanical Index Test Results

The results of mechanical index testing on soft clay soil can be presented in Table 4.2 as follows:

Vane shear test (s _v)	kg/cm ²	0.1223
Unconfined compression test		
qu	kg/cm ²	0.5682
c _u	kg/cm ²	0.2841
e	%	5.417
Sensitivity		1.464

Table 4.2 Mechanical Properties Test Results

Based on the USCS classification, the value of the soil is included in the Soft Clay category.

To see the behavior of changes in the friction bearing capacity of pile foundations due to straightness and cross-sectional area, variation scenarios are prepared. The first scenario for the straightness test presents variations in pile straightness with a bend from straight by 10%, 25%, 50%, 75%. The second scenario for the cross-sectional area difference test presents variations in the area difference of 10%, 25%, 50%, 75%. The method for calculating the percentage difference in straightness and cross-sectional area uses the following simple formula:

$$\% = \frac{\text{amount of change}}{\text{starting amount}} \times 100\%$$

Clay Soil Test Results with Pile Variations with Different Cross-Section Areas

Before the variation of the area difference is carried out, a test pole will be made first for the laboratory model with a scale comparison on the market with a diameter of 8 cm. where the scale is 1: 4, then the pole in the laboratory has a diameter of $D = 2$ cm

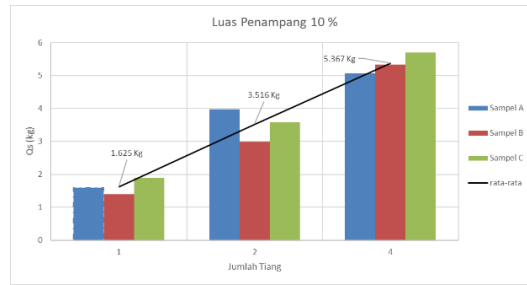


Figure 4.2 Test Results for 10% Difference in Cross-Section Area

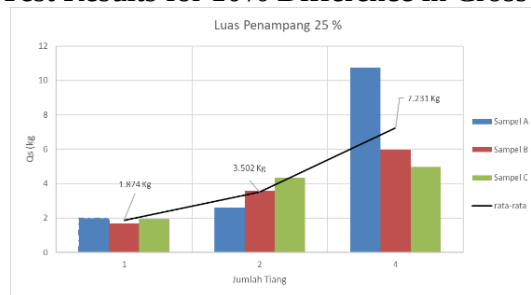


Figure 4.3 Test Results for 25% Difference in Cross-Section Area

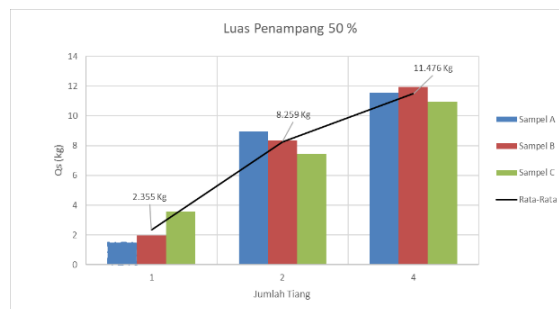


Figure 4.4 Test Results for 50% Difference in Cross-Section Area

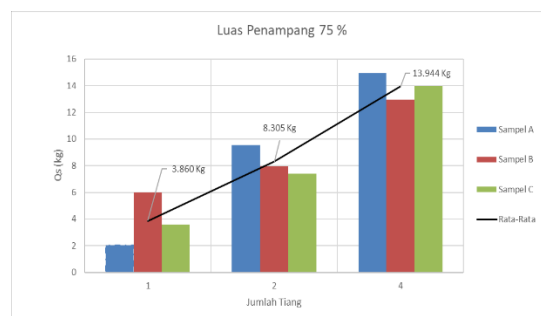


Figure 4.5 Test Results for 75% Difference in Cross-Section Area

Based on the results of tests for different cross-sectional areas, the friction or adhesion value of a soil increases as the cross-sectional area increases and the number of piles increases. Where if we look at the number of piles as one pile, the value of the friction carrying capacity becomes increasingly binding along with increasing variations in cross-sectional area. (Suroso, Harimuti 2021).

Test Results of Variation of Poles with Different Straightness

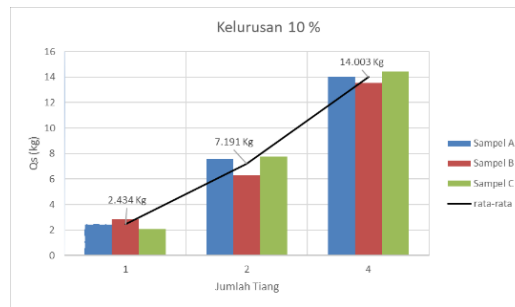


Figure 4.6 Results of 10% Straightness Difference Test

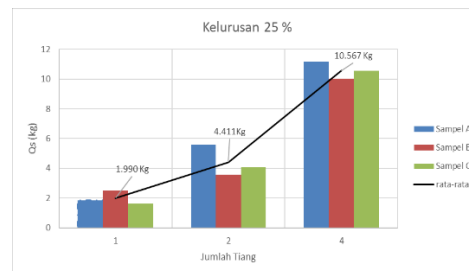


Figure 4.7 Results of 25% Straightness Difference Test

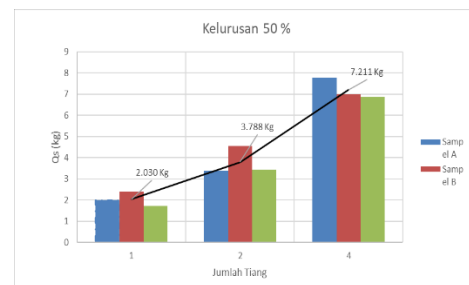


Figure 4.8 Results of 50% Straightness Difference Test

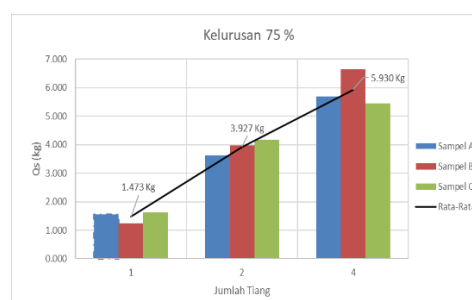


Figure 4.9 Results of 75% Straightness Difference Test

Based on the results of the straightness difference test, the friction or adhesion value of the soil cannot bind properly to a pole that is too bent. This can be seen in the test with a variation of 10% (a little bent) which has a high q_s value compared to the test with a variation of 75% (bent a lot) which has a low q_s value. Where if you look at the number of poles as 1 pole, the friction carrying capacity value decreases as the straightness variation increases.

Analysis of Variation Results of Poles with Different Cross-sectional Areas

After conducting the cross-sectional area variation test and the number of piles variation, the average value of each test was obtained. The results are presented in the table and graph below:

Table 4.1 Results of Friction Bearing Capacity Tests with Different Cross-Section Areas

Variation in Cross-sectional Area	Frictional Bearing Capacity		
	1 Pole	2 Poles	4 Poles
10%	1,325 kg	3,516 kg	5,367 kg
25%	1,874 kg	3,502 kg	7,231 kg
50%	2,355 kg	8,259 kg	11,476 kg
75%	3,860 kg	8,305 kg	13,944 kg

Analysis of Results of Variation of Different Straightness Poles

After testing the variation of Straightness Difference and the variation of the number of poles, the average value of each test was obtained. The results are presented in the table and graph below:

Table 4.2 Results of Friction Bearing Capacity Tests for Different Straightness

Variations of Different Straightnesses	Frictional Bearing Capacity		
	1 Pole	2 Poles	4 Poles
10%	2,434 kg	7,191 kg	14,003 kg
25%	1,990 kg	4,411 kg	10,567 kg
50%	2,030 kg	3,788 kg	7,211 kg
75%	1,473 kg	3,927 kg	5,930 kg

Discussion of Test Results

From the test results above by considering the variation of the pole, namely testing with one pole, two poles, and four poles on the variation of the cross-sectional area. The results of the Qs of one pole are in the range of 1.625 Kg to 3.860 Kg. For the Qs of two poles, the results of the Qs are in the range of 3.516 Kg to 8.305 Kg. For Qs four poles, the Qs results are in the range of 5.367 Kg to 13.944 Kg. Judging from the test result table and the graph above, basically the test with the four-pole variation test object has a high Qs value from each different cross-sectional area

variation and the test with the one-pole variation test object has the lowest Q_s value from each different cross-sectional area variation and the test with the two-pole variation test object has a medium Q_s value or is in the middle of the one-pole and four-pole variations.

In the straightness variation test, namely testing with one pole, two poles, and four poles on the variation of cross-sectional area. The results of Q_s for one pole are in the range of 1.473 Kg to 2.434 Kg. For Q_s for two poles, the results of Q_s are in the range of 3.927 Kg to 7.191 Kg. For Q_s for four poles, the results of Q_s are in the range of 5.930 Kg to 14.003 Kg. Judging from the test results table and the graph above, the Q_s value decreases when the % straightness increases, this is because in the pile test the straightness decreases, the Q_s value decreases because in general the bearing capacity of a soil is influenced by the pile cover so that when the pile cover or wall is not good as a whole, it will allow for a decrease in adhesion to the pile, this is also in line with research which states that the wall and pile material have an effect on increasing the pile friction capacity because the capacity of a single pile is the sum of the friction capacity and the end capacity. (Saddek, 2018).

From the results above based on the table and graph of the test results from each variation of cross-sectional area and straightness, there is a significant difference between the two variations, where for piles with variations in cross-sectional area, the Q_s value increases in line with the variation of the pile whose diameter increases, while for piles with variations in straightness, the Q_s value decreases in line with the increasing variation in straightness which is increasingly not straight. This proves that basically the bearing capacity of a pole is influenced by the friction capacity of the pole, namely the dimensions of the pole itself. A pole that is good at receiving the adhesion of a soil is a pole that does not experience many changes in shape that allow a reduction in the strength of the pole in receiving adhesion or friction of a soil. Christopher Henry Sugiarto in his research also said that the material affects the friction capacity of the pile (Sugiarto, 2020).

5. CONCLUSION

Conclusion

Based on the calculations from this final assignment, the following conclusions can be drawn:

1. The cross-sectional area affects the pile in receiving soil friction. The larger the cross-sectional area, the greater the soil friction capacity.
2. Friction capacity is influenced by piles that have walls that do not have many curves, because this reduces the strength of the pile in receiving soil friction.
3. The shape of a pole that is good and effective in accepting soil friction is a pole that has a fairly large cross-sectional diameter and a pole that does not experience much change in shape.

Suggestion

As a result of the research conducted, the following suggestions can be made:

1. For better and more accurate research results, it is necessary to add a wider variety of poles.
2. It is hoped that there will be further research regarding the influence of poles on different soil properties.

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