Analysis of the capability of pile assembly foundations in soft soil in physical modeling of variationsiin laboratory scale distances

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ABSTRACT

The capacity of raft foundations, pile foundations and pile rafts on soft soil with variations in the distance between the piles. Perform analysis of the carrying capacity and settlement of each foundation test and then compare the results of the theoretical carrying capacity research with the analysis of carrying capacity calculations. The implementation of the test prepares the test along with samples of the raft foundation, pile foundation and pile raft foundation. The test were carried out using a gradual load then a dial gauge is placed at both ends of the sample raft and the load reading is taken. The pile foundation was tested with a decrease of 10 cm while the settlement on the raft foundation and the pile raft foundation was 3 cm, the carrying capacity of the raft foundation was 24 kg, the pile foundation varied 4D distances; 6D and 8D, namely 7.5 kg and the foundation of the pile raft with variations in 4D distance; 6D and 8D are 26 ; 32 and 32 kg. In the interpretation method, the pile raft foundation with various distances increased from 4D to 6D but decreased in 8D. Pile raft foundations with various distances between pile have not a significant effect where raft foundations are more dominant in supporting resistance than pile foundations.

Keywords: raft pile foundation; pile distance; interpretation method; dominant; resistance.

INTRODUCTION

Soil material is very important in the field of construction, because on this soil a construction rests. However, not all soil is good for use in the construction sector, because there are several types of sub-grade which have problems both in terms of the carrying capacity of the soil and in terms of soil deformation. For this reason, in planning a construction, an investigation must be carried out on the characteristics and strength of the soil, especially the soil properties that affect the bearing capacity of the soil in holding the construction load on it (Agung et al., 2014).

To plan a foundation, soil classification is useful as the main guide to determine the nature of soil stiffness in the field (Hardiyatmo, 2017). This type of soil has a high-water content due to the relatively low permeability of the soil and great compressibility so that this soil experiences a large decrease in a very long time.

The Raft-piled foundation is a combination system between a number of pile foundations and a raft foundation that work as a single unit and simultaneously. Raft-piled foundations are usually designed to support loads on soft soils with the pile ends not reaching the hard soil layer. Under these conditions, the pile foundation along with the raft foundation above it will work together to distribute the load into the soil (Harpito et al., 2015)

Research on this combined raft-pole foundation was carried out in order to determine the increase in the bearing capacity of the foundation's resistance that works together between the raft and the pile in distributing the weight of the structure load to the soft soil. Therefore, a-research was conducted based on a laboratory scale physical model in order to determine the behavior of decreasing the weight of the given load in stages.

Pile Raft Foundation

Pile raft foundation as a type of foundation that works as a composite structure by utilizing three load-bearing elements, namely raft foundation piles and the type of soil under the structure. Therefore, there are four types of interactions that occur in the raft foundation structure. The four

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interactions are the interaction between the pile and the ground, and the interaction between the pile and the raft foundation. The interaction image is shown in Figure 1 below.

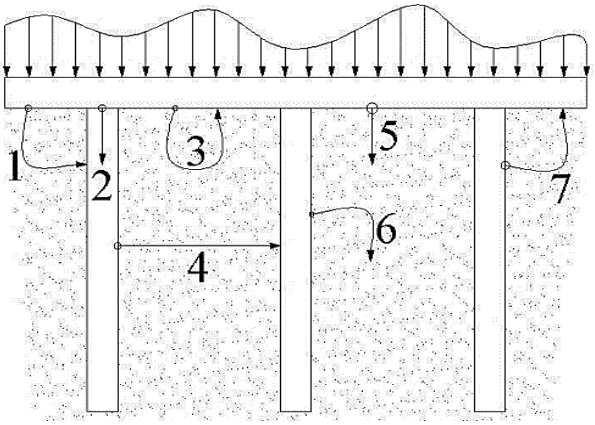

Figure 1. Interaction on the Pile-raft Foundation

METHODS AND RESEARCH

Tools and materials

The soft soil material used in this test came from the Pakning River area, Bengkalis Regency. Soil samples were taken to the Soil Mechanics Laboratory for testing of the tools used during the research as follows:

1. One set of testing tub
2. A set of water content testing equipment
3. Shear strength testing equipment (Vane Shear)
4. A set of specific gravity testing equipment
5. A set of liquid limit and plastic limit testing tools
6. Dumbbell iron loading
7. Land subsidence reading device
   The modeling of the test bath is shown in Figure 2

Figure 2. Testing Body

Foundation Load Test

In this test the method used to test the foundation loading using the Axial Compressive Loading Test test method. Details of the cross-section of the test bath and the test sample are shown in table 1 below.

Table 1. Dimensions of the Test Sample Tool

Test Sample	Dimensions			
	Long	**Wide**	**Tall**	**Diameter**
Test Tub	100 cm	100 cm	120 cm	-
F. Raft	30 cm	25 cm	3 cm	-
F. Pole	40 cm	-	-	2 cm

The stages of the testing procedure for raft foundations, pile foundations and pile raft foundations are almost the same. It's just that the difference in testing the raft foundation does not use a pile. The following are the stages of loading testing, namely:

1. Prepare the test basin and soil samples to be used in the test
2. Spread the soil sample and then re-wet it with additional water
3. Put the soil sample into a 3-layer test tank. Each layer of soil is tested for shear strength (Vane Shear) After the soil is completely filled, the test sample is allowed to stand for 24 hours and the next day the poles are planted.
4. Doing planting poles by pressing. The foundation of the pile is planted as deep as 37 cm and leaves 3 cm of the head of the pile not submerged and left for 24 hours
5. After 24 hours the pile is embedded, place the raft foundation on top of the pile head that is not immersed and attach a dial gauge to read the settlement on the pile raft foundation
6. Gradual loading test with an initial load of 2.5 kg. Decrease readings are carried out with the first reading every 1 minute to 10 minutes, followed by a second reading every 5 minutes to 30 minutes, the third reading every 10 minutes to 60 minutes, then readings every 15 minutes to 120 minutes, subsequent readings every 30 minutes to 240 minutes, readings every 60 minutes to 480 minutes and readings 1 day (24 hours). If the downward reading on the dial gauge is still decreasing, if the 8 hour reading to the 24 hour reading (1 day) continues to decline, then the downward reading test continues to the next day.
7. The reading of the settlement on the dial gauge is said to be complete if the modeling of the raft foundation which has a thickness of 3 cm has touched the surface of the soil sample.

RESULTS AND DISCUSSION

Soil Property Test Results

Properties test was conducted to determine the characteristics of the soil used in this test. The results of soil properties can be shown in table 2

Table 2. Results of Physical Properties and Soil Properties

Soil Characteristics Testing	Test result	Unit
Wet Volume Weight (γwet)	13,4	kN/m^3
Plasticity Index	31,5	%
Liquid Limit (LL)	67,5	%
Plastic Limit (PL)	35,9	%
Water content	64,7	%
Specific Gravity (Gs)	2,5	-

Based on the results of soil properties testing, the soil used in this study according to the USCS system is classified as MH soil or high plasticity silt.

Water Content and Shear Strength

The moisture content and shear strength of the soil were tested prior to loading testing. The test is useful as a control of the state of the soil. The value of the shear strength of the soil before the

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loading test is carried out between 1.5 – 3 kPa. The results of testing the soil shear strength and water content are shown in table 3 and table 4

Table 3. Shear Strength Test

Number of Poles	Pole Spacing Variations	Average Shear Strength (kPa)
-	Raft	2,0
4	4D Pole	1,5
	6D Pole	2,0
	8D Pole	2,0
4	Raft - 4D Mast	2,0
	Raft - 6D Mast	3,0
	Raft - Mast 8D	3,0

Table 4. Water Content

Number of Poles	Pole Spacing Variations	Average Moisture Content (%)
-	Raft	81,12
4	4D Pole	82,30
	6D Pole	81,50
	8D Pole	81,20
4	Raft - 4D Mast	80,94
	Raft - 6D Mast	80,00
	Raft - Mast 8D	80,20

According to the table above, it is known that the relationship between shear strength and water content is that the greater the value of the shear strength, the smaller the value of the water content will be.

Raft Foundation Loading Test Results

The raft foundation loading test is plotted into a load vs settlement graph. The raft foundation is capable of supporting a load of 24 kg. The graphic image is shown in Figure 3 below.

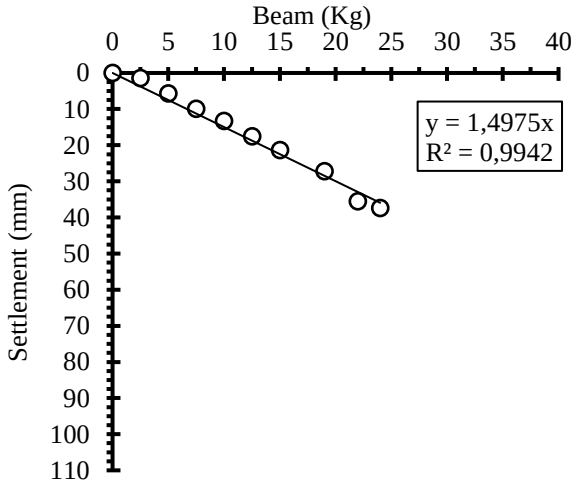

Figure 3. Load Vs Assembling of Raft Foundation

Based on Figure 3, the graph of the relationship between load and decrease is obtained from the graph of the relationship between load and time, where the maximum drop data is taken.

Appropriate testing shows that the decline tends to be linear. This indicates that each additional load results in an additional decrease that is relatively the same

Pile Foundation Loading Test Results

The load test on the pile foundation model with various distances is carried out with gradual loading. The following graph shows the results of the load vs. pile foundation settlement in Figure 4 below.

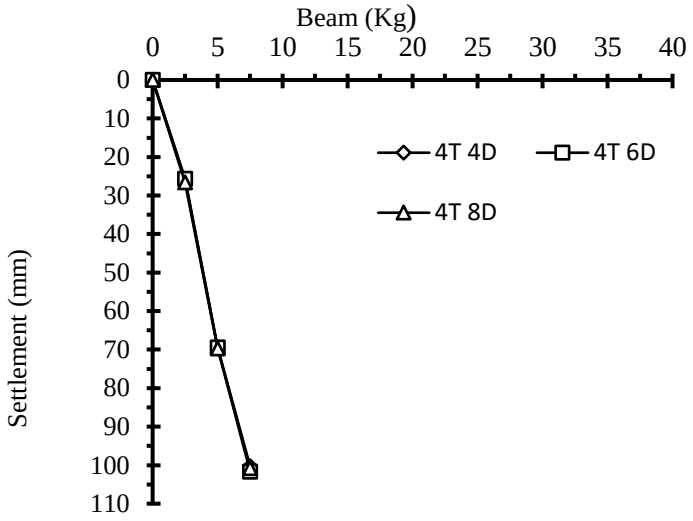

Figure 4. Load Vs Pile Foundation Depression

Test Results of Pile Raft Foundation Loading

Testing the load on the pile raft foundation with various distances is made into the load vs settlement graph shown in Figure 5 below.

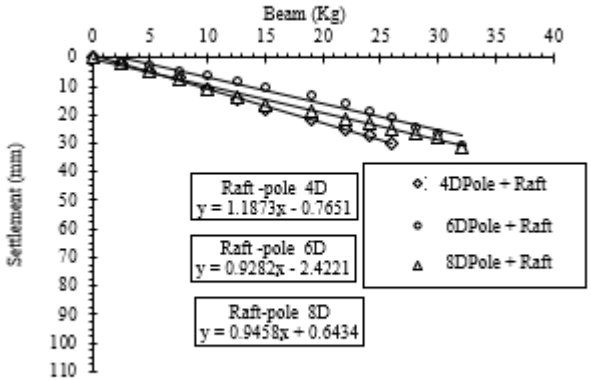

Figure 5. Load Vs Pile Raft Foundation Derivation

Figure 3 shows the results of testing the raft foundation capable of supporting a load of 24 kg, if added to the pile foundation test with a distance variation of 7.5 kg, the test results are almost the same as the pile raft test but not too much different. According to the graph above, it can be concluded that increasing the distance between the piles on the raft-pile foundation can increase the bearing capacity

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of the foundation. However, under certain conditions, increasing the distance between the piles has no significant effect on the settlement, as seen in 6D and 8D

Method Interpretation Results 25 mm

Various variations of the foundation are described as a load vs settlement graph, then the settlement limit is determined using the 25 mm interpretation method. For a drop of 25 mm, the bearing capacity of the raft foundation corresponds to a load of 17.2 kg. while the pile foundation with various distances between the piles is able to support a load of 2.1 kg each; 2.2 kg and 2.1 kg. The results of the recapitulation of the carrying capacity of 25 mm reduction can be shown in Table 5

Table 5. Recapitulation of Carrying Capacity 25 mm

Foundation Models	Total load (Kg)	Total drop (mm)
Raft	17, 2	25
4D Pole	2,1	25
6D Pole	2,2	25
8D Pole	2,1	25
Raft + 4D Pole	21,7	25
Raft + 6D Mast	28,9	25
Raft + 8D Mast	25,7	25

As per Table 5 shows the bearing capacity according to a decrease of 25 mm. This shows that the addition of pile spacing does not increase the carrying capacity. This condition is in accordance with Zaid et al., (2017) which states that the bearing capacity of the raft-pile foundation is not affected by the addition of the cross-sectional size of the pile foundation, height, and thickness of the raft foundation plate and the distance between the piles.

The bearing capacity of the pile foundation, as shown in Table 5 shows that the increase in the distance between the piles has no effect on the bearing capacity of the foundation. This condition indicates that the greater the distance between the piles, the carrying capacity decreases. This is in accordance with Amalia Dewi et al., (2010). He stated that the greater the spacing between the piles, the greater the contribution of the raft to carry the load.

Theoretical Carrying Capacity Analysis by Testing

Comparing the theoretical analysis with the results of the carrying capacity of the test. The results of the calculation of the theoretical carrying capacity are shown in Table 6 then perform a comparison between the theoretical calculations and the results of the test carrying capacity can be seen in Figure 6.

Table 6. Comparison of carrying capacity results

Foundation type	Testing kg	Calculation, kg		
		Raft	Pile foundation	Total
Raft+4D pole 21,7	Raft+4D pole 21,7	21,91	8,76	30,67
Raft+6D pole 28.9	Raft+6D pole 28.9	32,35	8,37	40,72
Raft+mast 8D 25,7	Raft+mast 8D 25,7	32,35	8,37	40,72

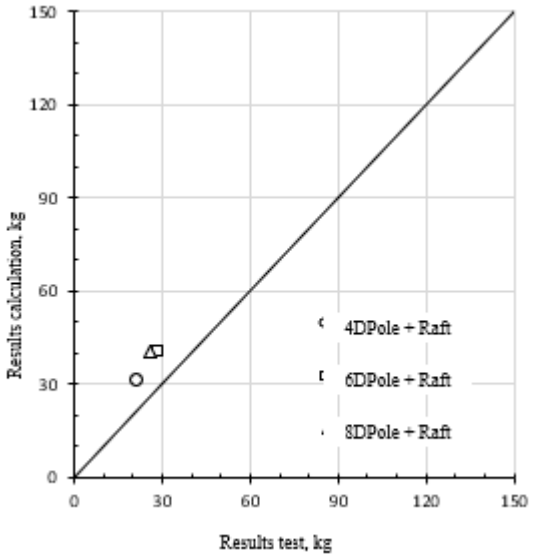

Figure 6. Theoretical Comparison Vs Testing

It can be seen in Figure 6 that the theoretical bearing capacity value of the combined foundation is greater than the bearing capacity value of the test results, but the difference between the test results and theoretical calculations is not much different. the effect of the distance between the piles in the test does not have a very significant effect because the size of the pile is small so that to get the resistance of the pile to soil friction it is also not of great value. In accordance with Sofyan's research, (2020) he said that the bearing capacity of the calculation on a plain foundation will be different from the type of foundation that has roughness.

CONCLUSION

The modeling of the pile raft foundation determined that the addition of the distance between the piles did not significantly affect the bearing capacity of the combined pile raft foundation. Based on the test that the carrying capacity of the raft dominates the carrying capacity of the total bearing capacity of the pile raft foundation. The results of the test calculations with theoretical calculations are not much different, because the test results will be almost the same if the calculation of the bearing capacity of the raft foundation is added to the calculation of the pile foundation. The results of the bearing capacity of the tested pile raft foundation with variations in the distance of the 4D pile is 21.7 kg, the variation of the distance of the 6D pile is 28.9 kg and the variation of the distance of the 8D pile is 25.7 kg. The results of the test bearing capacity are not much different from the results of the theoretical calculation of the raft foundation with various 4D distances of 21.91 kg, variations of 6D pile distances of 32.35 kg and variations of 8D pile distances of 32.35 kg. The test results on pile raft foundations in various distances between piles are able to reduce settlement but have no major effect if only variations in the distance between piles are modified. Efficiency methods that are close to the test results with calculations are the Feld efficiency method and the SeilerKenny method. Both of these methods were chosen based on the shape of the graph which is almost the same as the test efficiency graph. The pile foundation used is a plain pile, to increase the bearing capacity of the pile, try using a pile with roughness or other modifications. In the 25 mm interpretation method, the result of the bearing capacity of the raft foundation is 17.2 kg, the bearing capacity of the pile foundation with a 4D pile distance is 2.1 kg, a 6D pile distance is 2.2 kg and an 8D pile distance is 2.1 kg, the addition of piles on the raft foundation into a pile raft foundation is able to provide an increase in the carrying capacity. However, the small bearing capacity of the pile foundation does not make a large enough contribution to the bearing capacity of the pile raft foundation.

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