Analysis Of Bearing Capacity Of Shallow Foundation On Soft Soil Using Depth Variation PVC Pipe 4x4 Grid Pattern

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Abstract. Soft soil has low soil bearing capacity, large settlement and high water content. Therefore, reinforcement is needed so that the soil can withstand the load on it. In previous research, soil strengthening was carried out using PVC pipes with different variations. The results obtained concluded that the 4x4 grid pattern is a pattern that can reduce settlement. This research is a continuation of previous research, namely using a 4x4 grid pattern with varying PVC pipe depths, namely: 500mm, 750mm and 1000mm. The aim of this research is to see the soil carrying capacity or settlement that occurs. The method used was a onsite experiment. The results of the tests showed that using PVC as a medium to increase the bearing capacity of soft soil was very helpful. This comparison can be seen from the soil settlement value which is less and balanced compared to without PVC pipes. In shallow foundations without using PVC pipes, there is a soil subsidence of 26mm. Meanwhile, shallow foundations using PVC pipes as deep as 500mm experienced soil subsidence of only 14mm. At depths of 75mm and 100cm, settlement occurred with values of 10mm and 9 mm. So it can be concluded that the longer the pipe used, there is a tendency to increase the bearing capacity of the soil.

Keywords: Shallow Foundation, Bearing Capacity, PVC pipe.

1 Introduction

According to the topography of the city of Palembang, it is surrounded by water, even submerged by water that comes from both rivers and swamps, as well as rainwater.[1]. As one of the areas that has 52% of the land flooded with water (swamps), the city of Palembang certainly has a low soil carrying capacity and large settlements. This is because the soil conditions are classified as soft soil. Soft soil is an aggregate of

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microscopic and submicroscopic sized particles originating from the chemical decomposition of rock constituent elements, and is plastic in the range of moderate to wide water content.[2]. The characteristics of soft soil are small shear force, large compressibility, small permeability coefficient and low bearing capacity compared to other clay soils.[3]. Therefore, before the land is used for a settlement/housing area, the basic soil is usually stabilized first so that the soil's carrying capacity increases.

When planning building foundations, especially shallow foundations, it is necessary to pay attention to the stability and safety of the construction and the ability of the soil to support the loads on it[4]. Soil bearing capacity is the maximum pressure that the soil can bear without sliding. Meanwhile, ultimate bearing capacity is a condition/limit where the soil is unable to bear the pressure acting on it[5]. Determining the real limit bearing capacity is by direct loading by giving loading trials and measuring the decrease. If the foundation is considered to be infinitely long, then the failure plane can be described as follows:

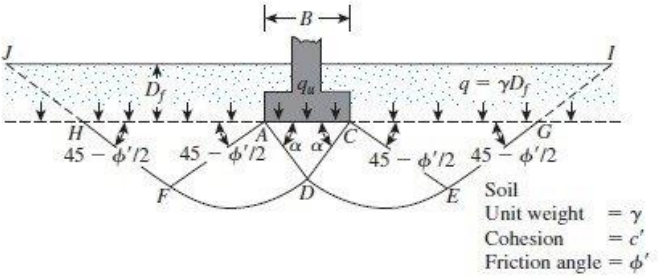

Figure 1. Collapse Line

The ACD soil under the foundation will move downwards and cause sideways pressure, eventually causing collapse along the DHF and DGE lines.

The foundation is the structure of the lowest part of a construction (building, bridge, highway, embankment, tower, tunnel, retaining wall, etc.) which functions to distribute vertical loads above it (columns) and horizontal loads to the ground.[6].In a building structure, the foundationThis is a very important aspect because it is directly related to hard soil/rock.The foundation is tasked with placing and transmitting the load of the upper structure (superstructure) to the ground. Therefore, the laying of the foundation must be ensured to be sturdy and strong, where the soil as support must be stable[7].

Foundation types can be divided into two types, namely shallow foundations and deep foundations. Shallow foundationknown as direct foundations, because they support the load directly, such as longitudinal foundations, footings and rafts[8]. This foundation is also only able to support simple buildings.Shallow foundations are usually defined as the depth of the foundation from the ground surface that is less or equal to the foundation width D≤B[5]. In addition, other experts reveal that shallow foundations are D≤5B[9][10]. This means that a shallow foundation has a limited depth that is adjusted to the width of the foundation.

The method for making shallow foundations for landed houses which is usually practiced on soft soil/peat is by embedding dolken/gelam sticks, bamboo, or using geotextiles at the bottom of the foundation at a certain depth.The use of bamboo grids and geotextiles has proven to be able to increase the bearing capacity of foundations on peat

soil[11]. Furthermore, development was carried out using the Plaxis method, still using the same pattern and materials, resulting in soil bearing capacity values which were influenced by the width of the reinforcement. The wider the reinforcement, the greater the percentage increase in the bearing capacity value for modeling[12]. The effective depth of the foundation and the increasing number of layers of reinforcement also affect the soil bearing capacity[13]. This method has been very successful in building houses using shallow foundations (footprints), however the availability of this material is not sufficient in all areas due to limited natural resources. So there is a need for innovation in the use of materials to strengthen the bearing capacity of the soil.

In 2022, a study was conducted on shallow foundations using PVC (PolyVinyl Chloride) pipes as an alternative material to replace bamboo/gelam. PVC pipe patterns are hard, light, strong and easy to find at an affordable cost. Using PVC pipes can work better than using iron pipes. Apart from that, PVC pipes are also resistant to almost all alkaline or toxic substances and are easy to install. PVC pipes are shaped like tubes, where the ends and base of the pipe are closed. This assumes that the air in the pipe is able to support and balance the position of the shallow foundation on soft soil. So that settlement decline can be reduced

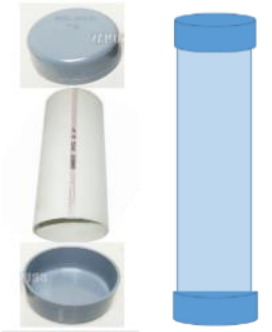

Figure 2. PVC pipe and cap

The results of this research prove that the use of PVC pipes to increase the bearing capacity of the soil has proven to be good. Patterns that show good results start from a 4x4 grid pattern[14]. This research is a continuation of previous research in which PVC pipes can be used as a replacement material for bamboo for shallow foundations on soft soil. Variations in depth are differentiated to determine the comparison of each depth without using PVC pipes.

The aim of this research is to obtain the right depth with a high soil bearing capacity which is inversely proportional to a low settlement value.

2 Methodology

2.1 Type and Location of Research

The type of research is experimental onsite, which is located in areas that have soft soil/swamps. Based on the results of the onsite survey, the location was determined at

Lebak Kranji, Bukit Lama, Palembang city. Meanwhile, the location for making precast reinforced concrete foundations in the form of squares and precast loading was made in the open workshop at the Sriwijaya State Polytechnic campus in Palembang.

2.2 Data collection techniques

2.2.1 Primary Data

Primary data was obtained from direct test results in the onsite. The data obtained is the value of onsite settlement reduction at each depth of the PVC pipe embedded under the shallow foundation.

2.2.2 Secondary Data (supporting data)

. Secondary data in this research is in the form of references from books, applicable regulations and published journals.

2.3 Research Variables

2.3.1 Independent variables

The independent variable here is the planting of PVC pipes (which have been closed up and down) combined with the configuration/planting pattern (grid). The size of the pipe used is 3 inches for 16 tubes in each shallow foundation hole. The tread foundation is made with a size of 60x60x20 cm and a pedestal size of 20x20x100 cm. Then fill the sacks/bags with split stones weighing 50 kg/sack as many as 20 sacks which will be used as loading model.

The quantities used for each onsite 'test object' are as follows:

1. P-0 is an existing foundation without reinforcement, without embedding PVC pipes. This is a comparison of the foundations that were treated.
2. P-1 is a foundation with reinforced PVC pipe tubes with a depth of 50 cm distributed perimetrically (four vertically and four horizontally)
3. P-2 is a foundation with reinforced PVC pipe tubes with a depth of 75 cm spread evenly over 16 tubes.
4. P-3 is a foundation with reinforced PVC pipe tubes with a depth of 100 cm spread evenly over 16 tubes.

2.3.2 Dependent variable.

The dependent variable here is the magnitude of the influence of applying the load gradually up to the maximum load for each foundation point. Each test object was given a first load of 250 kg, then a second load of 250 kg was added every 1 hour, until the total maximum load was 1025 kg.

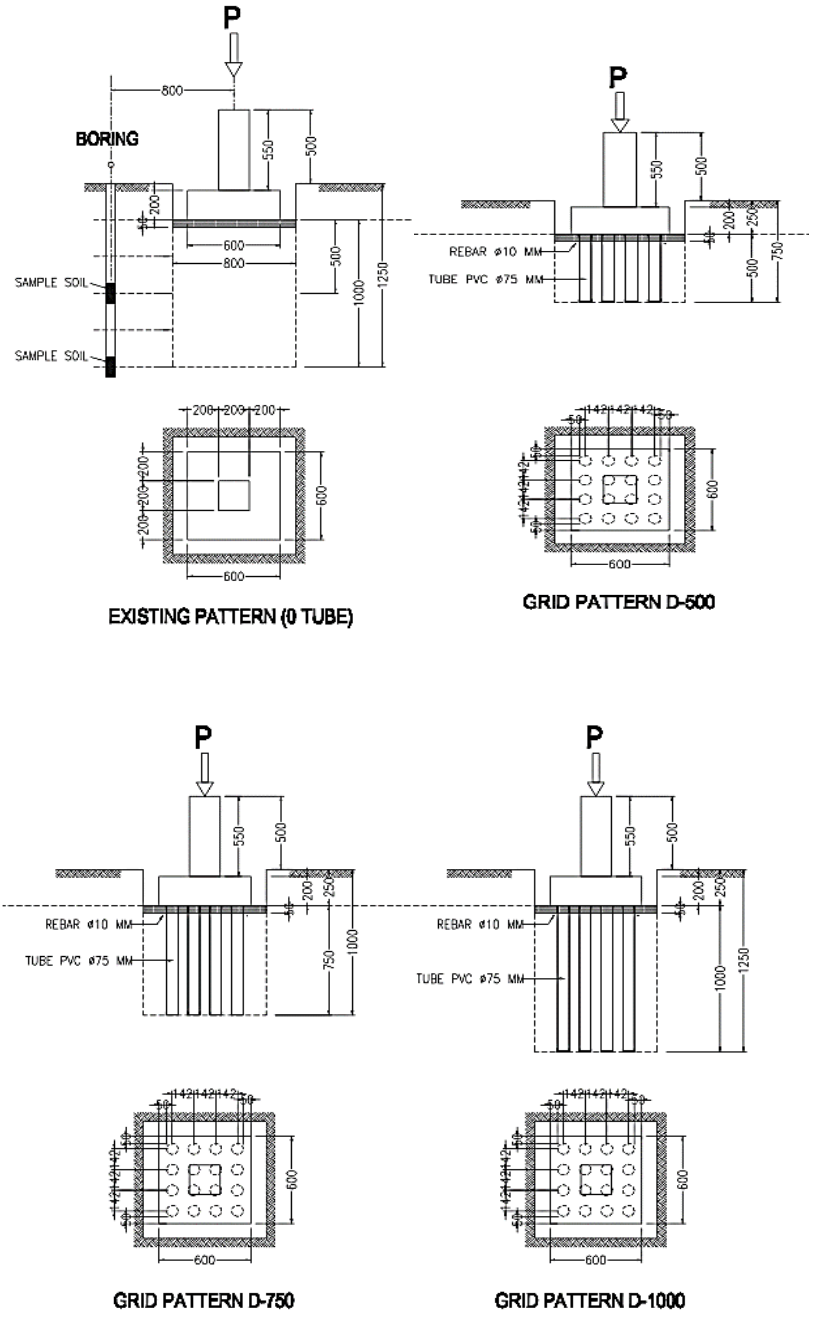

Figure 3. Pipe planter pattern under the foundation

2.4 Research Procedures

The implementation procedures in the onsite are:

a. Making foot foundation frecasts measuring 60x60x20 cm and pedestals measuring 20x20x100 cm, 2 pieces 60x60 cm. Making 5 pieces of loading of the same size as the foot foundation. The time required to make a frecast is 1 month.
b. Location survey.
   The location surveyed is a location that falls into the soft soil category.
c. Implementation of testing and measurements
   This activity requires a duration of 1 week for each variation in the depth of the PVC pipe tube. In detail, on the first day there was foundation installation and loading work. Every 1 hour, the soil's ability to withstand loads is measured up to the maximum planned load limit, namely 1025kg. Then every day the decrease is measured for 3 days. On the fourth day, the load was removed, and the soil's carrying capacity was measured as seen from the increase that occurred. Measurements were carried out every day for 3 days. For this research, it took approximately 2 months to carry out onsite testing.
d. Data analysis and conclusions
   Data analysis is based on the results of settlement reduction processing and soil carrying capacity directly obtained in the onsite. Data analysis aims to test the validity of the data which refers to basic theory.

For more details, see the following flowchart

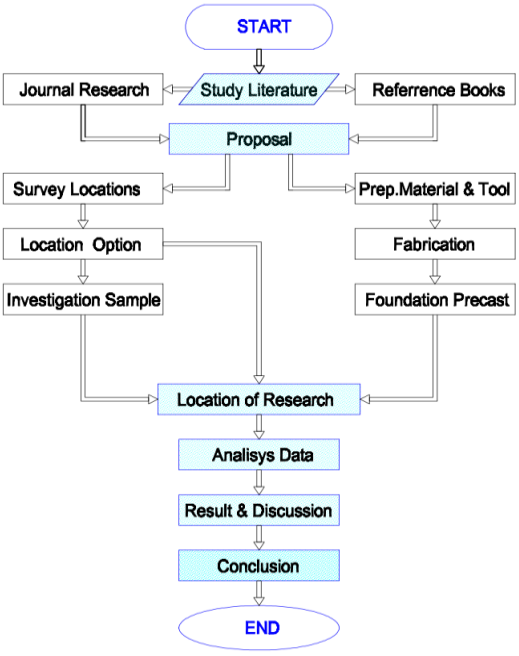

Figure 4. Flow chat research method

3 *Results and Discussion.*

From the results of tests carried out directly in the onsite, the following results were obtained:

3.1 Settlement and bearing capacity value P- 0 (loading & unloading)

Table 1. P-0 Pattern (no tube)

Date	Time / Duration (hours)	Load (kg)	Loading Set. (mm)	Unload-ing (mm)
September 30, 2023	start loading process	0	0	
	1 hour	225 = ow	2	
	2 hours	425	3	
	3 hours	625	7	
	4 hours	825	10	
	5 hours		17	
Oct 1, 2023	08.39		26	
Oct 2, 2023	07.39		26	
Oct 3, 2023	07.40		26	
Oct 4, 2023	07.32	225 = ow		26
Oct 5, 2023	08.25	225 = ow		26
Oct 6, 2023	08.27	225 = ow		26
			Increase	**0**

Source: Primary Data, 2023

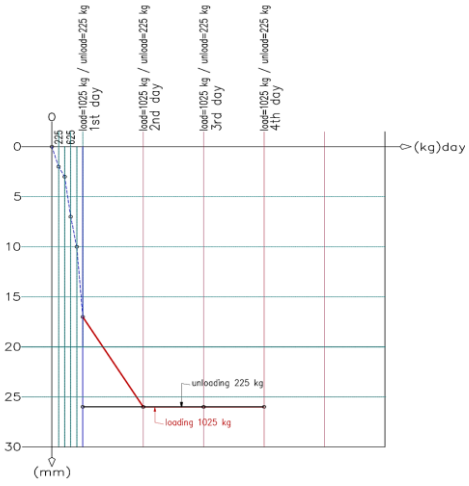

Figure 5. P-0 Pattern (0 tube)

From the test results, it can be seen that the settlement value in soft soil (swamp) is relatively high, reaching 26mm at maximum load. After the load is released, the soil should have soil bearing capacity and this will have an effect on reducing settlement. However, this does not apply to soft soil (swamps). The settlement value still remained at 26mm until the next day. So it means that soft soil does not have good bearing capacity so that the settlement value becomes high and remains even though the load has been reduced.

3.2 Settlement and bearing capacity value P-1 (loading & unloading)

Table 2. P-1 Pattern (16 tubes - deept 500mm)

Date	Time / Duration (hours)	Load (kg)	Loading Set. (mm)	Unloading (mm)
Oct 6, 2023	start loading process	0	0	
	1 hour	225 = ow	2	
	2 hours	425	4	
	3 hours	625	5	
	4 hours	825	6	
	5 hours		8	
Oct 7, 2023	07.34		12	
Oct 8, 2023	08.23		14	
Oct 9, 2023	07.40		14	
Oct 10, 2023	07.34	225 = ow		11
Oct 11, 2023	08.25	225 = ow		9
Oct 12, 2023	07.40	225 = ow		7
			Increase	3

Source: Primary Data, 2023

The table above shows that the use of 500mm PVC pipes planted at the bottom of shallow foundations can affect the bearing capacity of the soil in supporting the load above it. This can be seen from the settlement value which is much smaller than without the installation of PVC pipes. The settlement reduction in PVC pipe tubes with a depth of 500mm is 14mm. There was an increase in the soil bearing capacity of 12mm compared to without PVC pipes.

The increase in soil bearing capacity will become more visible if the load on the foundation is reduced. In a duration of 3 days, the increase in bearing capacity is 2mm. This proves that PVC pipes are able to increase the bearing capacity of soil in soft soil (swamp) conditions to stable conditions. For more details, see the following graph:

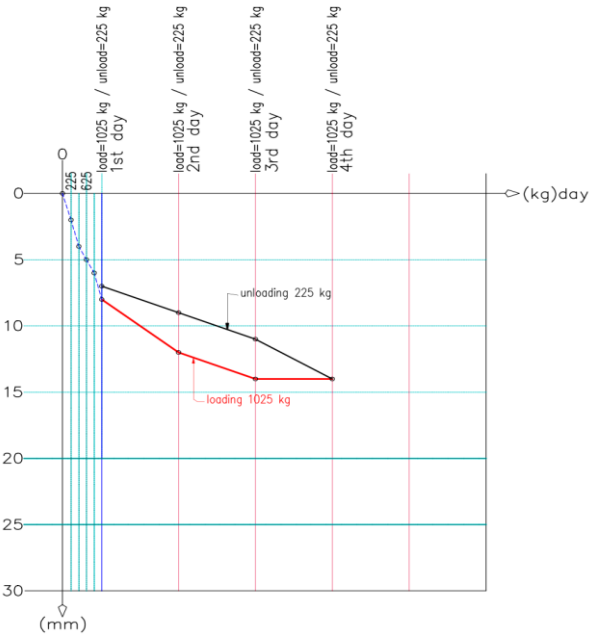

Figure 6. P-1 Pattern result (deept- 500mm)

3.3 Settlement and bearing capacity value P-2 (loading & unloading)

Table 3. P-2 Pattern (16 tubes - deept 750mm)

Date	Time / Duration (hours)	Load (kg)	Loading Set. (mm)	Unload-ing (mm)
Oct 3, 2023	start loading process	0	0	
	1 hour	225 = ow	2	
	2 hours	425	4	
	3 hours	625	6	
	4 hours	825	7	
	5 hours		7	
Oct 4, 2023	07.28		8	
Oct 5, 2023	07.34		10	
Oct 6, 2023	07.40		10	
Oct 7, 2023	07.34	225 = ow		8
Oct 8, 2023	07.30	225 = ow		5
Oct 9, 2023	07.40	225 = ow		5
			Increase	**2**

Source: Primary Data, 2023

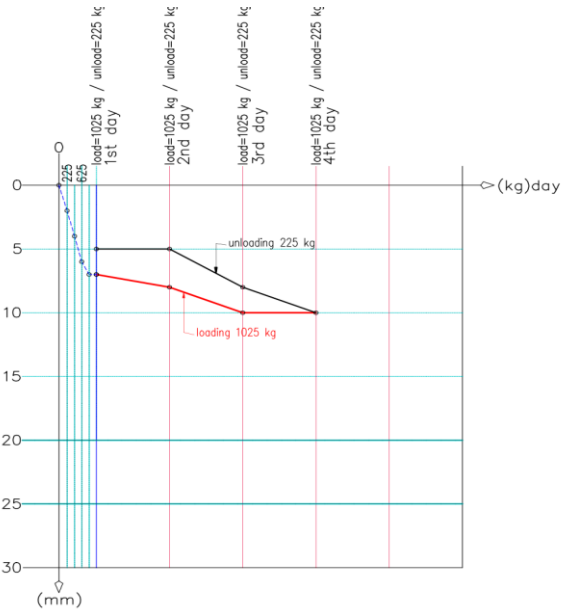

Figure 7. P-2 Pattern (16 tube- depth 750mm)

From the graph, it can be seen that the settlement value that occurs when planting a PVC pipe tube to a depth of 750mm given a maximum load (kg) is 10mm. There was an increase in the soil bearing capacity compared to the previous test (deept-500mm), namely 4mm. This proves that the deeper the pipe used, the smaller the settlement value. This can also be interpreted that PVC pipes can help increase the bearing capacity of the soil. In the unloading condition, the soil bearing capacity continued to increase, reaching a stable position at a depth of 5mm on day 3. The increase occurred by 5mm from the initial settlement.

3.4 Settlement and bearing capacity value P-3 (loading & unloading)

Table 4. P-3 Pattern (16 tubes - deept 1000mm)

Date	Time / Duration (hours)	Load (kg)	Loading Set. (mm)	Unloading (mm)
Oct 9, 2023	start loading process	0	0	
	1 hour	225 = ow	3	
	2 hours	425	4	
	3 hours	625	5	
	4 hours	825	6	
	5 hours		7	

Oct 10, 2023	07.29		8	
Oct 11, 2023	07.29		8	
Oct 12, 2023	07.29		9	
Oct 13, 2023	07.40	225 = ow		6
Oct 14, 2023	07.32	225 = ow		6
Oct 15, 2023	07.30	225 = ow		5
			Increase	3

Source: Primary Data, 2023

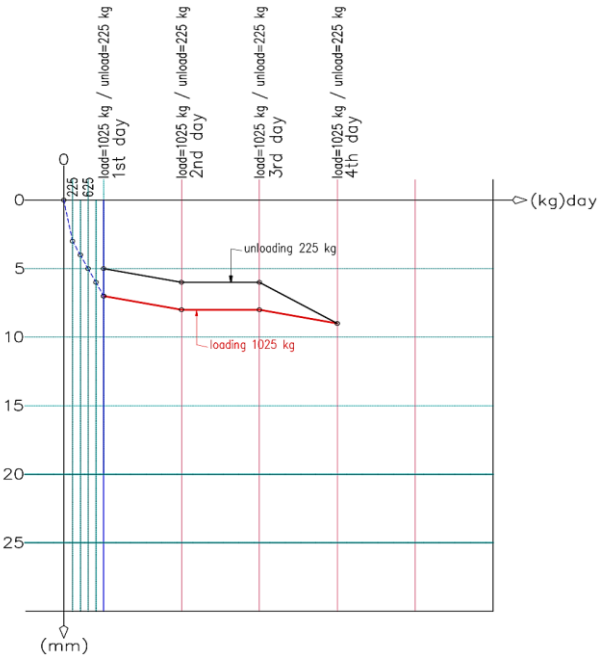

Figure 8. P-3 Pattern (depth 1000 mm)

In the fourth test, namely planting a 1000mm PVC pipe tube under a shallow foundation, a settlement value of 9mm was obtained. The settlement reduction ratio with a 500mm pipe is only 1mm. Meanwhile, the unloading conditions on the final day of testing were at a depth of 5mm and there was a possibility that there would be an increase on the following day.

3.5 Comparison

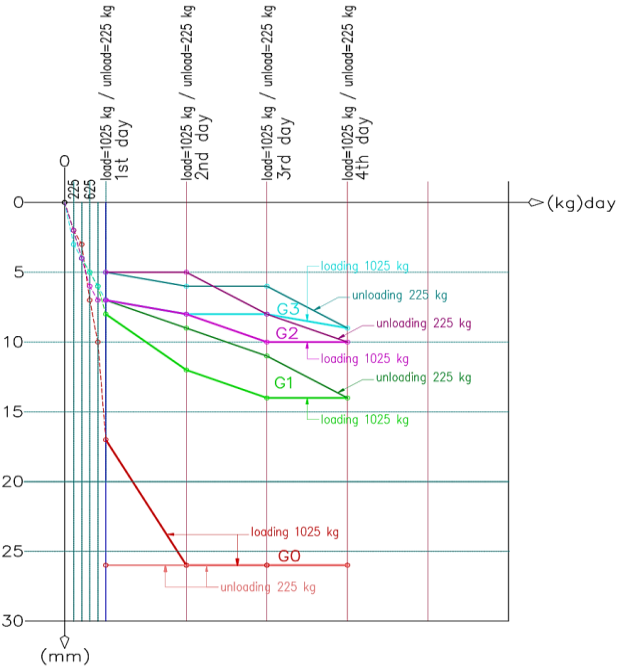

Figure 9. Comparison Result

From the onsite test results obtained, it can be seen that PVC pipes are able to increase the bearing capacity of the soil. This is evident from the high settlement value in soil without PVC pipe tube reinforcement, namely 26mm compared to PVC pipe tube planting which experienced quite low settlement values, namely starting with a settlement of 14mm on 500mm pipes, 10mm on 750mm pipes and 9mm on 750 mm pipes. Meanwhile, the soil bearing capacity value shows that soil that does not use PVC pipes is unable to resist the load on the foundation even though the load has been removed. The settlement value still remains at a depth of 26mm and there is no movement at all. In shallow foundations that have been planted with PVC pipes at different depths, there is an increase in the soil bearing capacity of around 1-3mm. This increase tends to continue to increase until it reaches a stable condition.

However, from the results of onsite tests, the depth of the pipe should be adjusted to the load on the ground. The heavier the load borne, the longer the pipe size can be. If the load to be borne is only small, then the length of the pipe planted does not need to be too long. This can be seen from the results of the difference in settlement value between pipe lengths of 750mm and 1000mm of only 1mm. Meanwhile, the soil's bearing capacity is stable at a depth of 5mm which is likely to increase in the long term.

4 Conclusion

From the test results, the conclusions obtained:

1. That PVC pipes are able to increase the bearing capacity of the soil as seen from the small settlement value compared to without treatment.
2. The bearing capacity of soil on shallow foundations by embedding PVC pipes underneath will continue to increase until it reaches a stable condition.

Acknowledgments`

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