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Test of Clay Soil Reinforcement Model Using Plastic Bottle Waste

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ABSTRACT: The construction of infrastructure on land with low bearing capacity results in large settlements and lateral movements. Various methods have been developed to overcome these problems, especially methods that utilize waste. Therefore, the author wants to determine the effect of using woven plastic bottle waste on soil with low bearing capacity using an experimental research method. Testing is carried out by observing the deformation that occurs in soft soil without reinforcement and reinforced using woven plastic bottles layer 1 and layer 2.From the results of the deformation test that occurred in the unreinforced soil with a load of 4 kN was 45.5 mm, while the reinforced using woven plastic bottles layer 1 and layer 2 with the same load of 4 kN was 41.60 mm and 38.20 mm, so it can be concluded that the soil reinforced with woven plastic bottles layer 1 experienced an increase in strength of 9.38% and for woven layer 2 by 19.11% against the vertical deformation that occurred. Judging from the deformation pattern that occurred, the results of this modeling are included in the local shear failure pattern.

KEYWORDS: Plastic Bottles, Clay Soil, Soil Reinforcement

INTRODUCTION

Soil is a relatively loose collection of minerals, organic matter, and sediments located on bedrock. The relatively weak bonds between particles can be caused by carbonates, organic matter, or oxides that precipitate between the particles. The spaces between particles can contain water, air, or both. [1]

Soil with a low bearing capacity is also known as soft soil, as water plays a significant role in the soil's characteristics. Soft soil, with a dry mass, has a higher bearing capacity but will behave plastically when water is added. This can cause problems in various construction projects due to the soil's high shrinkage rate.

The construction of infrastructure on land with low bearing capacity can cause lateral movement, which can lead to significant subsidence. Currently, there are many methods or ways to overcome disturbances or problems that can occur in construction projects located on land with low bearing capacity. Various methods to overcome this include the use of geosynthesis, soil mixing or replacing materials, the use of cerucuks, and also various natural materials or waste utilization. Plastic bottle waste is the most frequently encountered inorganic waste, this type of waste has properties that are difficult to decompose with soil. For organic waste in Merauke Regency, it reaches 75.73% and inorganic 24.27%, for plastic waste is 8.14%. [2]

This waste has not been utilized effectively, so researchers are trying to improve its utilization. In this case, plastic bottle waste, initially considered a less useful waste product and potentially harmful to environmental health, can be transformed into a valuable form of waste by processing it to reduce pollution.

LITERATURE REVIEW

Roads are needed to connect one location to another. The construction of a road body (embankment) on land with insufficient bearing capacity can cause lateral movement and also cause subsidence in the land. This type of research is an experimental type, namely to see the deformation that occurs in soft soil that is not given reinforcement and in soft soil that is given reinforcement using bus wood and with varying depths starting from 10 cm, 20 cm, 30 cm, and 40 cm with a wood diameter between 4 cm to 6 cm. From the results of laboratory tests it is known that bus wood can reduce deformation that occurs in soft soil. From the results of tests for a load of 4 kN on unreinforced soil, a deformation of 40.70 cm occurred, while for soil with bus wood cone reinforcement with a load of 4 kN experienced an increase in strength against vertical deformation that occurred by 6.14% at a depth of 20 cm, 12.29% at a depth of 30 cm, and 19.77% at a depth of 40 cm. [3]

One of the alternatives provided in this modeling is bamboo grid and bamboo matting as a substitute for geosynthetics for shallow foundation reinforcement materials on clay soil. The purpose of this modeling is to determine the value of soil bearing capacity and BCR with bamboo grid and bamboo matting reinforcement. Shallow foundation modeling is carried out using the Plaxis 8.2 program. The parameters studied are the effect of variations in the distance and number of reinforcement layers using the same reinforcement width on the soil bearing capacity value by looking at the graph of the relationship between settlement and load from the Plaxis program output. From the results of the study, it was found that the addition of 3 layers of reinforcement at a variation of reinforcement distance from the base of the foundation of 0.25 B gave the highest soil bearing capacity value of 409.537 kPa. It can be seen that the closer the reinforcement distance from the base of the foundation, the greater the soil bearing capacity will be. [4]

The foundation settlement process is caused by the compression of the soil layer beneath the foundation due to the structural load. In this study, the effect of reinforcement installation on shallow foundation settlement on soft soil in the Aie Pecah Padang area was calculated. Reinforcement analysis was carried out on soft clay soil and sand fill soil that were given 1, 2, 3, and 4 layers of reinforcement. From the results obtained, soft clay soil loaded with foundations experienced a settlement greater than the permitted settlement. The installation of 2 layers of reinforcement provided optimum results on clay soil, namely with a reduction in settlement of 97.26%. [5]

THEORETICAL BASIS

A. Definition of Clay Soil

Soil is a collection of minerals, organic matter, and relatively loose sediments located on bedrock. The relatively weak bonds between particles can be caused by carbonates, organic matter, or oxides that precipitate between the particles. Between soil particles are empty spaces called pores, which contain water and air. These spaces are interconnected, allowing water to flow from higher to lower points. [1]

Clay soil is a soil that, if not carefully identified and investigated, can cause instability and intolerable long-term settlement. This soil has low shear strength and high compressibility. Soft soil is divided into two types: soft clay and peat. If the existing subgrade is clay, which has low bearing and shear strength, construction on it can be damaged. Therefore, the subgrade must be hard to meet technical requirements.

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b. Soil Classification

Generally, determining soil properties is often encountered in technical problems related to soil. The results of these property investigations can then be used to evaluate specific problems. Almost all soil classifications use a simple test-type index to determine the characteristics of the soil and determine the classification group. Sieve analysis and plasticity form the basis for determining particle size in general soil classification. AASHTO (American Association of State Highway and Transportation Officials) and the Unified Soil Classification System are two systems frequently used in soil classification. [1]

The AASHTO classification system is useful for determining soil quality for road embankment, subbase, and subgrade design. This system is primarily intended for purposes within these areas. This system divides soil into eight groups, A-1 through A-8, including subgroups. Groups A-1 through A-3 represent particles passing a 0.075 mm sieve or a No. 1 sieve. 200 ≤ 35%, and for groups A-4, A-5, A-6, and A-7 are grains that pass through a sieve size of 0.075 mm ≥ 35%.

In this case, the following tests were performed:

1. Granule Analysis

This analysis aims to determine the percentage of grain weight passing each sieve; therefore, this test is always performed. This test is performed using standard sieves (sieve nos. 200, 80, 60, 50, 40, 30, 16, 10, 8, 4). Calculate the percentage passing for each sieve using the formula:

$$Pt = \frac{W_t}{W_1}\ x\ 100\% \qquad (1)$$

Where:

P_t = Percentage of soil weight on sieve (%)
W_t = Weight of soil on sieve (grams)
W_1 = Total soil weight (grams)

2. Soil Specific Gravity

The ratio of the weight of water to the weight of dry/solid soil grains is also known as soil specific gravity. The specific gravity of clay soil ranges from 2.58 to 2.75. [1]
In laboratory testing, analysis can be performed using the formula:

$$Gs = \frac{\gamma_s}{\gamma_w} \qquad (2)$$

Where:

Gs = Specific gravity of soil
γs = Volume weight of solid soil particles (grams)
γw = Volume weight of water (grams)

3. Atterberg limits

These tests include:

a. Liquid Limit (LL)

Defined as the water content of the soil at the boundary between the liquid and plastic states, namely the upper limit of the plastic region. [1]

b. Plastic Limit (PL)

Defined as the water content between the plastic and semi-solid states, namely the percentage of water content at which soil with a cylinder diameter of 3.2 mm begins to crack when rolled. [1]

c. Plastic Index (IP)

Represents the reduction/difference from the liquid to the plastic limit. [1]

IP = LL - PL (%) (3)

Where:

IP = Plastic Index (%)

LL = Liquid Limit (%)

PL = Plastic Limit (%)

B. Characteristics of Plastic Bottles

Plastic is a readily available and flexible packaging material. Besides being used for food packaging, it is often used as a paper coating, and we often encounter it in almost every product and place. Each type of plastic has a different level of hazard depending on the chemical composition, the type of food being packaged, the temperature at which the food is stored, and the duration of use. [9]

Plastic comes in various types, including: HDPE, PET, LDPE, PVC, PS, PP, and others. These plastics are flexible, difficult to decompose, unbreakable, come in a variety of colors, are durable, relatively inexpensive, transparent, and readily available. The majority of PET materials worldwide are synthetic fibers, accounting for approximately 60% of the total. In textiles, PET is used as the base material for packaging bottles, accounting for approximately 30%. This type of bottle is only recommended for single-use because frequent use, especially for storing hot or warm water, can cause the polymer coating to melt and release carcinogenic substances that can be harmful to our bodies. [9]

In this study, the plastic used was PET (Vit/Aqua bottles). Due to its economic value and its inherent resistance to natural decomposition, this research will reduce environmental pollution caused by plastic bottle waste.

RESEARCH METHODOLOGY

The research was experimental, testing plastic bottle waste weaving using typical laboratory modeling on soft soil. The research location was the Civil Engineering Laboratory at Musamus University. The samples were taken from Kampung Salor I (Telaga Sari). The plastic bottles used were Vit/Aqua bottles sourced from areas around Merauke Regency.

The sample locations can be seen in Figure 1.

Figure 1. Map of sampling locations

1. Implementation Method

Soil samples were taken from Kampung Salor I (Telaga Sari), Merauke Regency. The plastic bottles used were Vit/Aqua, cut into 1 cm wide circles and then woven into 40 cm x 40 cm sizes.

A. Preparation of Tools and Materials
   a. Preparation of equipment for testing physical and mechanical properties of the soil.
   b. Modeling test tank: A soil reinforcement model using a tank measuring 120 cm x 60 cm x 50 cm.
   c. Hydraulic pump: To apply the load to the plate.
   d. Dial indicator: To monitor soil deformation.

B. Research Implementation
   a. Soil specific gravity testing was carried out in accordance with Indonesian National Standards (SNI) [10]. The tools used were a hot plate, pycnometer, oven, electric scale, and spatula.
   b. Water content testing was carried out in accordance with Indonesian National Standards (SNI) [6]. The tools used were an oven, a cup, and an electric scale.
   c. Grain analysis testing complies with SNI [11]. The tools used are sieves, brushes, electric scales, water hoses, and cups.
   d. The Atterberg limits testing tools comply with SNI. [12], [13] The tools used are Casagrande, cups, glassware measuring 0.9 cm x 45 cm x 45 cm, spatulas, and ovens.
   e. The compaction test tools comply with SNI [14]. The tools used are ovens, standard proctor hammers, standard proctor molds, electric scales, and jacks.
   f. We place the base soil into a 30 cm deep tank, then add 10 cm of backfill. Place the mesh at a height of 20 cm and 30 cm from the bottom of the tank.

RESULTS AND DISCUSSION

Results

Based on the results of laboratory research, we will explain the data from soft soil testing. The soil classification used in this test used the AASHTO classification system. Based on the results of the particle size test, 88.38% of the samples passed the No. 200 sieve, as larger than 35%, making them classified as clay and loamy, classified as groups A-4 to A-7.

The clay soil test included the following tests: Soil Granule Analysis This analysis uses a filter for grains that have a diameter greater than 0.075 mm.

Table 1. Gradation of soil grains

Diameter (Φ) Sieve (mm)	Sieve Weight (Gram)	Sample Weight (Gram)	% Retained	% Retained Cumulative	% Passing Cumulative
4.75	353	7	1.4	1.4	98.6
2.36	343	5.3	1.06	2.46	97.54
2	447.5	5	1	3.46	96.54
1.18	310.5	5.7	1.14	4.6	95.4
0.6	344.5	6	1.2	5.8	94.2
0.42	319	5.3	1.06	6.86	93.14
0.3	317.5	5.5	1.1	7.96	92.04
0.25	325	5.3	1.06	9.02	90.98
0.18	310.5	5.6	1.12	10.14	89.86
0.075	256	7.4	1.48	11.62	88.38
Pan	-	441.9	88.38	100	0
Sum		500	100	-	-

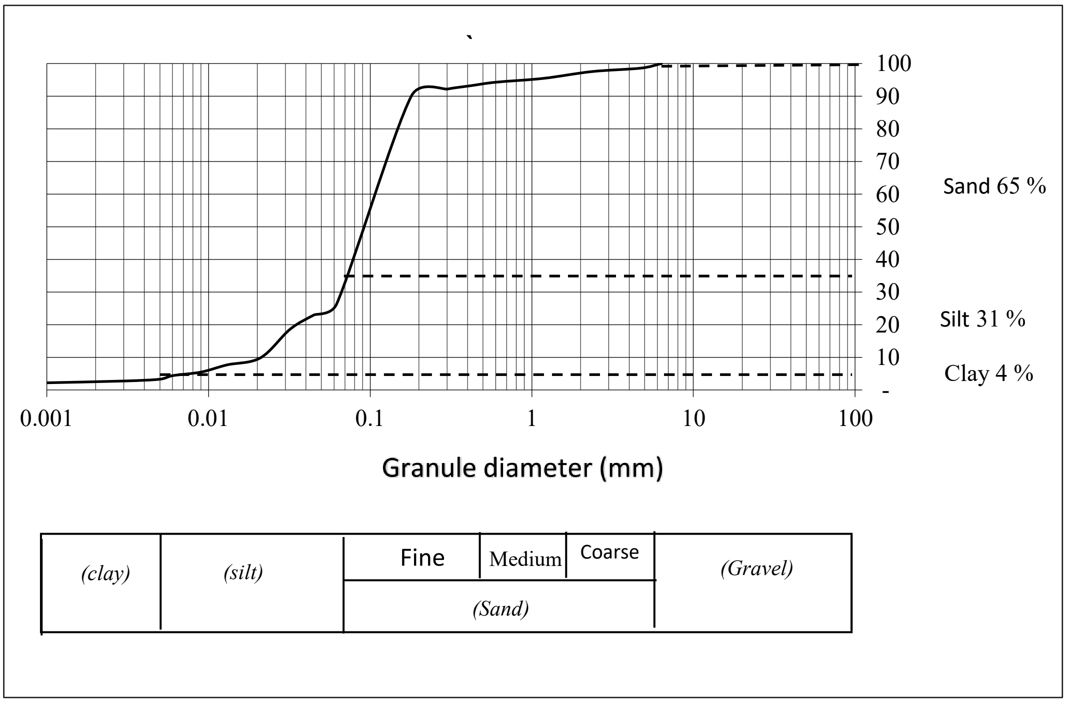

Figure 2. Soil Grain Analysis Graph

The results of the percentage of lag obtained by each are added together to obtain the cumulative percentage of lag and then from the data obtained cumulative pass, namely sieve no. 4 of 98.6%, no. 8 of 97.54%, no. 10 of 96.54%, no. 16 of 95.4%, no. 30 of 94.2%, no. 40 of 93.14%, no. 50 of 92.04%, no. 60 of 90.08%, no. 80 of 89.86%, and no. 200 of 88.38%.

Tabel 2. Atterberg test results

Liquid Limit			*Plastic Limit*	
No.	Number of Strokes	Water content	No.	Water content
1	16	51,61 %	1	14 %
2	24	45,45 %	2	18,18 %
3	33	42,11 %	3	22,22 %
4	42	37,50 %		
Average water content		44,17 %	Average water content	18,13 %
LL = 44,17 %			PL = 18,13 %	

Plastic index :

IP = LL – PL

= 44,17 – 18,13

= 26,04 %

This test is to see the optimum level of the soil being tested and determine the value of the relationship between water content and soil density, which can be seen in Figure 3.

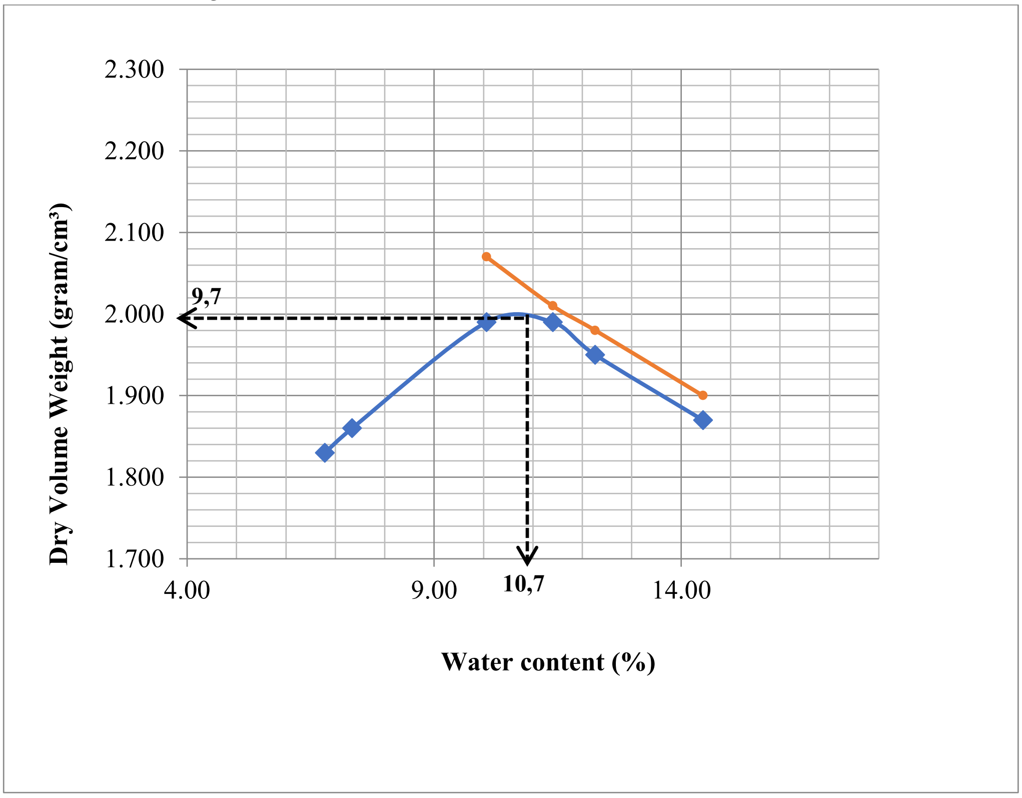

Figure 3. Relationship between dry unit weight and water content

Based on the test results, a summary of the physical and mechanical characteristics tests was prepared, as shown in the following table 3.

Table 3. Recapitulation of test inspection results

Types of Testing		Test Results	
Soil Characteristics Testing			
	Water Content (w)	14,71	%
	Specific gravity (Gs)	2,60	
Grain analysis test			
	Cumulative pass no. 200	88,38	%
Atterberg test			
1	Liquid limit	44,17	%

2	Plastic limit	18,13	%
3	Plastic index	26,04	%
Bulk density testing		1,84	gram/cm^3
Compaction testing			
1	Dry weight	1,97	gram/cm^3
2	Optimum water content	10,7	%

DISCUSSION

Laboratory testing results demonstrate the settlement and deformation that occurred. These tests were divided into three reinforcement schemes: one without woven bottles, one with woven bottles in one layer, and one with woven bottles in two layers.

From the results of the tests conducted, data on land subsidence has been obtained. For Schemes 1, 2, and 3, see the following tables 4.

Table 4. Land settlement without reinforcement

No	Distance (cm)	Decline(mm)				Information
		Burden 1 kN	Burden 2 kN	Burden 3 kN	Burden4 kN	
1	0	-27,5	-36,5	-40,3	-45,5	Decrease reading
2	-15	-27,5	-36,5	-40,3	-45,5	
3	15	-27,5	-36,5	-40,3	-45,5	
4	-30	1,4	2,6	3,0	5,7	Dial 1
5	-45	1,2	2,2	2,9	4,8	Dial 2
6	30	1,35	2,55	2,97	5,6	Dial 3
7	45	1,18	2,15	2,7	4,4	Dial 4

Table 4 shows the subsidence of unreinforced soil. The subsidence that occurs with a load of 4 kN in soil without woven reinforcement is -45.5 mm.

Table 5. Subsidence with 1st layer of woven reinforcement

No	Distance (cm)	Decline(mm)				Information
		Burden 1 kN	Burden 2 kN	Burden 3 kN	Burden4 kN	
1	0	-24,5	-34,15	-37,15	-41,60	Decrease reading
2	-15	-24,5	-34,15	-37,15	-41,60	
3	15	-24,5	-34,15	-37,15	-41,60	
4	-30	1,25	2,1	2,7	4,3	Dial 1
5	-45	1,1	2	2,6	3,8	Dial 2
6	30	1,2	1,96	2,56	4	Dial 3
7	45	1	1,8	2,5	3,2	Dial 4

Table 4.5 shows that the deformation occurring under a 4 kN load on the soil reinforced with the first layer of woven bottle mesh changed. The settlement was -41.60 mm.

Table 6. Land settlement with the second layer of woven bottle mesh.

No	Distance (cm)	Decline(mm)				Information
		Burden 1 kN	Burden 2 kN	Burden 3 kN	Burden4 kN	
1	0	-22,25	-34,45	-36,30	-38,20	Decrease reading
2	-15	-22,25	-34,45	-36,30	-38,20	
3	15	-22,25	-34,45	-36,30	-38,20	

4	-30	1	1,6	2	3,89	Dial 1
5	-45	0,7	1,3	1,8	2,85	Dial 2
6	30	0,9	1,1	1,94	3,1	Dial 3
7	45	0,57	0,9	1,76	2,89	Dial 4

Table 6 shows that the subsidence of the soil using reinforcement with a load of 4 kN on the soil reinforced with woven plastic bottles with two layers of reinforcement experienced a change in subsidence. The subsidence occurred by -38.20 mm.

Table 7. Unreinforced deformation dial readings

No.	Burden (kN)	Decrease reading	Deformation reading			
			Dial 1	Dial 2	Dial 3	Dial 4
1	0	0,00	0	0	0	0
2	0,5	19,2	0,6	0,47	0,52	0,4
3	1	27,5	1,4	1,2	1,35	1,18
4	1,5	30,7	1,86	1,62	1,73	1,5
5	2	36,5	2,6	2,2	2,55	2,15
6	2,5	38	2,87	2,56	2,70	2,24
7	3	40,3	3	2,90	2,97	2,70
8	3,5	43,1	4,1	3,7	3,7	3,38
9	4	45,5	5,7	4,8	5,6	4,4

Table 7 shows the deformation readings that occur in soil without reinforcement with a load of up to 4 kN. The deformation that occurs at a load of 4 kN for dial 1 is 5.7 mm, for dial 2 the deformation is 4.8 mm, for dial 3 the deformation is 5.6 mm, and for dial 4 the deformation is 4.4 mm.

Table 8. Deformation dial reading with 1st layer woven reinforcement

No.	Burden (kN)	Decrease reading	Deformation reading			
			Dial 1	Dial 2	Dial 3	Dial 4
1	0	0,00	0	0	0	0
2	0,5	15,3	0,4	0,38	0,34	0,32
3	1	24,5	1,25	1,10	1,2	1
4	1,5	28,4	1,67	1,43	1,54	1,33
5	2	34,15	2,10	2	1,96	1,8
6	2,5	35	2,49	2,36	2,35	2,2
7	3	37,15	2,70	2,6	2,56	2,5
8	3,5	39,1	3,20	3	3,10	2,99
9	4	41,60	4,30	3,8	4	3,2

Table 8 shows the deformation readings that occur in the soil using layer 1 bottle mesh reinforcement with a load of up to 4 kN on the soil. The deformation that occurs at a load of 4 kN for dial 1 is 4.30 mm, on dial 2 the deformation that occurs is 3.80 mm, on dial 3 the deformation that occurs is 4 mm, and on dial 4 the deformation that occurs is 3.20 mm.

Table 9. Deformation dial reading with 2-layer woven reinforcement

No.	Burden (kN)	Decrease reading	Deformation reading			
			Dial 1	Dial 2	Dial 3	Dial 4
1	0	0,00	0	0	0	0
2	0,5	14,20	0,28	0,22	0,21	0,19
3	1	22,25	1	0,70	0,90	0,57
4	1,5	26,7	1,33	1,07	1,02	0,81
5	2	34,45	1,60	1,30	1,38	0.9

6	2,5	35	1,87	1,49	1,73	1,22
7	3	36,30	2	1,80	1,94	1,76
8	3,5	37,60	3,10	2,10	2,68	2
9	4	38,20	3,89	2,85	3,10	2,89

Table 9 shows the deformation readings that occur in the soil using 2-layer woven bottle reinforcement with a load of up to 4 kN. The deformation that occurs in the soil for dial 1 is 3.89 mm, for dial 2 the deformation is 2.85 mm, for dial 3 the deformation is 3.10 mm, and 2.89 mm occurs for dial 4.

The results of the reinforcement model tests yielded combined data on soil deformation, including:

a. Reinforcement Scheme 1 without using plastic bottles.
b. Reinforcement Scheme 2 using a single-layer plastic bottle.
c. Reinforcement Scheme 3 using a double-layer plastic bottle.

CONCLUSION

From the analysis of laboratory test results, it was concluded that plastic bottles can be used as a reinforcement material for subgrade with low bearing capacity, because it can reduce the deformation that occurs in the soil. It is known that the deformation in unreinforced soil with a load of 4 kN is 45.5 mm, while using layer 1 and layer 2 bottles with the same load of 4 kN is 41.60 mm and 38.20 mm, respectively. It was concluded that the soil with layer 1 bottle reinforcement experienced an increase in strength of 9.38% and for layer 2 by 19.11% against the vertical deformation that occurred. Judging from the deformation pattern that occurred, the results of this modeling are included in the local shear failure pattern.

REFERENCES

1. H. C. Hardiyatmo, "Soil Mechanics I, III Edition," Gajah Mada University Press, 2002.
2. P. L. Dina, "Analysis of Incinerator Use in Waste Processing in Merauke," vol. 3, no. 3, pp. 561–565, 2014.
3. M. Baidowi A, Experimental Study of Embankment Reinforcement Models Using Bus Wood on Soft Soil. 2016.
4. M. A. Nusantara, "Analysis of the Bearing Capacity of Shallow Foundations on Clay Soil Using Woven Bamboo and Bamboo Grid Reinforcement with the Assistance of the Plaxis Program," Journal of Civil and Environmental Engineering, vol. 2, no. 3, pp. 2355–374, 2014.
5. B. A. Zaika, Yulvi; Kombino, "Use of geotextiles as an alternative soil improvement for shallow foundation settlement," J. Civil Engineering, vol. 4, no. 2, pp. 11-13. 91–98, 2010.
6. SNI 03-1965, "Soil Water Content," 1990.
7. R. F. Craig and B. S. S. Publisher Erlangga, "Soil Mechanics 4th Edition," 1989.
8. J. I. L. Braja and A. B. N. E. and I. B. M. Publisher Erlangga, "Soil Mechanics (Principles of Geotechnical Engineering)," 1995.
9. U. S. North, "Plastic," 2008.
10. SNI 03-1964, "Soil Specific Gravity," 2008.
11. SNI 03-1968, "Sieve Analysis," 1990.
12. SNI 03-1966, "Plastic Limit and Index Plastic," 1990.
13. SNI 03-1967, "Liquid Limit," 1990.
14. SNI 03-1742, "Soil Density," pp. 1–9, 1989.