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RESEARCH ARTICLE

Experimental Study Of Improving The Physical Properties Of Peat Soil Using Sand And Bio-Grouting Techniques With The Assistance Of Bacillus Subtilis Bacteria

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Abstract

Peat soil was categorized as soft soil, which means that the soil is in bad condition and problematic when construction was built on it. It was necessary to increase the carrying capacity of peat soils, one of which is chemical stabilization of the soil, by adding additives that can react with the soil and using new environmentally friendly methods.

In this study, samples of peat soil were taken from Buana Makmur Village km55, Dayun District, Siak Regency. The stabilizing agent used was sand as much as 5% by weight of dry soil, Bacillus Subtilis bacteria obtained from the Agriculture Laboratory of the Islamic University of Riau, and also $CaCL_2$ and Urea. The method for stabilizing the physical properties of peat soil in this study is the Bio-Grouting method, testing the physical properties of peat soil follows the procedures of ASTM (American Society For Testing And Materials) and SNI 1965-2008 for testing methods for determining water content for soil and rock in the laboratory. SNI 1964-2008 test method for soil specific gravity, SNI 8460-2017 geotechnical design requirements, SK SNI -04-05-1989-F fine sand used for construction, SNI-02-2801-1998 urea standard. To test the physical properties was carried out by providing variations in the mixing of bacterial cementation solutions with levels of 0% (without treatment), 5%, 10%, 15%, 20%, and 25% and then allowed to stand for 14 days using a tightly closed plastic container.

The results of testing the physical properties of peat soil found that the peat soil was included in the original soil type with water content = 407.45% and specific gravity (Gs) = 1.30gr, while from the physical properties tests carried out the highest water content occurred in the addition of bacterial cementation solution 10% = 177.2% and the lowest specific gravity occurs when the bacterial cementation solution is added 10% = 1.27gr.

Keywords: Bio-Grouting, Bacillus Subtilis, $CaCL_2$, Sand, Stabilization, Physical Properties, Urea

1. Introduction

1.1 Background

Peat soil is soil that comes from the remains or weathering of plants, thus peat soil is categorized as soft soil which usually has a low carrying capacity value. If a construction is to be built on it, soil improvement efforts are needed to increase the ability of the soil. The peat soil to be tested comes from Buana Makmur Village km55, Dayun District, Siak Regency.

Stabilization is an improvement to the properties and parameters of the original soil thus the soil can be used in construction. One of the efforts to increase the carrying capacity of peat soils is by improving the soil or stabilizing it chemically, by adding a mixture that can react with peat soil, the additional ingredients are sand and bacillus subtilis bacteria using the bio-grouting method.

Biogrouting is a soil stabilization technique involving microorganism-induced calcium carbonate (CaCO3) precipitation. Precipitation of calcium carbonate acts as a binding crystal between cells that stimulates the process of cementation between soil grains. In applying bio-grouting technology, it is necessary to consider the type of soil to be stabilized and the type of microorganism used as a bio-grouting agent. Several studies related to bio-grouting have been extensively tested during the last few years. DeJong et al, (2006) used Bacillus pasteurii to stabilize loose, collapsible sand. Nur and Sofyan showed that bio-grouting through Bacillus subtilis can reduce the permeability of sandy clay. Bacillus subtilis is also described to stabilize marine sandy loam soils by strengthening and reducing soil permeability.

Bacillus is a gram-positive rod-shaped bacterium with an optimum temperature for growth between 25-35°C. Although Bacillus was considered to be strictly aerobic, it was discovered later that they can live anaerobically under defined conditions. Bacillus is naturally found in soil, they colonize root systems and compete with other microorganisms such as fungi. Bacillus subtilis is known to be safe for use in food products as a probiotic and part of food ingredients. Under harsh conditions, Bacillus can form stress-resistant endospores as a defense mechanism. Spores are resistant to exposure to heat, radiation, and chemicals, and are resistant to desiccation.

For this reason, stabilization of peat soil is very necessary if you are going to carry out construction, soil stabilization is an effort to increase the stability and carrying capacity of the soil.

2. Library Survey

There are several previous studies related to compressive strength, shear strength, organic soils, and the addition of sand to increase soil carrying capacity which can be used as a reference in the discussion of this study. In this study, previous research was presented, namely Firman Syarif et al (2019), Willy (2015), Setiawan (2014), Angelina Lynda (2013), Afriani (2008) Nugroho (2008) and DeJong, J.T. (2006).

Sharif et al (2020), has conducted research with the title, "Application of the Biocementation Technique by Bacillus Subtilis and Its Effect on Permeability in Organic Soils"

Willy, 2015 carry out direct shear strength tests by mixing clay with sand with a mixture percentage of 10%, 20%, 30%, and 40%. From the test results obtained the value of the relationship between the percentage of the mixture and the shear angle

Setiawan, 2014 in his research on the effect of organic soils at optimum conditions, the wet side of the optimum and dry side of optimum on compressive strength. From the results of this study, it can be concluded that the compressive strength value at the optimum condition of organic soil is 0.063 Kg/cm².

Lynda (2013), has conducted research with the title "Characteristics of Soil Shear Strength Using Biogrouting Stabilization Method of Bacillus Subtilis Bacteria".

Afriani, 2008 researched the effect of adding sand to clay soil.

Nugroho, 2008 has researched the stabilization of peat swamp soil using a mixture of Portland cement and synthetic gypsum (CaSO42H2O) in terms of the California Bearing Ratio (CBR) value.

DeJong, J.T. (2006) has researched biological grouting technology known as bio-grouting technology through the mechanism of calcium carbonate deposition.

3. Theoretical Basis

Soil is a material that consists of solid mineral grains that are not chemically bound to each other and from organic materials that have weathered together with liquid and gas substances that fill the empty spaces between the solid particles (Das, 1988).

Weak bonds between soil particles are caused by the influence of carbonates or oxides that are compounded between the particles, or they can also be caused by the presence of organic material. soil).

Ground transport media in the form of gravity, wind, water, and glaciers. When moving, the size and shape of the particles can change and are divided into several size ranges. Soil according to Bowles (1989) is a mixture of particles consisting of one or all types.

Table 1. Particle According *Bowles* (1989).

Particles	Description
Boulder	Bigger than 250 mm until 300 mm and for size range 150 mm – 250 mm, fragment of these stones are called cobbles/ pebbles.
Sand	Size 0,074 mm – 5 mm, ranging from rough (3 mm–5 mm) until fine (< 1 mm).
Silt	Size from 0,002 mm – 0,074 mm
Clay	Size more than 0,002 mm
Colloid (colloids)	Size more than 0,01 mm.
Gravel	Size more than 5 mm until 150 mm

Peat soil is soil that contains many organic components, the thickness of which is from several meters to tens of meters underground. Organic soils are black and are the main constituent of peatlands. This type of soil is generally prone to large settlements.

Table 2. Soil Type Based on Organic Content (road embankment construction plan on peat using a preloading method, 2004)

Soil Type	Organic Level
Clay	<25
Organic Clay	25-27
Peat	>75

The physical properties of peat soil have a very high organic content, whereas the soil formation process itself comes from plants. The high water content and large pore value cause the seepage coefficient of peat soil to resemble sand, this is because the large pores cause the water in the pores to easily escape, especially when there is a load on it.

The small volume of peat soil indicates that the density of peat soil is not like that of soil in general and when it is associated with a high water content, the weight of the water contained in peat soil is 6 (six) times heavier than the weight of the peat soil grain.

Table 3. Physical Characteristics of Indonesian Peat Soil (Mochtar, 2002)

No	Physical Trait	Value
1	Organic Content (Oc)	95 - 99%
2	Volume Weight (t)	0,9 - 1,25 t/m³
3	Water Level (W)	200% - 900%
4	Pore Number (e)	5 – 15
5	Ph	4 – 7
6	Ash Level (Ac)	1 – 15%
7	Gravity Specification (Gs)	1,38 – 1,95
8	Seepage (k)	2^{-02} s/d $1{,}2^{-06}$

Table 4. Engineering Properties of Peat Soil (Mochtar, 2002)

No	Trait	Value	Description
1	Soil cohesion/shear strength	0	non cohesive
2	Compressibility	Very High	Sensitive towards
3	Bearing capacity	5 – 7 kpa	Scandinavia
4	Inside sliding angle	> 50 degrees	Especially fibrous
5	Soil tek coefficient at rest	Max 0,5	Smaller than
6	Consolidation	Very long	4

4. Research methods

The sampling location for Peat Soil was taken from the Buana Makmur Village area km 55, Dayun District, Siak Regency, for bacteria from the Agricultural Laboratory of the Islamic University of Riau, Pekanbaru. In this study, the materials used are:

1. The soil used was peat soil

peat soil samples in unstable or disturbed conditions, where the samples were taken at a depth of ± $50cm$ from the top soil surface using a hoe and makeshift tools, then the soil sample is taken to the laboratory for testing, before being tested the soil sample is dried first by utilizing the sun's heat, then after drying the soil sample is sieved using a no4 sieve until it passes.

2. Sand was a natural aggregate that comes from volcanic eruptions, rivers, soil, and beaches, therefore sand can be classified into three types, namely dug sand, sea sand, and river sand.

3. Bacillus subtillis was a gram-positive, rod-shaped, and catalase-positive bacterium. Like other bacteria of the Bacillus genus, Bacillus subtilis can form endospores, to survive extreme environmental conditions of temperature and desiccation. Bacillus subtillis is a facultative anaerobe and was considered an obligate aerobe until 1998.

4. Urea, alcalled nitrogen (N) fertilizer, has a nitrogen content of 46%. Urea is made from the reaction between ammonia and carbon dioxide in a chemical process to become solid urea in the form of prills (1-3 mm in size) or granules.

5. CaCl2 (Kalsium Kloride)

Stage Process Flowchart

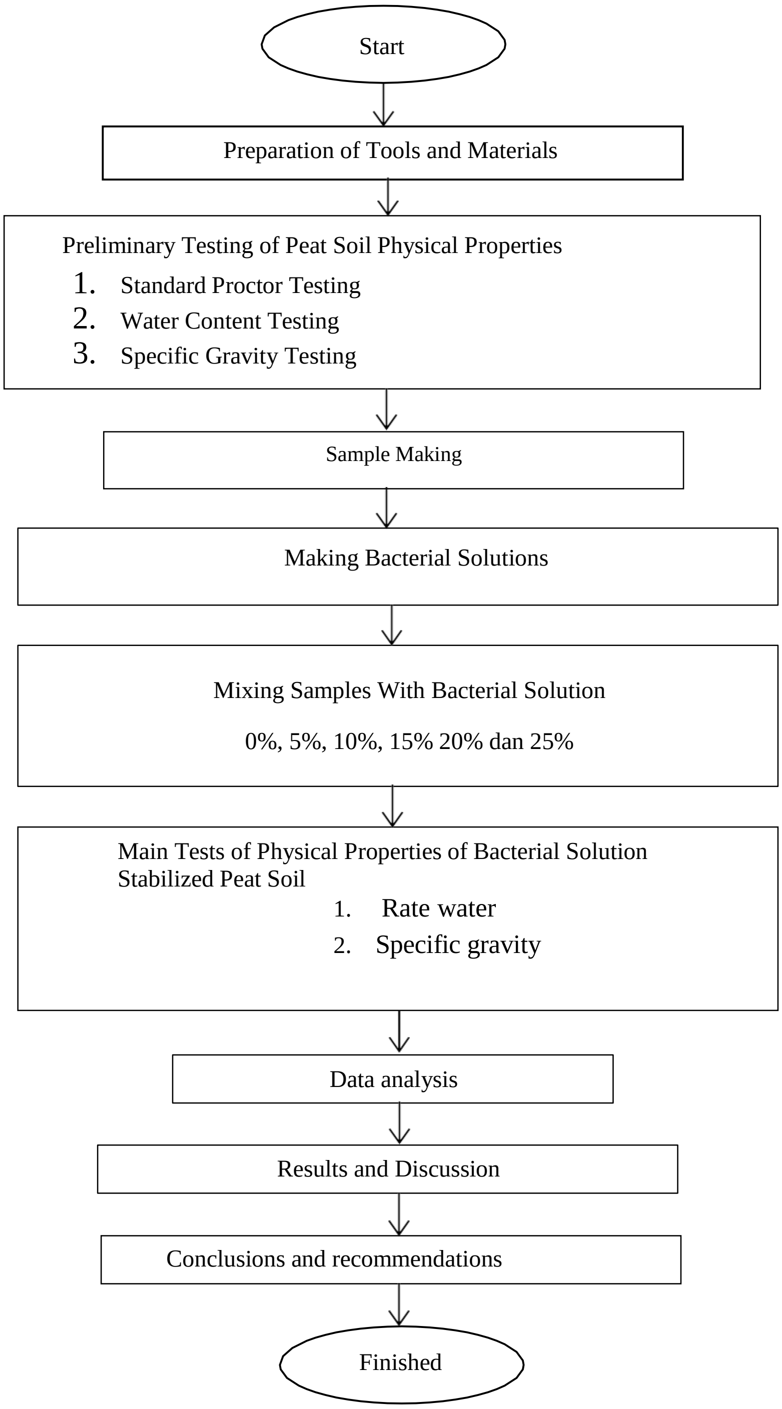

Fig 1. Research Flowchart

5. Results and Discussion

The results of the observations were in the form of tests, namely the characteristics and physical properties of peat soil using a mixture of sand and Bacillus Subtilis bacteria using the Bio-Grouting method.

The effect of Bacillus subtilis on the engineering properties of organic soils is still not fully understood. Organic soils and sandy loams show different characteristics. In general, organic soils are problematic soils associated with low unit weight, unsatisfactory strength characteristics, and high compressibility. These undesirable organic soil properties can cause serious foundation problems. Therefore, organic soils need to be stabilized before civil infrastructure is built on them.

Preliminary testing is carried out before mixing peat soil with sand and Bacillus Subtilis bacteria using the Bio-Grouting method. This test is carried out using peat soil as a test. Several tests include testing the original soil water content, a specific weight (Gs), and compaction testing.

Soil water content. The procedure for testing the water content is carried out following the procedure in ASTM D2216. From the water content test carried out on the soil, the water content value was 407.5%. The high water content is because native soil consists of organic fiber (peat) which can absorb a lot of water, according to the Center for Transportation Infrastructure Research and Development, while peat moisture content ranges from 200% to 900%.

Procedure for testing the specific gravity (Specific Gravity) was carried out following ASTM 854. From the tests that have been carried out on the original soil, the specific weight (GS) value of the soil used is, can be seen in Appendix A-2. The specific weight value (GS) is affected by wood fiber and other organics.

Maximum Soil Density Compaction testing was carried out to obtain a maximum dry unit weight (γd max) value of 0.467 gr/cm3 and an optimum moisture content (OMC) of 157% of native soil.

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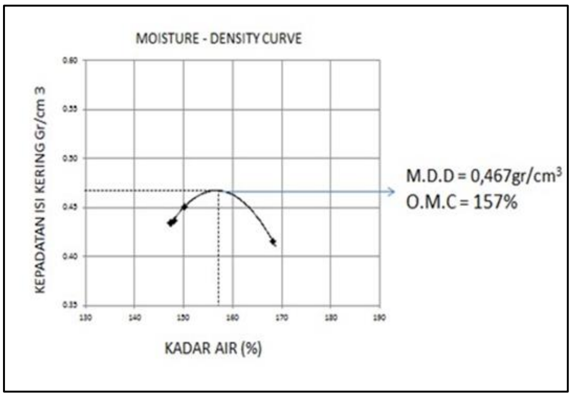

Fig 2. Dry Volume Weight Relationship with Water Level

The high value of the optimum moisture content (OMC) is caused by the large pores in the soil because the soil consists of plant (organic) fibers causing the soil to absorb a lot of water to achieve optimum density. The optimum moisture content (OMC) obtained from the compaction test on the original soil is used as a comparison to the soil conditions used in the modeling test. according to the dry unit weight obtained, the classification of peat is based on the dry unit weight at the level of weathering or decomposition > 0.2 gr/cm3 (Mutalib, et al., 1991) peat soil originating from siak is categorized as *saprik* peat to the influence of soil minerals

5.1 Properties of peat soil

Based on the tests carried out, the physical properties of the soil can be summarized. The following table shows the physical properties of peat soil obtained from preliminary testing.

Tabel 4. Properties of peat soil.

No	Traits	Size	Unit
1	Specific Weight, *GS*	0,544	-
2	Water Level, *w*	407,5	%
3	Wet Volume Weight, γ	0,983	kN/m^3
4	Dry Volume Weight, γd	0,168	kN/m^3
5	Maximum Dry Content Weight, (γd maks)	0,467	Gr/cm^3
6	Optimum Water Level, (OMC)	157	%

5.2 Testing of Bacterial Solution Stabilized Physical Properties

Testing of Physical Properties uses the methodbiogrouting namely by mixing the bacteria bacillus subtiliswhich is made into a solution (cementation solution) with the addition of sand. The percentage of sand in the specimen sample is as much as 5% by weight of the peat soil sample. The following is the percentage of addition of cementation solution to the sample of the test object:

a. Sample 1 = 0%
b. Sample 2 = 5%
c. Sample 3 = 10%
d. Sample 4 = 15%
e. Sample 5 = 20%
f. Sample 6 = 25%

5.3 Stabilized Water Content of Bacterial Solution

Test the water content in the sample of the test object mixed with the addition of cementation solution

Table 5. Value of Moisture Content (W) Against the Addition of Cementation Solution

No	Treatment of Bacterial Solution (%)	Water Level (%)
1	0%	166,6
2	5%	172,7
3	10%	177,2
4	15%	164,6
5	20%	169,7
6	25%	162,5

Table results 5 value of water content (W) to the combination of adding bacterial cementation solution 0% 5% 10% 15% 20% and 25% can be seen in the following graphic :

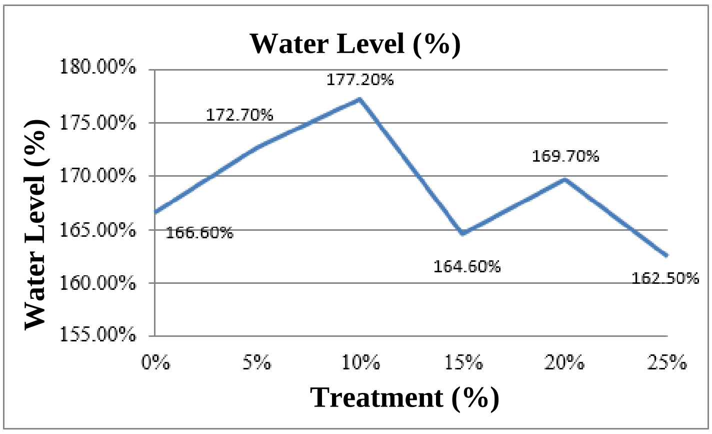

Fig 3. Relationship of Water Content (W) to the Addition of Bacterial Solution

Looking at the results of Figure 3 on the graph of the relationship between water content (W) and mixing of bacterial solutions, it can be concluded that the addition of 5% and 10% bacterial solutions experienced an increase in water content (W) when the addition of 15% bakery solution decreased by 6% from the water content. (W), on the addition of 20% bacterial solution, the water content (W) increased again by 3.1%, and on the addition of 25% bacterial solution, the water content (W) decreased again by 4.1%. The highest water content (W) occurred in the treatment of adding 10% bacterial solution with a value (W) = 177.2% with an increase of 10.6% from the sample of the test object without treatment or 0%.

In the 0% treatment, there was an increase in water content due to the addition of sand this study, which was 5% of the sample weight of the test object in each treatment.

5.4 Bacterial Solution Stabilized Specific Gravity

Specific gravity tests on peat soil samples mixed with a bacterial solution can be seen in Table 6.

Table 6. Value of Specific Gravity (Gs) of Peat Soil Against the Addition of Bacterial Solution Bakteri

No	Treatment of Bacteria Solution (%)	Soil Specific Gravity (gr)
1	0	1,56
2	5	1,62
3	10	1,27
4	15	1,67
5	20	1,77
6	25	1,80

Table results**6** specific gravity (Gs) for the addition of 5%, 10%, 15%, 20% and 25% bacterial solution is explained in the graph below:

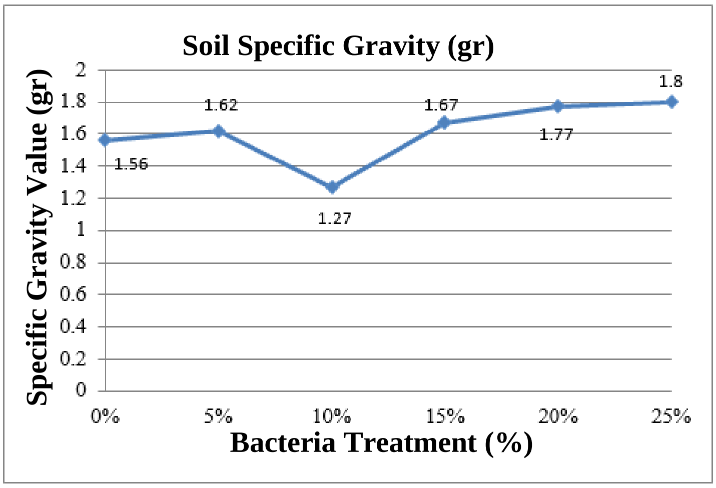

Fig 4. Relationship of Specific Gravity (Gs) Value to the Addition of Bacterial Solution

The results of Figure 4 in the graph above the relationship of specific gravity (Gs) to the addition of bacterial solution, it can be concluded that the addition of 5% bacterial solution increases the specific gravity (Gs) of = 0.06gr from the sample of the test object without treatment. When the 10% bacterial solution was added, the specific gravity decreased by = 0.35gr from the addition of 5% bacterial solution, and the addition of 15%, 20%, and 25% bacterial solution continued to increase in specific gravity (Gs) from 10% addition. The highest specific gravity (Gs) value occurred in the addition of 25% bacterial solution with a specific gravity value (Gs) = 1.80gr with an increase (Gs) = 0.25gr from the (Gs) value of the test object without treatment.

5.5 Comparison of Gs Values (*specific Gravity*) From Stabilization With*Bio- Grouting* And Other Stabilization

Comparison between stabilization*bio-grouting* with tabilization and the materials are usually seen in **table 7** below this.

Table 7. Comparison of the Gs Value of Stabilization with Bio-Grouting with other Stabilization:

No	Cement Level (Nugroho, 2008)		Lime Level (Nugroho, 2008)		Non Organic Soil (Nugroho, 2008)		Bio-Grouting (This Research)	
1	%	Value	%	Value	%	Value	%	Value
2	0	1,40	0	1,49	0	1,48	0	1,56
3	2	1,45	2	1,61	10	1,55	5	1,62
4	4	1,51	4	1,85	20	1,59	10	1,27
5	6	1,55	6	1,89	30	1,61	15	1,67
6	8	1,64	8	2,35	40	1,72	20	1,77
7					50	1,90	25	1,80

From the comparison table above, the highest Gs values are in peat soils which are stabilized with lime content, while those with the lowest Gs values are stabilized with cement content.

Below is a line diagram image of each peat soil stabilization with the addition of different materials: 1. Line diagram of the relationship between the specific gravity of peat soil and the addition of cement content

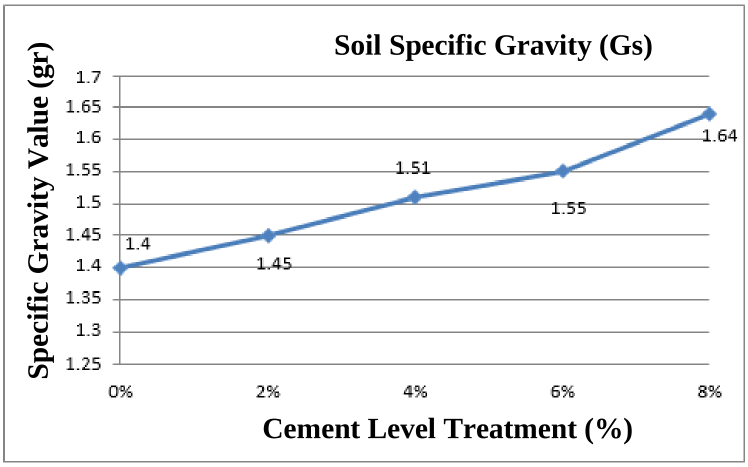

Fig 5. Relationship of Specific Gravity to Addition of Cement Content in Peat Soil (Nugroho, 2008)

From Figure 6, the relationship between specific gravity and the addition of cement content in peat soils can be concluded that the addition of a stabilizing agent in cement content causes an increase in specific gravity.

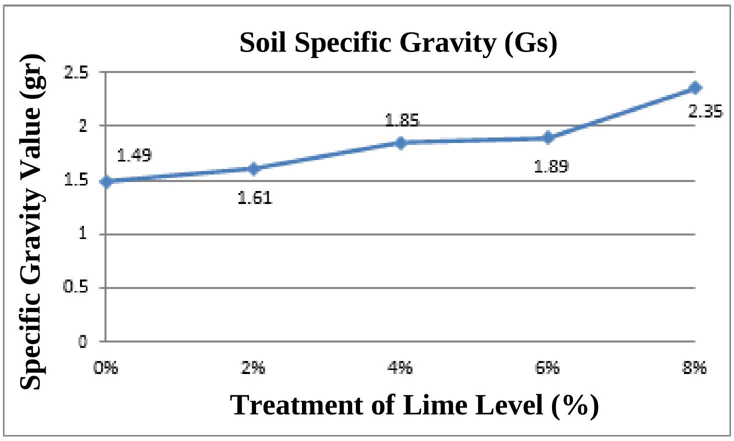

Fig 6. Relationship of Specific Gravity to Addition of Lime Content in Peat Soil (Nugroho, 2008)

From Figure 7, the relationship of specific gravity to the addition of lime content in peat soils can be concluded that along with the addition of a stabilizing agent, the lime content also causes an increase in specific gravity.

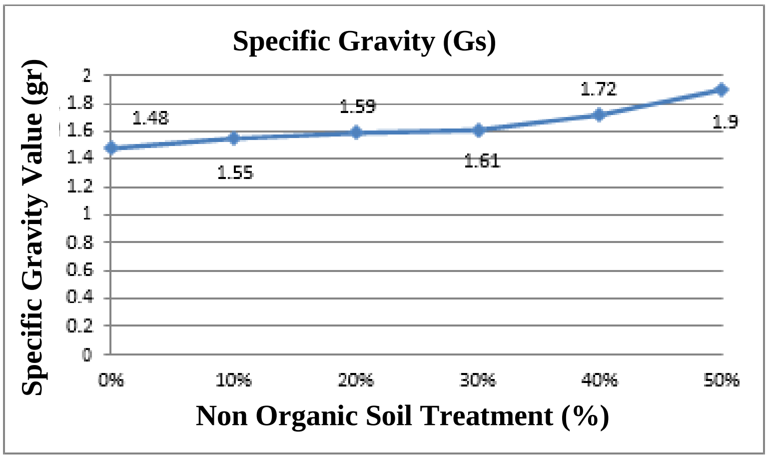

Fig 7. Relationship of Specific Gravity to Addition of Non-Organic Soil in Peat Soil (Nugroho, 2008)

From Figure 8, the relationship between specific gravity and the addition of non-organic soil to peat soil can be concluded that along with the addition of a stabilizing agent, lime content also causes an increase in specific gravity.

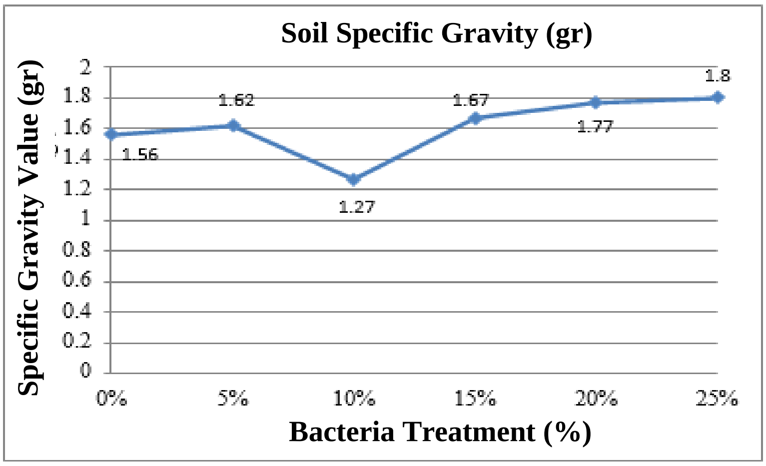

Fig 8. Relationship of Specific Gravity to Bacterial Addition *Bacillus Subtilis* On Peat

From Figure 9 the relationship of specific gravity to the addition of bacteria bacillus Subtilison peat soil it can be concluded that the decrease occurred when the addition of bacteria as much as 10%, then subsequently caused an increase in specific gravity.

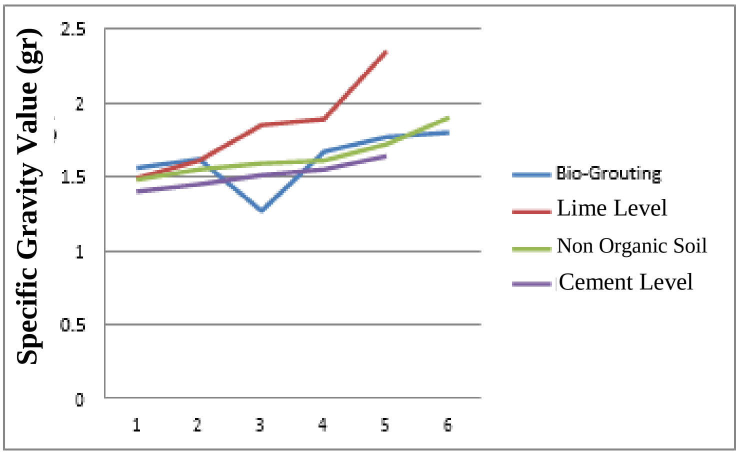

Fig 9. Line Diagram Comparison of Gs Values From Stabilization WithBio- Grouting With Other Stabilization, on the Z axis is the value of the specific gravity (gr) of each stabilization and X is the treatment of additional stabilization materials (%).

The Effect of *Bacillus Subtilison* The engineering properties of organic soils are still not fully discovered. Organic soils and sandy loams show different characteristics. In general, organic soils are problematic soils associated with low unit weight, unsatisfactory strength characteristics, and high compressibility. These undesirable organic soil properties can cause serious foundation problems. Therefore, organic soils need to be stabilized before civil infrastructure is built on them

6. Conclusion

Peat soil which was stabilized by adding sand and bacterial solution for testing the water content did not fully improve and the decrease in water content even experienced a significant increase in the addition of a 10% bacterial solution, an increase of 10.6% from the test object sample without treatment or 0%.

Peat soil which was stabilized by adding sand and the help of a bacterial solution for specific gravity testing also did not fully improve and the specific gravity value increased. The highest increase in specific gravity occurred in the addition of 25% bacterial solution with a specific gravity value (Gs) = 1.80 with an increase of 0.25 from the value (Gs) of the sample without treatment or 0%3

The relationship between water content and the specific gravity value of peat soil with the addition of sand and the help of a bacterial solution is compatible with each addition of 10% bacterial solution where the higher the water content, the lower the specific gravity value and the compatibility also occurs with the addition of 25 bacterial solutions. %, there shows that the lower the water content, the higher the specific gravity value.

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