Soil Stabilization Using Gypsum and The Effect Based on The Unconfined Compressve Strength Values

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Abstract

The process of soil stabilization refers to changing the physical properties of soil in order to improve its strength, durability, or other qualities. Typically, this is important for road construction, and other concerns related to the building and maintenance of infrastructure. Soil that has been stabilized will have a vastly improved bearing capacity, and will also be significantly more resistant to being damaged by water, frost, or inclement conditions soil). This research briefly describes the suitability of the gypsum to be used in the stabilized soil. Unconfined compressive strength (UCS) used as indicator to the strength development and hence evaluating the performance of gypsum stabilized soil. This research focusing on the effect of gypsum as a soil stabilizer. A various mix design at different percentage of gypsum (0, 4%, 8%, 10% and 15%) were prepared and cured for 0, 7, 14 21 and 28 days. Then the unconfined compressive strength (UCS) was carried out on 38mm diameter x 76mm height specimens. The lowest unconfined compressive strength test results were found in the gypsum content of 0% and curing for 0 days of 3.8667 kg / cm^2. While, the largest found in the gypsum content of 8% with 28 days of 14.2 kg / cm^2. Curing increases the strength of soil. The addition of gypsum is effective for stabilization of clay soil.

Keywords

Soil stabilization, Gypsum, Clay soil, Atterberg Limits, unconfined compressive strength

1. Introduction

In indonesia, the development of national road networks has encroached into the areas underlain with very soft soils. Generally, clay soil usually living in rural area where the existing soils are weak and more deformative. Clay soil is an easy soil to swelling if the soil is wet in the rain season and will shrink if the soil is dry in the dry season (Samer Dessouky et al., 2012). Swelling and shrinkage happens because water content in the soil change the volume of soil (Rama indera Kusuma, 2017). The characteristics of this soil type have a low strength and high plasticity, so that condition also supports the occurrence of landslides (Arwan Priyono, 2009). This condition makes civil engineers and geotechnical engineers find a solution that is to strengthen soil through soil stabilization (A V Lazarescu et al., 2017). The process of soil stabilization refers to changing the physical properties of soil in order to improve its strength, durability, or other qualities. Typically, this is important for road construction, and other concerns related to the building and maintenance of infrastructure (Laxmikant Yadu, 2013). The usual soil stabilization is by adding chemical materials to the soil. Chemical stabilization methods are presented to provide soil strength improvement, shorter construction period, reduced construction costs, and other characteristics which may impact on their utilization to specific projects on clay soil. The most common additives are Portland cement and lime. The clay stabilization research was done by adding gypsum. Gypsum is a mineral consisting of hydrated calcium sulfate. The chemical formula is calcium sulfate dehydrate ($CaSO4.\ 2(H2O)$). Gypsum has better properties than organic additives because it does not cause air pollution, relatively cheap, fire resistant, and resistant to deterioration by biological factors and chemicals (Roesyanto, 2017). In this research, study is carried out in pandeglang district which is known to have abundance of soft clay. This study presents a design and performance of gypsum as a soil stabilizer. By stabilizing the soil with gypsum, it is hoped that the soil will be more suitable as road subgrade and any road construction.

2. Experimental

2.1 Materials

2.1.1 Gypsum

The gypsum was collected from PT.Griya Bintaro Gypsum, Bintaro, Tanggerang, Banten, Indonesia . Gypsum is use as raw materials in this study. The raw material of gypsum is clearly shown in Figure 1.

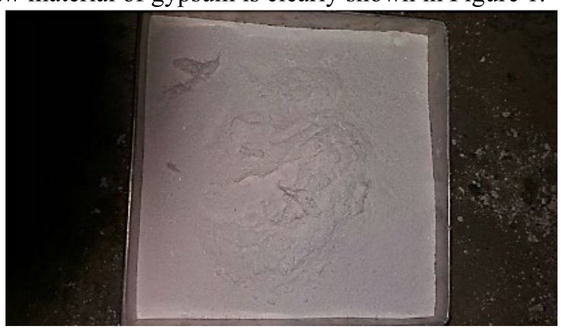

Figure 1. Gypsum

2.1.2 Clay soil

The soil used in the study from Pandeglang, Banten, Indonesia. The soil collected from a depth of 30 cm the natural ground level. the soil was pulverized to perform the various experimental testing for the study. The location shown in Figure 2.

Figure 2. Location of soil.

2.2 Methodology

The soil and gypsum were dry mixed together to allow the gypsum distributed uniformly. After that, the water is poured into gypsum and soil mix together until mixed evenly. Then, the mixture is poured into the pre-oiled cylindrical mould (38 mm × 76 mm) and compacted until solid for UCS sample. The sample for UCS is removed from mould with an extruder and samples are sealed after casting by using plastic to prevent moisture loss. All sample UCS cured for 0, 7, 14 21 and 28 days. Finally, the sample test under unconfined compressive strength (UCS) to obtain the maximum strength. The addition of percentage of gypsum was fixed at 0, 4%, 8%, 10% and 15%) The unconfined compressive strength (UCS) used to determine the shear strength of each sample. Details mix design tabulated in Table 1.

Table 1. Mix Design.

Percentage of Gypsum (%)	Mass of Mixed Materials (Gram)		
	Clay Soil	Water	Gypsum
0	1159.492	253.929	0
4	1159.492	253.929	42.669
8	1159.492	253.929	85.339
10	1159.492	253.929	106.673
15	1159.492	253.929	160.010

2.3 Laboratorium Testing

The detailed procedures for conducting the laboratory tests involved in this research were described below.

2.3.1 Particle Size Distribution Analysis

This method covers the quantitative determination of the distribution of particle size in soil and gypsum. The sieving test was done following the ASTM D 422 (Test sieves, technical requirements and testing).

2.3.2 Water Content

Water content is a comparison of the weight of water contained in the soil with the dry weight of the soil. W ater content can be used to calculate the parameters of soil properties.

2.3.3 Liquid Limit

The liquid limit (LL) is the minimum water content where the properties of a soil change from a liquid state to a plastic state. The liquid limit is used to determine the properties and classification of the soil. This experiment serves to determine the liquid limit of a soil sampleThe liquid limits of soil were measured complying to the BS 1377-2: 1990 as well as the apparatus used, NL 5003 X / 002 Digital Cone Penetrometer.

2.3.4 Plastic Limit

The plastic limits of soil were measured complying to the BS 1377-2: 1990. The soil was molded in the fingers and formed into 6 mm diameter thread between first finger and thumb of each hand and further rolled to about 1/8 in (3,2 mm) diameter. The sample then will be divided into subsamples at around 10 grams each. The determination of moisture content could be done through oven-drying method. The soil sample will be oven dried fot 24 hours at the temperature of 105 ˚C to 110 ˚C.

2.3.5 Soil Density

The definition of soil density is the ratio between the mass of soil grain content and the mass of water content (Indonesian National Standard SNI 1964-2008). How to determine the density of soil is to measure the weight of the amount of soil whose contents are known.

2.3.6 Compaction

Soil compaction is carried out to find the overall density and water content in order to determine the dry density. Loose soils must be compacted to increase in volume. The Soil Compaction Test was done following the ASTM D 698 (Compaction characteristic test for soil).

2.3.7 Unconfined Compressive Strength

Unconfined Compressive Stength Test (UCS) was done by using NL 5023 X Motorized Unconfined Compression Apparatus in accordance with ASTM D 2166.

3. Result and Analysis

3.1.1 Clay Soil Properties

According unified soil classification system, the soil was classified as organic clay soil with high plasticity. Clay soil with high plasticity will shrink with reducing of moisture content and swell with increasing of moisture content. Furthermore, this soil can cause damage to the road pavement such as crack to the road pavement and reduce strength of soil. thus, there needs to be measures such as soil stabilization. The following are the results of sieve analysis, Plastic Limit, Liquid Limit, Water Content, and soil density without mixture Gypsum to find out which soil type tested was shown in Table 2.

Table 2. Soil properties.

No.	Soil Properties	Unit	Value
1	Water content	%	38.72
2	Density	-	2.58
3	Liquid limit	%	62.4
4	Plastic Limit	%	44.82
5	Plasticity Index	%	17.58
6	Particle Size Distribution: *Fine - grained (> 50% Passes No.200 Sieve). *Course - grained (> 50% Retained on No.200 Sieve).	 % %	 61.6 38.4
7	USCS Classification		OH (Organic Clay with high plasticity)

3.1.2 Compaction of Clay soil

The compaction test aims to determine the optimum moisture content value and the maximum dry weight of the soil. The Figure 3 shows that the optimum water content is 32.5% and ϒ d maximum of 1.306 gr / cm^3, here are the results of the compaction test:

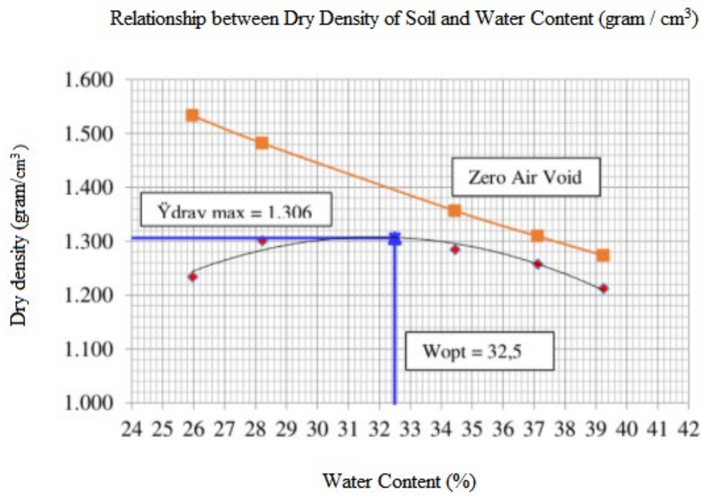

Figure 3. Relationship between dry density of soil and water content.

3.1.3 Stabilization Material Testing

The properties of gypsum were shown in Table 3. Based on the table, the percentage of particles exceeded 50% thus classified as fine-grained particle. Furthermore, the density of gypsum is 2.682.

Table 3. Properties of Gypsum.

No.	Soil Properties	Unit	Value
1	Density	-	2.682
2	Particle Size Distribution: *Fine - grained (> 50% Passes No.200 Sieve). *Course - grained (> 50% Retained on No.200 Sieve).	 % %	 100 0

3.1.4 Soil Density of Soil stabilization with Gypsum

The results of testing the Density value based on the percentage of Gypsum 0%, 4%, 8%, 10% and 15% were shown in Table 4. From the table it can be seen that the addition of gypsum soil density value is increasing. This is the reason why adding gypsum can increase soil strength (Rama indera Kusuma, 2017).

Table 4. Soil Density with Gypsum

Recapitulation of Soil Density with Gypsum		
No.	**Percentage of Gypsum (%)**	**Spesific Gravity**
1	0 (%)	2.580
2	4 (%)	2.585
3	8 (%)	2.587
4	10 (%)	2.612
5	15 (%)	2.646

3.1.5 Liquid Limit of Soil stabilization with Gypsum

The liquid limit of soil stabilization with gypsum were shown in Table 5. The trend of liquid limit of the soil stabilization with gypsum sample could be observed as the addition of the percentage of gypsum increased. The soil stabilization with gypsum having a reduction of liquid limit with increasing of the percentage of gypsum.

Table 5. Liquid limit of soil stabilization with Gypsum

No.	Percentage of Gypsum	Liquid Limit
1	0 (%)	50 (%)
2	4 (%)	49 (%)
3	8 (%)	46.1 (%)
4	10 (%)	45.8 (%)
5	15 (%)	44.8 (%)

3.1.6 Plastic Limit of Soil stabilization with Gypsum

The plastic limit of soil stabilization with gypsum were shown in Table 6. The trend of plastic limit of the soil stabilization with gypsum sample could be observed as the addition of the percentage of gypsum increased. The soil stabilization with gypsum having an increase of plastic limit with increasing of the percentage of gypsum.

Table 6. Plastic limit of soil stabilization with Gypsum

No.	Percentage of Gypsum	Plastic Limit
1	0 (%)	32.10 (%)
2	4 (%)	32.26 (%)
3	8 (%)	34.6 (%)
4	10 (%)	35.36 (%)
5	15 (%)	37.77 (%)

3.1.7 Unconfined compressive strength of Soil stabilization with Gypsum

All samples were test under unconfined compressive strength (UCS) to determine the shear strength for each sample. UCS test used to indicate the best mix design for soil stabilization with gypsum. The result then plots in Table 7. Based on the result, the lowest unconfined compressive strength test results were found in the gypsum content of 0% and curing for 0 days of 3.8667 kg / cm^2. While, the largest found in the gypsum content of 8% with 28 days of 14.2 kg / cm^2. The addition of the percentage of gypsum increases and curing time can lead to improve the soil strength (Rama indera Kusuma, 2017).

Percentage of Gypsum (%)	Curing Time (Days)	UCS (kg/cm^2)
0	0	3.86
4		6.02
8		10.6
10		8.86
15		4.86
0	7	4.36
4		7.53
8		12
10		10.06
15		7.4
0	14	5.23
4		8.25
8		13.3
10		10.13
15		10.13
0	21	6.13
4		8.41

Table 7. Unconfined Compressive Strength of stabilization soil with Gypsum

8		13.53
10		12.06
15		11.2
0	28	7.6
4		8.66
8		14.2
10		12.55
15		11.73

4. Conclusion

The results of clay and clay soil testing with gypsum with a percentage of 0%, 4%, 8%, 10% and 15% with curing for 0 days, 7 days, 14 days, 21 days, and 28 days can be concluded as follows:

- Based on the results the original soil samples taken on the road of Mangkualam Village, Cimanggu District, Pandeglang Regency. The liquid limit (LL) is 62.4% and the plastic limit (PL): 44.82. According to unified soil classification system, the soil was classified as clays with high development potential. Whereas, for the soil stabilization with gypsum addition of 0%, 4%, 8%, 10% and 15% with curing time of 0 days, 7 days, 14 days, 21 days, and 28 days, it shows that the LL values have decreased with increase in the percentage of gypsum. The liquid limit value shows a decrease.
- Based on the results of the specific gravity test (Gs), there was an increase from Gypsum levels 0% with Gs 2.547 to 2.646 for Gypsum levels 15%.
- The lowest unconfined compressive strength test results were found in the gypsum content of 0% and curing for 0 days of 3.8667 kg / cm^2. While, the largest found in the gypsum content of 8% with 28 days of 14.2 kg / cm^2. Curing increases the strength of soil. The addition of the percentage of gypsum increases the soil strength, but there is a maximum point, if too many specimens dry out, the soil strength will decrease.
- Thus, it can be concluded in general that the percentage of gypsum mixture which is effective for the stabilization of clay soil in Mangkualam Village, Cimanggu District-Pandeglang Regency is the addition of gypsum by 8% with curing time of 28 days.

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Biography

Syafiadi Rizki Abdila., born in Jakarta on 1996. He earned his Bachelor Degree from Civil Engineer from Sultan Ageng Tirtayasa University, Banten, Indonesia in 2017. Then he earned his Master Degree in Civil Engineer with concentration in Geotechnical from University Malaysia Perlis, Malaysia in 2020. His research interests include experiment, simulation, survey, case study and evaluation.

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