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Study Of The Effectiveness Of The Use Of Gypsum And Volcanic Ash On Stability Of The Clay Soil Based On The CBR Value And The Unconfined Compression Test

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ABSTRACT

Stabilization is one of the efforts to improve the condition of the soil which has a poor index of properties. One of the soil stabilization that is usually done is by adding chemicals to the soil. Chemicals commonly used in the form of cement, lime, bitumen. In this study, the stabilization of clay was carried out by adding gypsum and volcanic ash. The purpose of this study was to determine the value of the index properties due to the addition of 2% gypsum and volcanic ash on the clay soil, then to determine the maximum compressive strength value due to the addition of variations in stabilizing materials by testing the Unconfined Compression Test (UCT) and testing the California Bearing Ratio (CBR).) laboratory. From the research, it was found that the original soil sample had a moisture content of 12.42%; specific weight 2.65; liquid limit 46.82% and plasticity index 29.40%. The original soil classification according to USCS is classified as Clay – Low Plasticity (CL) and according to AASHTO it is classified as A-7-6 (10). Unconfined Compression Test (UCT) values for native soil and native soil plus 2% gypsum were 1.40 kg/cm2 and 1.66 kg/cm2. The laboratory CBR values for soaked and unsoaked for the original soil were 4.44% and 6.28%, respectively. While the laboratory CBR values soaked and unsoaked for the original soil plus 2% gypsum were 6.74% and 8.02%, respectively.The most effective results were obtained from a mixture of 2% gypsum and 10% volcanic ash with a UCT value of 2.79 kg/cm2 (an increase of 99.28%). For laboratory CBR testing, the most effective mixture was on a mixed variation of 2% gypsum and 9% volcanic ash with laboratory CBR values soaked and unsoaked of 9.07% (an increase of 104.27% from the original soil) and 10 ,29% (an increase of 63.85% from the original land). The soil that has been mixed with the most effective stabilizer material, namely 2% gypsum and 9% volcanic ash is classified as Clay - Low Plasticity (CL) based on the USCS classification and is classified as A-6 (4) based on the AASHTO classification.

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1. INTRODUCTION

Soil is an important part of a construction. Apart from being a building material in various civil engineering works, soil also functions as a support for the foundation of the building. At first, the art of soil engineering was carried out only based on past experience. But with the growth of science and technology, the design and implementation of better and more economical structures is urgently needed (Das, 1998).

Clay soil is one type of soil that is often used in the stabilization process. This is because clay is very hard in dry conditions and plastic at moderate water content, but when the water content is high, clay will be sticky (cohesive) and very soft, causing large volume changes due to the influence of water and causing the soil to swell and swell. shrink in a relatively short period of time. This property is the reason for the need for a stabilization process so that these properties are improved so as to increase the bearing capacity of the soil. (Hardiyatmo, 2002) One way to improve unstable soil properties is by means of stabilization. Soil stabilization can be done by mechanical, physical and chemical means (modification of admixture).

The eruption of Mount Sinabung resulted in the eruption of volcanic ash which rained down on several villages and towns around it. The amount of ash material spewed from Mount Sinabung was estimated at 2.4 million cubic meters from September 2013 to January 2014 (BBC Indonesia, 2014). With that much volume, Sinabung volcanic ash is still considered polluting, this is because Sinabung volcanic ash is easy to fly if blown by the wind so that it can cause pollution in the form of respiratory problems, eye irritation and reduce visibility. In addition, volcanic ash also has the potential to contaminate water because its fine grains make it easier for volcanic ash to mix with water, while the content of volcanic ash is dangerous if consumed. In the short term the eruption of Mount Sinabung was felt as a disaster for the community around the mountain and brought a fairly large negative impact. But not in the short term, the materials spewed out of Mount Sinabung are beneficial to the soil and surrounding plants. Currently, sinabung ash is used as a mixture of plant fertilizers and is being studied as a mixture of bricks and bricks and is being investigated as a filler for asphalt concrete mix – wearing course. Due to the underutilization of sinabung ash so far, it is used as a soil stabilizing agent. Sinabung ash is used as a mixture of plant fertilizers and is being studied as a mixture of bricks and bricks and is being investigated as a filler for asphalt concrete mix – wearing course. Due to the underutilization of sinabung ash so far, it is used as a soil stabilizing agent. Sinabung ash is used as a mixture of plant fertilizers and is being studied as a mixture of bricks and bricks and is being investigated as a filler for asphalt concrete mix – wearing course. Due to the underutilization of sinabung ash so far, it is used as a soil stabilizing agent.

In chemistry, gypsum is called Calcium Sulfate Hydrate (CaSO42(H2O)), which is a material that belongs to sulfate minerals that are on earth and its value is very beneficial. Currently, gypsum is widely used in building decoration, the basic material for making cement, paint filler, fertilizer making material (feltilizer) and various other purposes. One of the advantages of using gypsum in civil engineering works is that gypsum can increase the stability of organic soils because it contains calcium which binds organic soils to clay which provides stability to soil aggregates. In this study, it is expected that gypsum powder can increase the CBR value and compressive strength of the soil.

2. RESEARCH METHOD

The research methodology that the author conducted in this study used experimental methods at the Soil Mechanics Laboratory, Faculty of Engineering, University of North Sumatra. The research was conducted on soil samples that were not given stabilization material (original soil) and on soils that were given chemical stabilization materials in the form of addition of gypsum (G) and volcanic mountain ash (AGV) with various mixture variations.

After all the data obtained both from testing the physical properties and mechanical properties, then data collection was carried out. After the data is collected, then data analysis is carried out. All the results obtained from the implementation of the research will be displayed in the form of tables, graphs of relationships and explanations.

3. RESULTS AND DISCUSSIONS

3.1 Testing of Physical Properties of Samples

a. Testing the physical properties of the original soil

The results of the physical properties of the original soil are shown in Table 1 below. The results of testing the physical properties of this soil include:

1) Water content
2) Specific weight
3) Atterberg's boundaries
4) Granular analysis test

Table 1. Test data for the physical properties of the original soil

No.	Test	Results
1.	Water content	12.42%
2.	Specific weight (specific gravity)	2.65
3.	Liquid limit (liquid limit)	46.82%
4.	Plastic limit (plastic limit)	17.42%
5.	Plasticity index (plasticity index)	29.40 %
6.	Percent pass filter no 200	49.17%

From the data above, based on the AASHTO classification system, the data obtained are in the form of the percentage of soil that passes sieve no. 200 is 49.17% and the liquid limit value is 46.87%, so the soil sample meets the minimum requirements to pass sieve no. 200 of 36%, has a liquid limit of 1 and a plasticity index of > 11, so that the sample soil can be classified in soil type A-7-6.

According to the USCS classification system, the data obtained are in the form of a plasticity index value of 29.46% and a liquid limit value of 46.87% so that a plot on the graph for determining the soil classification is shown, which is shown in Figure 4.1. From the plot results, the soil is included in the CL group, namely inorganic clay with low to moderate plasticity.

b. Gypsum physical properties testing

The results of the physical properties of gypsum are shown in Table 2 below. The results of testing the physical properties of gypsum include:

1) Water content
2) Specific weight
3) Atterberg's boundaries
4) Granular analysis test

Table 2. Gypsum physical properties test data

No.	Test	Results
1.	Water content (water content)	-
2.	Specific weight (specific gravity)	2.74
3.	Liquid limit (liquid limit)	Non Plastic
4.	Plastic limit (plastic limit)	Non Plastic
5.	Plasticity index (plasticity index)	Non Plastic
6.	Percent pass filter no 200	51.62%

From the data above, based on the AASHTO classification system, the data obtained are the percentage of gypsum that passes sieve no. 200 is 51.62% while the liquid limit, plastic limit, and plasticity index are non-plastic.

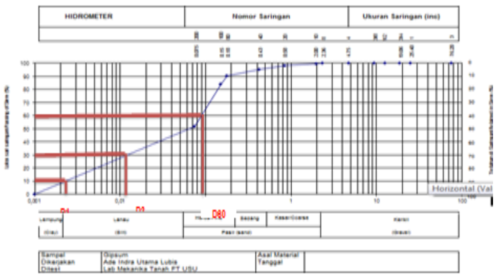

Figure 1. Gypsum sieve analysis graph

c. Testing the physical properties of volcanic ash

The results of the physical properties of volcanic ash are shown in Table 3 below. The results of testing the physical properties of volcanic ash include:

1) Water content
2) Specific weight
3) atterberg boundaries
4) Granular analysis test

Table 3. Test data for the physical properties of volcanic ash

No.	Test	Results
1.	Water content (water content)	-
2.	Specific weight (specific gravity)	2.62
3.	Liquid limit (liquid limit)	Non Plastic
4.	Plastic limit (plastic limit)	Non Plastic
5.	Plasticity index (plasticity index)	Non Plastic
6.	Percent pass filter no 200	22.71%

From the data above, based on the AASHTO classification system, data is obtained in the form of the percentage of volcanic ash that passes sieve no. 200 is 22.71% while the liquid limit, plastic limit, and plasticity index are non-plastic.

3.2 Testing the physical properties of the soil with stabilizers

The results of testing the physical properties of the soil that have been mixed with gypsum and volcanic ash are shown in Table 4. The graph of the relationship between the liquid limit value (LL) and the variation of the mixture is shown in Figure 4.6, the relationship between the plastic limit value (PL) and the variation of the mixture is shown, and the relationship between the plasticity index value (IP) and the variation of the mixture .

Table 4. Atterberg Limit . test data

Sample	Limits - Atterberg Limits			
	LL	PL	PI	LI
Native Land	46.82	17.42	29.40	-0.17
2% G + 0% AGV	42.51	15.98	26.53	-0.13
2% G + 2% AGV	40,18	16,16	24.01	-0.15
2% G + 3% AGV	39.44	16.39	23.05	-0.17
2% G + 4% AGV	39.08	17.01	22.07	-0.20
2% G + 5% AGV	37.59	17.07	20.52	-0.22

2% G + 6% AGV	36,60	17.49	19.11	-0.26
2% G + 7% AGV	35.83	17.57	18.26	-0.28
2% G + 8% AGV	34.59	17.91	16.68	-0.32
2% G + 9% AGV	33.75	18.43	15.32	-0.39
2% G + 10% AGV	33.20	18.76	14.44	-0.43
2% G + 11% AGV	32.16	18.97	13.20	-0.49
2% G + 12% AGV	30.86	19.05	11.81	-0.56
2% G + 13% AGV	29.69	19.31	10.37	-0.66
2% G + 14% AGV	28.86	19.48	9.38	-0.75
2% G + 15% AGV	28,12	19.52	8.59	-0.82

3.3 Soil Mechanical Properties Testing

a. Original soil compaction test (Compaction)

In this test, the relationship between optimum moisture content and maximum dry density was obtained. Researchers used the test method with the Proctor Standard compaction test. Where the tools and materials used include: The results of the Proctor Standard compaction test of the original soil are shown in Table 5.

Table 5. Original soil compaction test data

No	Test result	Score
1	Optimum water content	21.32%
2	Maximum dry weight	1.31 gr/cm3

3.4 Testing soil compaction (compaction) with stabilizers

The results of testing the mechanical properties of soil that have been mixed with a stabilizer in the form of gypsum and volcanic ash are shown in Table 6 and the relationship between the dry density value and the variation of the mixture for a curing time of 7 days.

Table 6. Compaction test results (7 days)

Sample	d max (gr/cm³)	W_{opt}(%)
2%G + 0%AGV	1.32	21.07
2%G + 2%AGV	1.32	20.78
2%G + 3%AGV	1.34	20.70
2%G + 4%AGV	1.35	20.64
2%G + 5%AGV	1.37	20.49
2%G + 6%AGV	1.39	20.39
2%G + 7%AGV	1.42	20.25
2%G + 8%AGV	1.45	20.09
2%G + 9%AGV	1.49	19.56
2%G + 10%AGV	1.52	19.06
2%G + 11%AGV	1.48	19.75
2%G + 12%AGV	1.45	20.02
2%G + 13%AGV	1.43	20,20
2%G + 14%AGV	1.42	20.33
2%G + 15%AGV	1.41	20.54

a. Maximum dry fill weight (γd max)

From the soil compaction test that has been carried out on the original soil, the dry density value of the original soil is 1.31 gr/cm³. Figure 2 shows that the dry density value increases when gypsum and volcanic mountain ash are added and is greatest when the soil is added with stabilizing material 2% gypsum (G) + 10% volcanic ash (AGV) at 7 days of curing, which is 1.521 gr. /cm³ and decreased when the next volcanic ash content was added.

This is due to the gypsum and volcanic ash filling the soil pores, which in the original soil conditions, the pores are filled with water and air. Due to the presence of gypsum and volcanic ash in the soil pores, the percentage of water contained in the soil is reduced. The increase in the number of solid particles in the soil has an impact on increasing the dry volume weight compared to the original soil condition.

Meanwhile, the decrease in dry density of the soil occurred because the soil had passed the effective addition of stabilizer material, which was 2% G + 10% AGV. The amount of stabilizer that is increasing with respect to the original weight of the soil will reduce its binding ability so that it will reduce the bond between the grains in the soil and water so that the soil becomes easily broken.

In addition, the increase in maximum density is due to the occurrence of posolanic reactions which are increasing due to the addition of SiO2, Al2O3, and Fe2O3 elements by gypsum. The pozzolanic process occurs when calcium hydroxide from soil reacts with silicate (SiO2) and aluminate (AlO3) from gypsum to form a binding material consisting of calcium silicate or aluminate silicate. The reaction of Ca2+ ions with silicate (SiO2), and aluminate (Al2O3) from the surface of clay particles forms gypsum paste (hydrated gel) so that it binds soil particles.

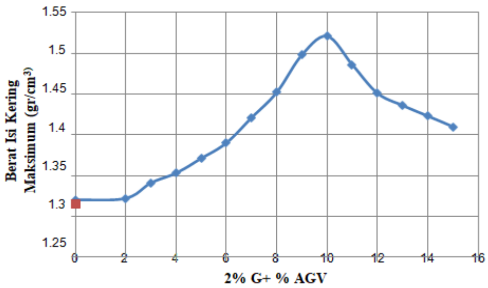

Figure 2. Graph of the relationship between maximum dry weight (γd max) soil with mixed variation (7 days)

b. Optimum moisture content (w*opt*)

The results of the optimum water content of the experiments conducted showed that the optimum water content value of the original soil was 21.32% and then decreased. Lowest optimum water content value when adding 2% gypsum (G) + 10% volcanic ash (AGV) which is 19.06% and increases when the next volcanic ash content is added.

c. Laboratory CBR testing (California bearing ratio)

The effect of mixing gypsum and volcanic ash on clay on the strength of clay soil can be seen from the results of the CBR test in soaked and unsoaked conditions with each variation of soil that has been mixed with gypsum stabilization material and volcanic ash with a curing time of 1 7 days.

This test is carried out in soaked and unsoaked conditions. In general, the value of the unsoaked CBR is higher than the soaked CBR, but the soaked condition is a condition that often occurs in the field, so that in the calculation of building construction the soaked CBR price is used as the basis for the calculation because in reality water is always affect building construction. Soaked CBR is used to obtain the original CBR value in the field with a saturated state of water and experiencing maximum expansion.

The bond between grains is the ability to interlock between grains, and the presence of a bond that glues the surface of the grains, the stronger the bonds between grains will produce a higher CBR value and vice versa. The CBR test conducted in this study is intended to see whether the addition of the additive percentage will have an effect on the CBR value.

The results of the CBR tests performed on each variation of the mixture are shown in Table 7 for soaked CBR and Table 4.8 for unsoaked CBR.

Table 7. Data on CBR test results soaked (7 days)

Sample	d max (gr/cm³)	Wopt(%)	CBR (%)
Native Land	1.31	21.32	4.44
2%G+0%AGV	1.32	21.07	6.74
2%G+3%AGV	1.34	20.70	7.02
2%G+5%AGV	1.37	20.49	7.91
2%G+7%AGV	1.42	20.25	8.63
2%G+9%AGV	1.49	19.56	9.07
2%G+11%AGV	1.48	19.75	8.64
2%G+13%AGV	1.43	20,20	7.57
2%G+15%AGV	1.41	20.54	7.18

Table 8. Unsoaked data from the CBR test (7 days)

Sample	d max (gr/cm³)	Wopt(%)	CBR (%)
Native Land	1.31	21.32	6.28
2%G+0%AGV	1.32	21.07	8.02
2%G+3%AGV	1.34	20.70	8.59
2%G+5%AGV	1.37	20.49	8.93
2%G+7%AGV	1.42	20.25	9.81
2%G+9%AGV	1.49	19.56	10.29
2%G+11%AGV	1.48	19.75	9.11
2%G+13%AGV	1.43	20,20	8.36
2%G+15%AGV	1.41	20.54	8.03

3.5 Unconfined compression test

In this test, the relationship between the value of the soil free compressive strength (qu) on the original soil and the artificial soil (remoulded) and the value of the soil free compressive strength (qu) will be obtained in each variation of soil that has been mixed with gypsum stabilization material and volcanic mountain ash with time. curing for 7 days. Furthermore, from the results of the value of qu obtained the value of cohesion (cu) which is equal to qu.

The results of the free compressive strength tests performed on each variation of the mixture are shown in Table 9. shows the comparison of the compressive strength of the soil (qu) between the original soil and the remoulded soil shows the value of the compressive strength of the soil (qu) obtained in each variation of the mixture.

Table 9. Data from the free compressive strength test of 2% G with various variations in the addition of % AGV (7 days)

Sample	Qu (kg/cm²)	cu (kg/cm²)
Native Land	1.40	0.70
Remoulded Soil	0.67	0.34
2%G+0%AGV	1.66	0.82
2%G+2%AGV	1.72	0.86
2%G+3%AGV	1.88	0.94
2%G+4%AGV	2.08	1.04
2%G+5%AGV	2.28	1.14
2%G+6%AGV	2.39	1.19
2%G+7%AGV	2.48	1.24
2%G+8%AGV	2.57	1.28
2%G+9%AGV	2.70	1.35
2%G+10%AGV	2.79	1.39
2%G+11%AGV	2.67	1.34
2%G+12%AGV	2.55	1.27
2%G+13%AGV	2.46	1.23
2%G+14%AGV	2.43	1.21
2%G+15%AGV	2.21	1.10

Table 10. Comparison between the compressive strength of the original soil and the remoulded soil

Strains (%)	Original soil qu (kg/cm²)	Remoulded soil qu (kg/cm²)
0.5	0.28	0.16
1	0.51	0.30
2	0.69	0.41
3	1.18	0.54
4	1.40	0.61
5	1.16	0.67
6	1.06	0.57
7	0.78	0.35

The original soil compressive strength value (qu) was 1.40 kg/cm². Then with the addition of a mixture of gypsum and volcanic ash, the compressive strength value increased but only until the variation of the mixture was 2% G + 10% AGV, in this variation the maximum compressive strength value of the soil at 7 days of curing was 2.79 kg. /cm². The cementation reaction that occurs in the soil - gypsum mixture forms new, harder granules so that they are stronger to withstand the given load.

Gypsum and volcanic ash mixed with the soil result in the exchange of alkaline cations (Na+ and K+) from the soil being replaced by cations from gypsum so that the clay grain size increases (flocculation). In addition to the flocculation process that occurs in soil stabilization, there are also pozzolanic processes, hydration processes, and cementation processes. ..

Furthermore, there was a decrease in the compressive strength value with the addition of volcanic ash 11% - 15%. However, the qu value in this variation is still higher than the original soil qu value. This is because the addition of volcanic ash content to the soil reduces the bond between soil grains and water, so that the soil becomes easily broken when subjected to vertical pressure.

4. CONCLUSION

Based on the USCS classification, the soil sample is classified as CL (Clay-Low Plasticity), which is inorganic clay with low to moderate plasticity.

Based on the AASHTO (American Association of State Highway Transportation Official) classification, the original soil samples were classified as type A-7-6 (10). With a curing time of 7 days, the soil mixture with 2% G and 2%-12% AGV was classified as type A-6 and the soil mixture with 2% G and 13-15% AGV was classified as type A-4. The soil mixture with 2% G and 9% AGV belongs to the soil type A-6 (5). The soil mixture with 2% G and 10% AGV is included in the soil type A-6 (4).

From the results of the water content test, it was found that the original soil water content value was 12.42%.

From the results of the specific weight test, it was found that the specific weight of the original soil was 2.65 and the specific weight of gypsum was 2.74 and the specific weight of volcanic ash was 2.62.

From the Atterberg test on the original soil, the liquid limit (LL) value of 46.87% and the plasticity index (IP) of 29.46% and the liquidity index of -0.16% (LI < 0). Based on the experimental results, it is known that with the addition of 2% G + 15% AGV, it has the lowest plasticity index (IP) of 8.59% and liquid limit (LL) of 28.12%.

From the results of the Proctor Standard test, the optimum water content value in the original soil is 21.32% and the maximum dry density is 1.31 g/cm³, while the maximum dry density value of all mixtures is at a mixture variation of 2% G + 10% AGV which is 1.52 g/cm³ and the optimum water content is 19.06% with a curing time of 7 days.

From the laboratory CBR test carried out on the original soil, the CBR value was 4.44% for the soaked CBR test and the CBR value was 6.28% for the unsoaked CBR test, while the maximum CBR value of all mixtures was at mixed variation of 2% G + 9% AGV where 9.07% for the soaked CBR test and 10.29% for the unsoaked CBR test with a curing time of 7 days

From the unconfined compression test, the value of soil compressive strength (qu) in the original soil was 1.40 kg/cm², while in remoulded soil the value was 0.67 kg/cm². The maximum compressive strength value (qu) of all mixtures was in the variation of the mixture of 2% G + 10% AGV with a curing time of 7 days of 2.79 kg/cm².

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