Clay Stabilization Using the Ash of Mount Sinabung in Terms of the Value of California Bearing Ratio (CBR)

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Abstract. Most areas in Indonesia consist of clay soils with high plasticity so that to meet technical requirements the soil needs improvement, which is known as soil stabilization. There are three ways of soil stabilization process, i.e. mechanical, physical and chemical. In this study, chemical stabilization was performed, that was by adding stabilizing agents to the soil. The stabilizing agent used was the ash of Mount Sinabung. Since 2010 until now, Sinabung Mountain is still experiencing eruption that produces a lot of volcanic ash and it inconveniences the environment. So, it is expected that this research will be able to optimize the utilization of Sinabung ash. The purpose of this study was to investigate the effect of the addition of Mount Sinabung ash to CBR (California Bearing Ratio) value, to determine the effect of the curing time of one day and fourteen days mixture on the CBR value, and to find the mixed content with effective curing time to produce the largest CBR value. Based on this study, the soil type CL (Clay – Low Plasticity) was obtained, based on the classification of USCS (Unified Soil Classification System) and categorized as A-6 (6) based on the classification of AASHTO (American Association of State Highway and Transportation officials) with the most effective mixed stabilizer material which was the variation of 10% Mount Sinabung ash with fourteen days of curing time. The CBR value resulted from the mixture of 10% Sinabung ash that was cured within fourteen days was 8.95%. By the increase of the content of the Sinabung ash, the CBR value always improved to the level of 10%, Sinabung ash then decreased and became constant at the mixture of higher volcanic ash mixture but remained above the CBR value of the original soil.

1. Introduction
Generally, most of the areas in Indonesia consist of the clay with high plasticity. If the existing base ground is in the form of clay, which has a low shear support capacity, then the construction above it can suffer from damage. Therefore, the base ground must be solid to conform to technical requirements. Clay is the soil that has certain mineral particles that produce plastic properties on the soil when mixed with water. Clay is commonly used as the hoard of the roads. The general properties of the clay soil are extremely hard in dry conditions and plastic in a state of moderate moisture content. However, when the water content is high, clay will be sticky (cohesive) and very soft. Therefore, clay needs to be stabilized. Soil stabilization is the mixing of soil with certain materials, in order to improve the technical properties of the soil, or it may also mean attempts to change or improve the technical properties of certain soils to meet certain technical requirements [1].

Subgrade is the part that will support the pavement thickness. The subgrade is located on the entire width of the road, so it can be in the excavation area, heap, and soil surface. Subgrade materials are
taken from local soil. If the materials are in a poor condition (CBR <2%), it is necessary to do soil improvement. There are several ways to increase the value of CBR in subgrade layer, one of them is stabilizing the soil. Stabilization of soil conducted in this research is chemical stabilization by adding chemicals to the soil that is going to be stabilized. Volcanic mountain ash used in this study comes from Mount Sinabung. From the latest data, the volume of the lava of Mount Sinabung that came out has reached 3.3 million cubic meters [2]. The volcanic ash that comes out during the eruption provides long-term benefits like fertilizer. But when the eruption happened, volcanic ash will spread to various regions so that it could damage plants, houses, inhibit water channels, disturb the health of the population, etc. The volcanic ash itself contains aluminum, silica, iron, calcium, and magnesium. Silica (SiO2) contained by the volcanic ash is a major constituent in the manufacture of cement. The pozzolanic nature is the binding behavior of other minerals in the clay so that it becomes harder in a certain period of time [3]. For that reason, Mount Sinabung ash can be utilized as the mixture of soil stabilization, in addition to its silica content, it can also reduce untreated waste by residents.

CBR (California Bearing Ratio) is a comparison between test load and standard load which is expressed in percentage. CBR value is a value that states the quality of the base soil compared with standard materials in the form of crushed stone that has a CBR value of 100% in carrying the load. Subgrade on new road construction can be original soil, embankment soil, or dug soil that has been compacted until it reaches 95% of maximum density. Thus, the bearing capacity of the base soil is the value of the soil layer ability to bear the load after the soil is compacted. CBR is called CBR laboratory, because it is prepared in the Laboratory. CBR Laboratories are divided into two types, they are soaked and unsoaked.

In the research of Ronny Hutauruk (2016) analyzed with Unconfined Compression Test conducted on original soil, obtained that compressive strength (qu) of original soil is 1.40 kg / cm², meanwhile the compressive strength (qu) of remoulded soil is 0.50 kg / cm². The addition of 11% Sinabung ash with 14 days of curing time has the greatest compressive strength (qu) value, which is equal to 2.32 kg / cm². There was an increase in the compressive strength of the soil due to the addition of Sinabung ash. [4]

2. Method
The research methodology that was carried out used experimental method at Soil Mechanics Laboratory, Department of Civil Engineering, Universitas Sumatra Utara. The conducted research was the sample of original soil and sample of the soil that has been given additional ash of Mount Sinabung. The material used are: Soil from Patumbak Deli Serdang and Volcanic Ash from Mount Sinabung North Sumatra. Chemical composition of Sinabung Ash SiO₂ is 85.90%, Fe₂O₃ is 0.007%, Al₂O₃ is 11.93% and CaO is 0.133%. The use of 2% to 20% of Sinabung ash was based on previous research that has been done by Ronny Hutahuruk by analyzing through Unconfined Compression Test (UCT) [4]. This study analyzes the addition of Mount Sinabung ash with the California Bearing Ratio (CBR) laboratory test so that the results of the research can be implemented for a pile of roads. In this study, we use soaked CBR to adjust to the field conditions in case of rain.

2.1. Manufacture of specimens
The test specimen that was utilized in outline consists of the original soil samples and samples using soil that has been mixed with the ash of Mount Sinabung. The percentage of mixture used in this study is 2% to 20%.

2.2. Implementation of testing
Testing is divided into 2 parts namely the test for the original soil and soil testing that has been mixed with stabilizer material. The test was held as follows:
2.3. Data analysis
After all the data were collected, then data analysis was performed. All results obtained will be displayed in the form of tables, graphs and explanations. The flowchart of the research can be seen in Figure 1 below.

3. Results and Discussion

3.1 Original soil testing and stabilizer testing
The results of the original soil physical properties test are listed in Table 1.

| No. | Testing                          | Soil     | Sinabung Ash |
|-----|----------------------------------|----------|--------------|
| 1.  | Water Content                    | 14.52%   | -            |
| 2.  | Specific Gravity                 | 2.64     | 2.62         |
| 3.  | Liquid Limit                     | 48.64 %  | Non Plastic  |
| 4.  | Plastic Limit                    | 18.81 %  | Non Plastic  |
| 5.  | Plasticity Index                 | 29.82 %  | Non Plastic  |
| 6.  | Sieve Analysis                   | 50.04%   | 11.40%       |
| 7.  | Optimum Moisture Content         | 21.38 %  | -            |
| 8.  | Maximum Dry Density              | 1.32 gr/cm³ | -          |

![Research flow chart](image-url)

Figure 1. Research flow chart.
3.2 Test of physical properties and soil mechanics with stabilizers

The result showed that the addition of volcanic ash could improve the physical and mechanical properties of the soil. This can be seen in Figure 2 and Figure 3 which shows the value of Atterberg boundaries.

![Figure 2. Graph of the relativity between liquid border value and mixed variation of 2% - 20% Mount Sinabung Ash for one day and fourteen days curing.](image1)

![Figure 3. Graph of Plasticity Index value with mixed variation of 2% - 20% Mount Sinabung Ash mixture for one day and fourteen days curing time](image2)

In Figure 2, it is show that the liquid limit due to the addition of volcanic ash stabilization material has experienced decrement, the greater the percentage of volcanic ash, the smaller the liquid limit. In the original soil liquid limit reached 48.64% while the lowest liquid limit value was in the addition of 20% volcanic ash with 14 days of curing time that was 30.15%. This is due to the soil under goes a cementation process by the ash of Mount Sinabung so that the soil becomes larger grains that make the pull force between particles in the soil decreases Figure 3 shows that with the addition of stabilizers the plasticity index value will decrease. The decreasing value of the plasticity index may reduce the development potential and depreciation of the soil. This is due to the hydration process of volcanic ash added to the soil. This process strengthens the bonding between the soil particles, resulting in the formation of harder and more stable grain. The filling up of soil pores minimizes the occurrence of seepage on the volcanic ash-soil mixture that affects the decrease of shrinkage potential. Then it is added with stabilizer material in the form of volcanic ash. Silica and alumina from volcanic ash mixed with water form a paste that binds clay particles and covers the pores of the soil. Pore cavities that are surrounded by cementation materials that are more difficult to be penetrated by water will make the soil mixture and volcanic ash become more resistant to water absorption thereby decreasing the plasticity. It can be seen that the decrease of plasticity index from original soil which was initially
29.82%, decreased along with the increasing of volcanic ash mixture until lowest plasticity index value at mixture of 20% volcanic ash at fourteen days curing time, which was 9.04%.

Figure 4. Graph of the relationship between maximum γd of soil with mixed variation 2% - 20% of Sinabung Ash for one day and fourteen days curing

In Figure 4 it can be seen that the maximum dry content weight of the whole test is in a 10% mixture of volcanic ash with fourteen days curing period was 1.49 g/cm³, in contrast to the time when the mixture of 10% volcanic ash is only cured in one day with value of maximum dry fill weight of 1.44 g/cm³. The increasing value of the maximum dry content weight that was affected by the length of the curing caused by the mixture of clay and volcanic ash that was more even. At the optimum moisture content, the 10% volcanic ash mixture in one day curing time that was 19.49% decreased along with the fourteen days curing time to be 19.35%. This was caused by the even mixture of water along with the duration of curing towards the volcanic mountain ash mixture and clay soil as seen in Figure 5 below. The results of CBR testing performed on each variation of mixed content, the maximum CBR value of all the tests was 8.95% obtained from the mixture of 10% Mount Sinabung ash and clay soil with curing period of fourteen days. The CBR value in the 10% mixture of Mount Sinabung ash increased along with the duration of curing period, in which when the mixture was cured for 1 day, the CBR value was only 8.22%. For the graph of CBR value relationship on the mixing variation of Sinabung ash with the duration of one day and fourteen days curing period can be seen in Figure 6

Figure 5. Graph of the relationship between wopt with mixed variation of 2% - 20% of Sinabung ash for one day and fourteen day curing time
Figure 6. Graph of relationship between CBR value with the mixed variation of 2% - 20% of Sinabung ash for one day and fourteen-day curing time

In the graph it was shown in Figure 6, in addition to the increase experienced by the addition of 10% of Mount Sinabung ash along with the duration of curing, it can also be seen that the value of CBR testing for the largest one day curing is in the 12% mixture of Mount Sinabung ash by 8.87%, while for the fourteen days curing, the maximum CBR value is obtained at 10% of Mount Sinabung ash mixture by 8.95%. With the addition of Mount Sinabung ash, the CBR value increases up to 8.95%. The greater the CBR value the greater the soil bearing capacity, so that for the same traffic load it will require a thinner thickness of the pavement.

4. Conclusions
From the research result, it can be concluded that:
1. Based on USCS classification, the soil samples are included in CL (Clay-Low Plasticity) type, which is inorganic clay with low to moderate plasticity and remain on CL type after mixed with Mount Sinabung ash.
2. Based on the AASHTO classification, the original soil samples are included in types A-7-6 (11). At the curing time of fourteen days, the soil mixture and 2% -9% of Sinabung ash are included in type A-7-6, then in the 10% - 18% Sinabung ash mixture included in type A-6, and in the 19% - 20% Sinabung ash mixture included in type A-4. In soil mixture and 10% Sinabung ash included in type A-6 (6).
3. The decline in the plasticity index (IP) value in 20% of Mount Sinabung ash with one day curing time is 9.73% to 9.04% at fourteen days curing caused by the effect of curing period on the chemical reaction of volcanic ash mixing and the soil.
4. From the Proctor Standard results, the optimum moisture content on the original soil is 21.38% and the maximum dry content weight is 1.32 g / cm³, while the maximum dry content value of all mixture is 10% ash of Mount Sinabung At fourteen days curing at 1.49 g / cm³, an increase over the previous curing time when only one day of the dry weight of the maximum value of 1.44 g / cm³, while the optimum water content of 10% mixture of Sinabung ash on the curing one day of 19.49% decreased at the curing of fourteen days to 19.35%.
5. CBR value after the soil was mixed with Sinabung ash, the largest is in 10% of Sinabung ash mixture with fourteen days curing time, that is 8.95%.
6. The curing period resulted in the soil and the Sinabung ash mixture are more even, resulting in higher CBR value.
References

[1] Hardiyatmo, H C 2010 *Mekanika Tanah I* (Yogyakarta: Gadjah Mada University Press)
[2] Ronny Hutahuruk, 2016 *Stabilisasi Tanah lempung dengan menggunakan abu Vulkanik di tinjau dari Nilai Unconfined Compression Test (UCT)* (Medan: Program Studi Teknik Sipil Universitas Sumatera Utara)
[3] Ika Puji Hastuty, Roesyanto, and Jeriko A 2017 Study of the Effectiveness of the Use of Cement and Bottom Ash Towards The Stability of Clay in Term of UCT Value Science Direct *Procedia Engineering* 171, 484 – 491
[4] Gunawan, Hendra, and Huda N A 2013 *Pemanfaatan Limbah Karbit Untuk Meningkatkan Nilai Cbr Tanah* (Surakarta: Program Studi Teknik Sipil Universitas Sebelas Maret)