

# A study of the effectiveness of the use of gypsum and volcanic ash against the stability of clay soil in terms of UCT and CBR values

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**Abstract.** Soil stabilization is an effort to improve engineering properties of soil. The conventional soil stabilization is by adding additives to the soil such as Portland cement, lime, and bitumen. The clay stabilization research was done by adding gypsum and volcanic ash. The research purposes were to find out the value of engineering properties of clay due to the addition of 2% gypsum and 2% - 15% volcanic ash. The soil was classified as Clay – Low Plasticity (CL) based on USCS and was classified as A-7-6 (10) based on AASHTO classification system. The UCT values of original soil and original soil plus 2% gypsum were 1.40 kg/cm<sup>2</sup> and 1.66 kg/cm<sup>2</sup> respectively. The CBR soaked and unsoaked values of original soil were 4.44% and 6.28% correspondingly. Meanwhile, CBR soaked and CBR unsoaked values of original soil plus 2% gypsum were 6.74% and 8.02% respectively. The research results showed that the additives materials of gypsum and volcanic ash improved the engineering properties of clay. The UCT result from the stabilized soil by 2% gypsum and 10% volcanic ash gave value of 2.79 kg/cm<sup>2</sup> (increased 99.28% from original soil). For CBR test, the most effective mixture were in variation of 2% gypsum and 9% volcanic ash which gave value of 9.07% (104.27% increase from original soil) for CBR soaked and 10.29% (63.85% increase from original soil) for CBR unsoaked. The stabilized soil with 2% gypsum and 9% volcanic ash was classified as CL based on USCS and was classified as A-6 (4) based on AASHTO classification system.

## 1. Introduction

Soil stabilization is a mixture of soil with certain materials, in order to improve the engineering properties of soil [1]. The soil stabilization is by adding chemical materials to the soil. The most common additives are Portland cement, lime, bitumen and tar [2,3]. In this research the stabilization of clay was done by adding gypsum and volcanic ash. Gypsum is mineral with calcium levels that dominate in the minerals. Gypsum as an additive material 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 [4]. Volcanic ash (VA) used in this research was originated from Mount Sinabung. From the last data, the volume of lava from Mount Sinabung which erupted has reached 2.3 million m<sup>3</sup> [5]. Research about stabilized clay using portland cement and volcanic ash from Mount Sinabung had been proved to enhance the engineering properties of clay [6,7,8]. This research analysed the stabilization of clay which was mixed with gypsum and volcanic ash as stabilizing materials which were expected to improve the engineering properties of the clay sample so that the clay could be used in the construction.



**2. Method**

The research used experimental method which was conducted in the Laboratory of Soil Mechanics, Civil Engineering Department, University of Sumatera Utara. The research samples were original clay which was taken from PTP II, Patumbak, Deli Serdang, North Sumatera and clay samples which had been mixed with gypsum and volcanic ash erupted from Mount Sinabung.

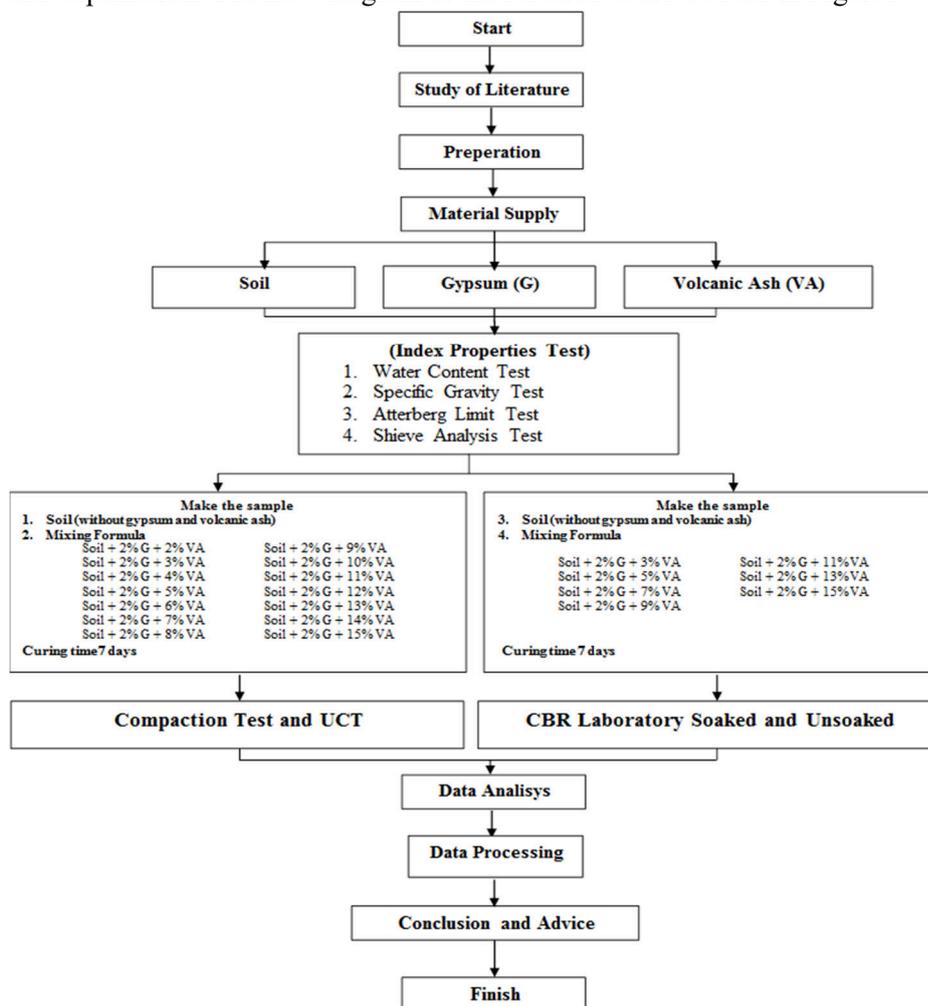
*2.1 Tested Materials*

There were 62 soil samples in the research, one of them was the sample of soil without being mixed with gypsum and volcanic ash, while the remaining 14 (fourteen) samples were soil which was mixed with gypsum and volcanic ash for UCT and 48 (forty-eight) soil samples for CBR test. The index properties of clay are shown in Table 1.

*2.2 Testing Execution*

Proctor Standard test was done to obtain the optimum water content and the maximum dry density. Besides that, there were Unconfined Compression tests and CBR Laboratory test. The curing time of each testing samples was 7 days.

After all data were gathered, they were analyzed. All results would be presented in the form of tables, graphs, and explanation. The flow diagram of the research could be seen in Figure 1.



**Figure 1.** The flow diagram of the research

### 3. Results and Discussion

#### 3.1 Original Soil Testing

Engineering properties of original soil was shown in Table 1.

**Table 1** Engineering properties of original soil

No.	TEST	RESULT
1	Water Content	12.42%
2	Specific Gravity	2.65
3	Liquid Limit	46.82%
4	Plastic Limit	17.42%
5	Plasticity Index	29.40%
6	Sieve Analysis	49.17%
7	Optimum Moisture Content	21.32%
8	Maximum Dry Density	1.31 gr/cm <sup>3</sup>
9	CBR soaked	4.44 %
10	CBR unsoaked	6.28%

#### 3.2 Stabilizing Material Testing

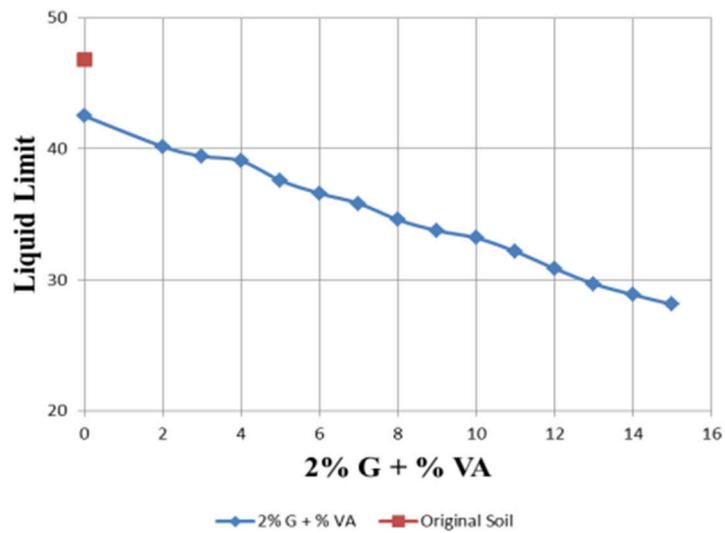
Index properties of volcanic ash and gypsum was presented in Table 2.

**Table 2** Index properties of volcanic ash and gypsum

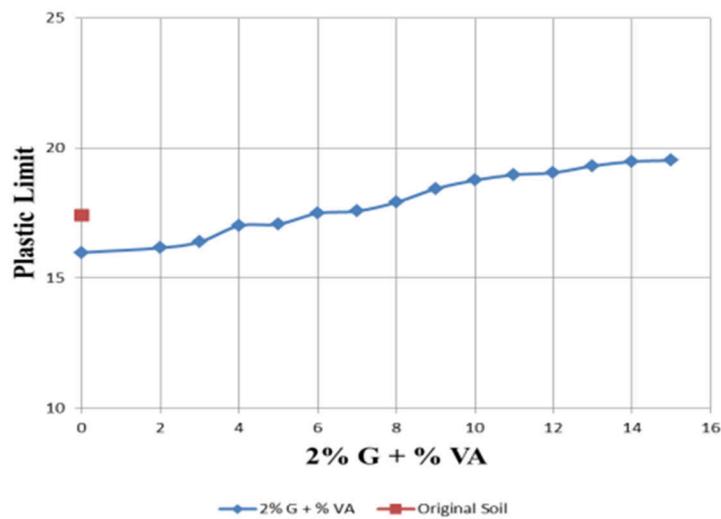
No.	Test	Volcanic Ash	Gypsum
1	Specific Gravity	2.62	2.59
2	Liquid Limit		
3	Plastic Limit	Non Plastis	Non Plastis
4	Plasticity Index		
5	Sieve Analysis	22.71%	51.62%

#### 3.3. Engineering properties of the stabilized soil

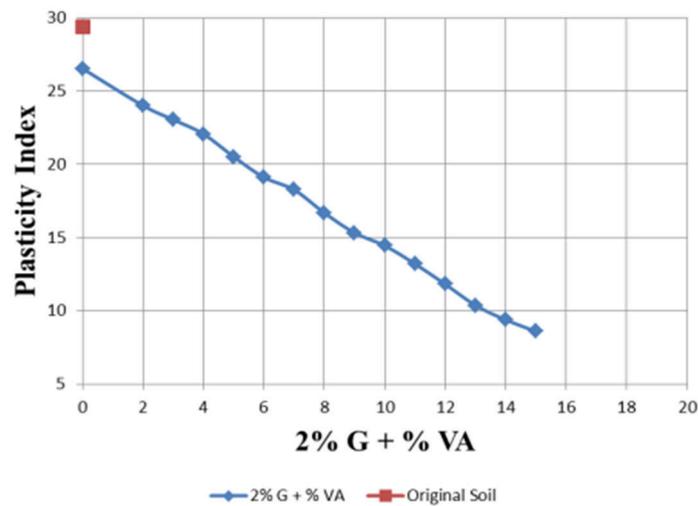
The engineering properties of stabilized soil with gypsum and volcanic ash were presented in Figure 2.



**Figure 2.** Correlation of Liquid Limit (LL) value with the variation of 2% gypsum in the addition of 0% - 15% of volcanic ash.



**Figure 3.** Correlation of Plastic Limit (PL) value with the variation of 2% of gypsum in the addition of 0% - 15% of volcanic ash



**Figure 4.** Correlation of Plasticity Index (PI) value with the variation of 2% gypsum in the addition of 0% - 15% of volcanic ash

In Figure 2, it was found that Liquid Limit as the result of the mixture of stabilizing materials, gypsum and volcanic ash decreased. The higher percentage of the volcanic ash was, the lower its liquid limit. In the original soil, the liquid limit reached 46.82%, while the lowest liquid limit was in the variation of the mixture of 2% G + 15% VA with curing time of 7 days at 28.12%. This was because in the short-term reactions the soil underwent flocculation process and was marked by flocculation of the soil particles, a reduction in plasticity and swelling potential, improvement in workability and its strength. In the longer-term was cementation process in which stabilized soil developed strength as a result of pozzolanic reactions.

Figure3 indicated the increase in the value of Plastic Limit as the result of the addition of gypsum and volcanic ash. For the original soil, plastic limit was 17.42% and was increasing to the highest value of 19.52% in the variation of 2% G + 15% VA.

Figure4 indicated the decrease in the value of Plasticity Index as the result of the addition of gypsum and volcanic ash so that its value decreased. The total decrease in plasticity index was 29.40%. The lowest plasticity index was 8.59% for the mixture of 2% G + 15% VA with the curing time of 7 days.

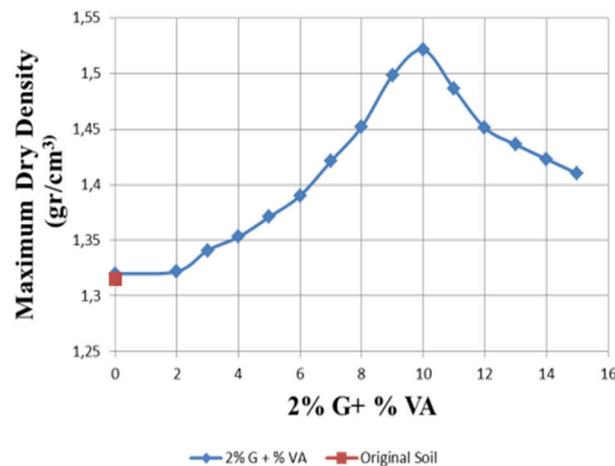


Figure 5 Correlation of  $\gamma_{dmax}$  soil with the variation of 2% gypsum in the addition of 0% - 15% of volcanic ash.

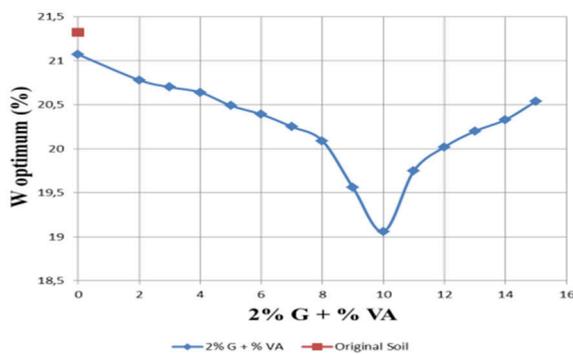


Figure 6. Correlation of  $W_{opt}$  with the variation of 2% gypsum in the addition of 0% - 15% of volcanic ash.

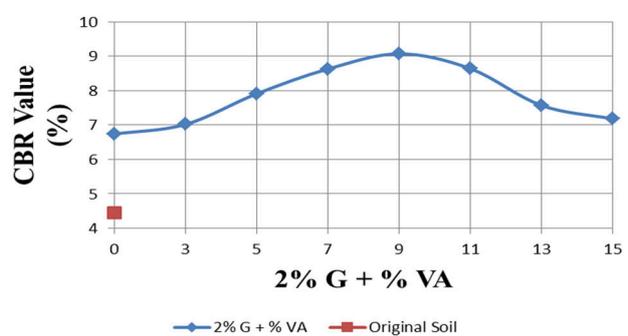
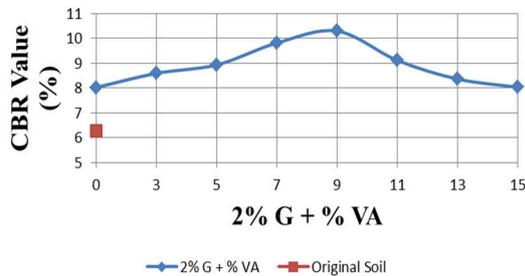
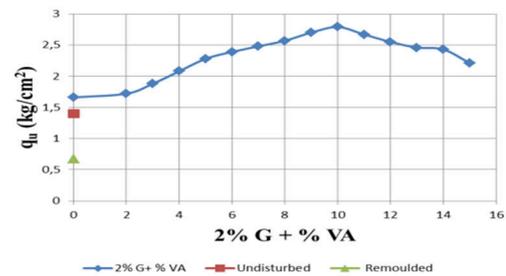


Figure 7. Correlation of soaked CBR value with the variation of 2% gypsum in the addition of 0% - 15% of volcanic ash.

The optimum water content of the original soil was 21.32% and decreased until it reached minimum dry density and increased when it reached 10% of volcanic ash.



**Figure 8.** Correlation of unsoaked CBR value with the variation of 2% gypsum in the addition of 0% - 15% of volcanic ash.



**Figure 9** Correlation of UCT value with the variation of 2% gypsum in the addition of 0% - 15% of volcanic ash.

Figure 7 and Figure 8 showed that the highest CBR value was in the variation of 2% G + 9% VA at 9.07% for soaked CBR and 10.29% for unsoaked CBR. Addition of volcanic ash more than 9% caused the CBR value decreased because the soil pores were filled with more mixture of volcanic ash and gypsum.

Figure 9 showed that the stabilized clay with variation of 2% G + 10% VA produced highest UCT value of 2.79 gr/cm<sup>2</sup>.

#### 4. Conclusion

From the research results, it could be concluded that:

1. Based on the classification of USCS, the soil sample was classified in the Clay – Low Plasticity (CL).
2. Based on AASHTO classification, the sample of original soil was the A-7-6 (10) type.
3. The specific gravity of original soil was 2.65. The specific gravity of the gypsum was 2.74 and the specific gravity of the volcanic ash was 2.62.
4. The original soil had Liquid Limit (LL) of 46.82% and plasticity index of 29.40%. The mixture of 2% G + 15% VA had the lowest plasticity index of 8.59% and liquid limit (LL) of 28.12%
5. The optimum moisture content of original soil was 21.32% and the maximum dry density was 1.31 gr/cm<sup>3</sup>. While the stabilized soil mixture of 2% G + 10% VA had optimum moisture content of 19.06% and the maximum dry density of 1.52 gr/cm<sup>3</sup>.
6. The CBR value of original soil was 4.44% for soaked CBR and 6.28% for unsoaked CBR respectively. The mixture of 2% G + 9% VA produced highest value of CBR of 9.07% for soaked CBR and 10.29% for unsoaked CBR respectively.
7. The value of UCT original soil was 1.40 gr/cm<sup>2</sup>. While the stabilized soil mixture with 2% G + 10% VA had resulted the highest UCT value of 2.79 gr/cm<sup>2</sup>.

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