INFLUENCE OF VOLCANIC ASH AND LIME ON RESILIENT MODULUS FOR SUBGRADE

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ABSTRACT

The soil is an important part of the road construction system so that the strength and stability of subgrade material are necessary to support the vehicle load. The determination of strength, stiffness, and stability of subgrade materials on road construction is expressed by CBR (California Bearing Ratio) and Resilient Modulus.On soil that has a low bearing capacity value cause stiffness and soil stability to be low. This has an impact on soil instability to support the vehicle load, so it is necessary to treat soil by mixing the Deep with a suitable material called stabilization. The additive material was used in the study are volcanic ash and lime.This paper presents resilient modulus values in stabilizing subgrade with volcanic ash and lime. Volcanic ash material is derived from Merapi volcano which is varied with the proportion of 20%, 22%, 25%, 27%, 30%. The resilient modulus test was following AASHTO T 307 using a cyclical triaxial instrument laboratory. The test also aims to evaluate the effectiveness of adding volcanic ash and lime to soils in increasing subgrade rigidity. The results showed an increase main stiffness characterized by an increase in the resilient modulus value.

Keywords: stabilization; volcanic ash; Resilient modulus.

A. INTRODUCTION

The soil is an important part of the road construction system, the strength, and stability of the subgrade material is necessary to support the vehicle load. The determination of strength, stiffness, and stability of subgrade materials in road construction is expressed by CBR (California Bearing Ratio) and Resilient Modulus (Mr). The California Bearing Ratio (CBR) is a simple test that compares the bearing capacity of the material with the broken stone which is considered good (high quality crushed stone material should have about 100% CBR). Resilient Modulus is the test used to estimate the modulus of elasticity (stress-strain relationship material test) will be needed if the soil material receives a dynamic load.

On soil that has a low bearing capacity value causes stiffness and soil stability to be low. This has an impact on soil instability to support the vehicle load, so it is necessary to treat soil by mixing the DOI: with a good material called stabilization. Additive material was used in the study are volcanic ash and lime.

In this study, local materials such as volcanic ash and lime are utilized as additive materials that have not been widely used by the community. The erupted material raises the environmental issue of material buildup. Nowadays, volcanic ash is the waste material with significant numbers. Soil stabilization using volcanic ash waste and lime is expected to increase soil stiffness value that is resilient modulus value. This paper discusses the effect of adding volcanic ash and lime to the value of the resilient modulus on the subgrade.

B. LITERATURE STUDY

1. Effect of volcanic ash stabilization on soil physical and mechanical properties.

Rifa'idanYasafuku (2013) discussed the characteristics, classification, and advantages of volcanic ash erupted by Merapi volcano as the material for soil stabilization with a composition of 15%, 20%, 25%, 30% and 35% of volcanic ash and a 5% and 10% addition of lime. The result against the physical and mechanical properties of the soil experienced a decrease in the value of Liquid limit, Swelling potential and a significant increase in the CBR value on the mixture of 35% volcanic ash and 5% lime. Rifa'i et al., 2014 studied that the fineness of volcanic ash (pozzolan) is the primary factor in the stabilization process. The utilization of volcanic ash with the grain size passing no. 270 sieves is proven to be more efficient. The effect of volcanic ash content to the soil stabilization can: (1) improve the engineering properties of soft soil; (2) change the grain size distribution curve by decreasing the fine fraction; (3) decrease consistency limits and become non-plastic soil; (4) increase bearing capacity; and, (5) decrease swelling potential. The addition of 35% volcanic ash and 9% lime gives the most significant effect on soil improvement. Latif et al. (2016) studied the chemical characteristics of volcanic ash erupted by Merapi, Kelud, and Sinabung volcanoes. Such study employed XRD and SEM to obtain mineral and morphological composition from volcanic ash which later can be used as the stabilization material. The result signifies that the morphological and mineral composition contained in those three volcanic ashes is slightly different but the volcanic ash's pozzolanic contents of Si and Al are at 45-60% and 14-20% respectively, therefore volcanic ash can be used for stabilization material. Latif et al. (2016) conducted research on the effect of the addition of volcanic ash erupted by Kelud volcano and lime on the physical properties of expansive clay soil with the mixture variation of 20%, 22%, 25%, 27% and 30% of volcanic ash and 3%, 5%, 7% and 8% of lime. Such research signifies that the mixture variation of 20%, 22%, 25%, 27% and 30% of volcanic ash and 3%, 5%, 7% and 8% of lime is the optimum mixture and is the mix that provides a significantly decreased value of LL, PL,

2. Resilient Modulus

Seed et al. (1962) introduced the concept of resilient modulus as the ratio between the maximum cyclic stress (σ_{cyc}) to the elastic Strain (ε_r) in dynamic loading, or the phase obtained from the slope of stress and strain which occurs during the load takes place i.e., the vehicle load passes through the pavement. The resilient modulus test measures stiffness on cylindrical test specimens by applying repetitive loads. For the deviatoric stress is given the resilient modulus defined as the slope of the deviatoric stress curve and the axial strain

$$M_r = \frac{\sigma_{cyc}}{\varepsilon_r} \quad (3.5)$$

with,

σ_{cyc} : Maximum cyclic stress (kN/m^2),

ε_r : Elastic Strain (%)

C. METHODOLOGY

The laboratory test method used to determine subgrade resilient modulus is a triaxial test with recurrent load equipped with hardware technology especially in data acquisition systems and Laboratory technology and field methods that enhance new developments in hardware technology, particularly in data acquisition systems and computer technology. The repetitive load triaxial test to determine the resilient modulus is regulated by AASHTO T 307: "Determining the Resilient Modulus of Soils and Aggregate Materials." The triaxial test apparatus applies a cyclic load to the cylindrical test specimen under constant confining pressure (σ_3 or σ_c) and measures recoverable strain (ε_r).

Figure 1 TriaxialTest Apparatus

D. RESULTS AND DISCUSSION

1. Material Characteristics

The soil used in this study is clay from Sidowayah, Ngawi. The visual observation shows a black colored material. The characteristics or physical and mechanical properties of the original soil discovered based on the laboratory test result is presented in Table 1. Volcanic ash used in this research is collected from Merapi volcanoes. The physical properties test result, i.e., specific gravity test of volcanic ash and composition of Si, Al and Ca, and then volcanic ash is categorized into class N pozzolan material, used in this research is presented in Table 2. The test is carried out with volcanic ash content variation of 20%, 22%, 25%, 27% and 30% as well as the lime content of 3% and 5%.

Tabel 1. Test Result Physical Properties and Mechanical Clay Sidowayah, Ngawi

No	Physical and Mechanical Properties of Soil	Test Results
1	*Specific gravity (Gs)*	2,63
2	*Water content (w)*	55,93 %
3	*Liquid limit (LL)*	79,83 %
4	*Plasticity limit (PL)*	41,91 %
5	*Plasticity index (PI)*	37,92 %
6	*Shrinkage limit (SL)*	10,83 %
7	*Dry unit weight (γd)*	1,02 g/cm^3
8	*Moist unit weight (γb)*	1,60 g/cm^3
9	*Maximum Dry Density (MDD)*	1,197 g/cm^3
10	*Optimum moisture content (wopt)*	39,49 %
11	Fraction of gravel, %	7,29 %
12	Fraction of sand, %	3,38 %
13	Fraction of silt, %	36,74 %
14	Fraction of clay, %	52,59 %
15	Modulus Elastisitas (E_{50})	10.4 kg/cm^2
16	CBR *unsoaked*	7 %
17	CBR *Soaked*	0.5 %
18	Swelling potential	19,19 %
19	Swelling pressure	451 kPa

Table 2. Specific Gravity and Chemical Content of Pozzolan material in the volcanic ash collected from Merapi and Kelud volcanoes

Volcanic Ash from	Specific Gravity	Total % of Si	Total % of A1	Total % of Ca
Merapi	2.64	51.31	19.53	7.80

2. Physical properties of soil stabilization

The physical properties test of stabilized with volcanic ash and lime which the plasticity index test and grain size distribution shown in Figure 2 and Figure 3

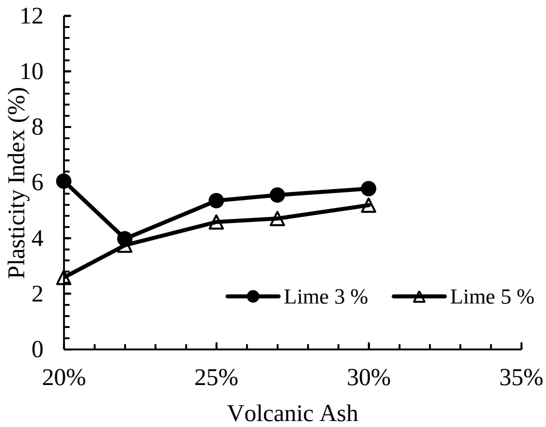

Figure 2. Influence of Merapi volcanic ash and lime on Plasticity Index.

Decreased plasticity index value of the soil mixture is due to the reduced clay granules caused by chemical reactions and cation exchange of calcium ions from volcanic ash and lime into the soil. The calcium ions derived from the decomposition of Ca (OH)2 and water exchange with the alkaline ion from the soil, and subsequently flocculation is the coating of the clay grains into larger and coarser granules. The larger the particle size, the specific surface area (specific surface) the smaller and slightly absorb water.

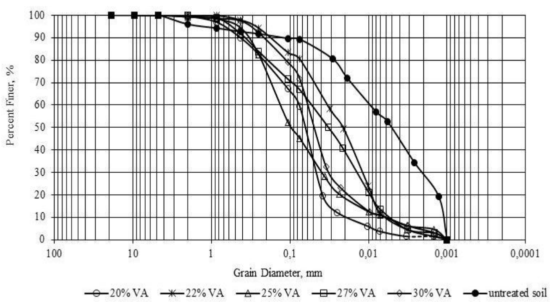

Figure 3. Graph of addition of Merapi volcanic ash and 3% of lime against grain size distribution

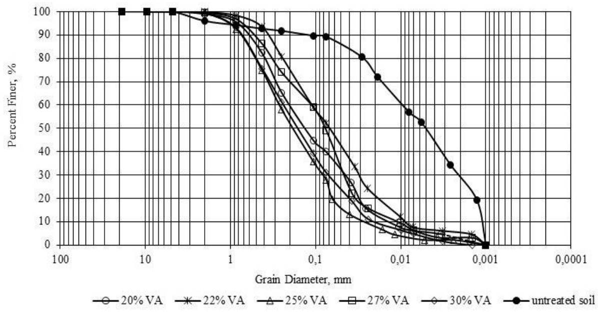

Figure 4. Graph of addition of Merapi volcanic ash and 5% of lime against grain size distribution

The test result, there is a change of soil fraction composition, i.e., the decrease of clay fraction and the increase of sand fraction in the soil mixture. The reduction in clay fraction is due to the reduction in soil plasticity index value, whereas the increase of sand fraction, due to the silica reaction present in the soil, volcanic ash, lime, and water cause more cementation process, so that the soil grains are arranged into larger clumps.

3. Mechanical Properties

Testing of mechanical properties aims to determine the effect of adding volcanic ash to the value of soil density and resilient modulus value.

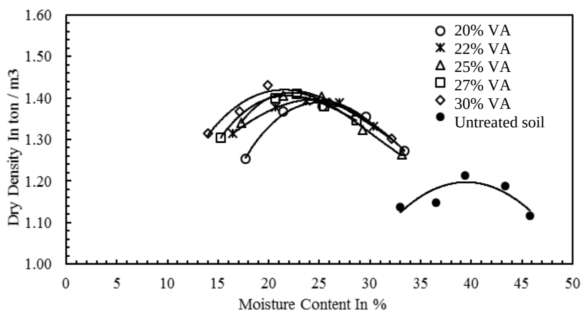

Figure 5. Graph of standard proctor result on original soil and soil mixed with volcanic ash of Merapi volcano and 3% of lime

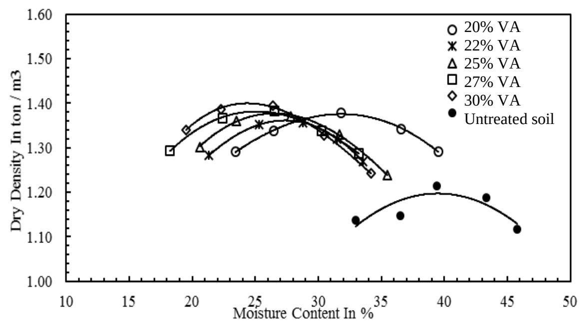

Figure 6. Graph of standard proctor result on original soil and soil mixed with the volcanic ash of Merapi volcano and 5% of lime.

Fig. 5 and Fig. 6 present the graphs of decreased optimum water content which is accompanied by an increase in its maximum dry volume weight. The greater the volcanic ash content in the mixture with the lime percentage of 3% and 5%, the greater the soil compaction will be. It is due to the addition of a significant amount of volcanic ash and lime that leads to the decreased clay content and increased sand fraction. Increase in sand fraction signifies that there is a silica reaction present in the soil, volcanic ash and lime.Several laboratory test methods and nondestructive tests were used to determine resilient modulus of the subgrade. The laboratory test method includes a recurrent load triaxial test, which is the most commonly used method for determining the modulus elasticity of soil. The density of the specimen used in this test is 95% of the maximum dry density. The testing phase includes two stages: the conditioning stage and the primary test phase. The conditioning phase consists of 1000 cycles which can be seen in Figure 6 and the primary test results on the confining stress can be observed in Figure 7 and Figure 8.

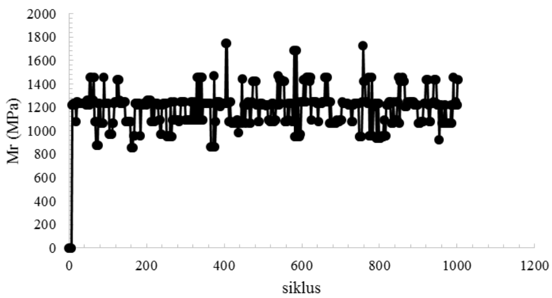

Figure 7. Addition of 20% Merapi volcanic ash and 3% lime stage conditioning Resilient Modulus.

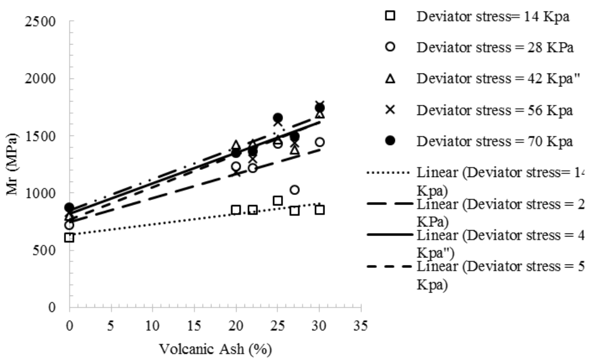

Figure 8. Influence the addition of volcanic ash of Merapi and 3% of lime to Resilient Modulus at σ_3 = 42 kPa.

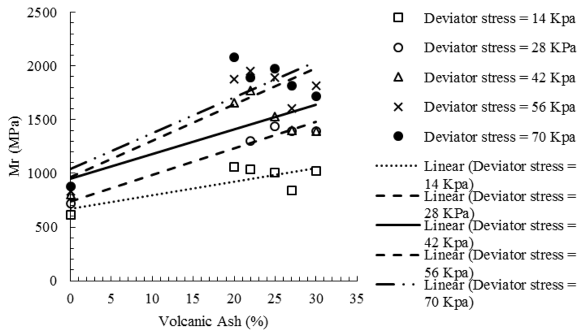

Figure 9. Influence the addition of volcanic ash of Merapi and 5% of lime to Resilient Modulus at σ_3 = 42 kPa.

The addition of volcanic ash and lime which is given in Figure 8 to Figure 9 shows a trend of increasing the resilient modulus value with the addition of volcanic ash up to 200% of the original resilient soil modulus value. It indicates the addition of volcanic ash and lime makes the subgrade more rigid. The optimum value of resilient Modulus also occurs of 30% Merapi volcanic ash and 3% lime, i.e., 1871,67Mpa.

E. CONCLUSION

From the results of the test and analysis then obtained the more percentage of soil stabilization with volcanic ash and lime, value of plasticity index decreased to low plasticity in the mixture of lime 3% and 5%. It has an effect on the soil mechanical properties of soil density value increased and decreased the value of optimum water content. This is caused by the addition of volcanic ash and lime in large amounts to make the clay content decreases and the sand fraction increases. The addition of volcanic ash and lime shows an upward trend in resilient modulus value with the addition of volcanic ash up to 200% of the original resilient soil modulus value. This indicates the addition of volcanic ash and lime makes the subgrade more rigid.

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