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Effect of Lime Stabilization on Vertical Deformation of Laterite Halmahera Soil

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Abstract. In this paper, the study was conducted to determine the lime effect on vertical deformation of road base physical model of laterite Halmahera soil. The samples of laterite soil were obtained from Halmahera Island, North Maluku Province, Indonesia. Soil characteristics were obtained from laboratory testing, according to American Standard for Testing and Materials (ASTM), consists of physical, mechanical, minerals, and chemical. The base layer of physical model testing with the dimension; 2m of length, 2m of width, and 1.5m of height. The addition of lime with variations of 3, 5, 7, an 10%, based on maximum dry density of standard Proctor test results and cured for 28 days. The model of lime treated laterite Halmahera soil with 0,1m thickness placed on subgrade layer with 1,5m thickness. Furthermore, the physical model was given static vertical loading. Some dial gauge is placed on the lime treated soil surface with distance interval 20cm, to read the vertical deformation that occurs during loading. The experimentals data was analyzed and validated with numerical analysis using finite element method. The results showed that the vertical deformation reduced significantly on 10% lime content (three times less than untreated soil), and qualify for maximum deflection (standard requirement L/240) on 7-10% lime content.

1. Introduction

Indonesia in recent years is actively to build various infrastructure in support of economic growth. Rapid development of infrastructure necessitate acquiring sufficient information and technology about methods of improving soil for geotechnical applications especially road contruction. Nowadays, chemically soil improvement are commonly used to increase the soil performance. Soil stabilization is the process of improving the physical and engineering properties of soil to obtain some predetermined targets [1]. One of the soil that can be developed to road construction is laterite soil in East Halmahera Regency, North Maluku Province, Indonesia. This area is limited to obtain the soil type that conform for technical requirements as base material, even must be imported from the other regions. While this area is dominated by laterite soils with relatively high metal content, specifically FeO, MnO, and NiO, which is simply wasted from nickel mining [2-4].

Various studies on the use of laterite soil as construction materials have been widely practiced, especially in areas where soil is present. Research related to soil improvement with stabilization among others; chemical stabilization using lime, cement, charcoal, and corn cob ash [5-10]. Chemical stabilization using liquid sodium [1], stabilization using fed gasoline mixture [12]. This research was conducted to analyze the vertical deformation characteristic of laterite soil with lime stabilization, so

that it can be used as an alternative base layer of road foundation. Meanwhile, the determination of base layer criteria can be done by model test or by simulation model using numerical analysis.
Reffering to the results of previous studies, the study was conducted to determine the effect of lime on the vertical deformation of laterite Halmahera soil with base layer modeling. Deformation of model was measured on a mixture of 3, 5, 7, and 10% lime. Furthermore, it will be known the percentage of lime addition which qualifies of surface deflection in base layer of road foundation.

2. Materials and Methods

The materials used in this research is laterite soil from East Halmahera Regency, North Maluku Province, Indonesia with coordinates N 1^{o}3'46,24" - N 0^{o}40'17,80" and E 128^{o}8'28,56" - E 128^{o}16'51,20" as shown on Figure 1. Physical and mechanical properties, chemical and mineral contents of soil obtained from laboratory test according to ASTM standard. Laterite soil stabilization using lime with 97,8% CaO and 2,2% SiO_2, with various addition of 3, 5, 7, and 10% in optimum water content of standard Proctor test results. The modeling of road foundation layer with dimensions of length (P) = 2m, width (W) = 2m, and height (H) = 1.6m.

The road foundation layer consists of a subgrade alluvial soil of 1.5m thick and lime treated laterite soil 0.1m thick. Furthermore, the model was given static loading based on unconfined compression strength of soil after cured for 28 days. Vertical deformation was measured for each soil mixture using dial gauge placed on surface with inter distance 0.2cm. Experimental data was analyzed to determine the relationship of vertical deformation and dial reading distance. Subsequently, experimental analysis was validated with numerical analysis using finite element method. The layer model testing procedure as shown in Figure 2.

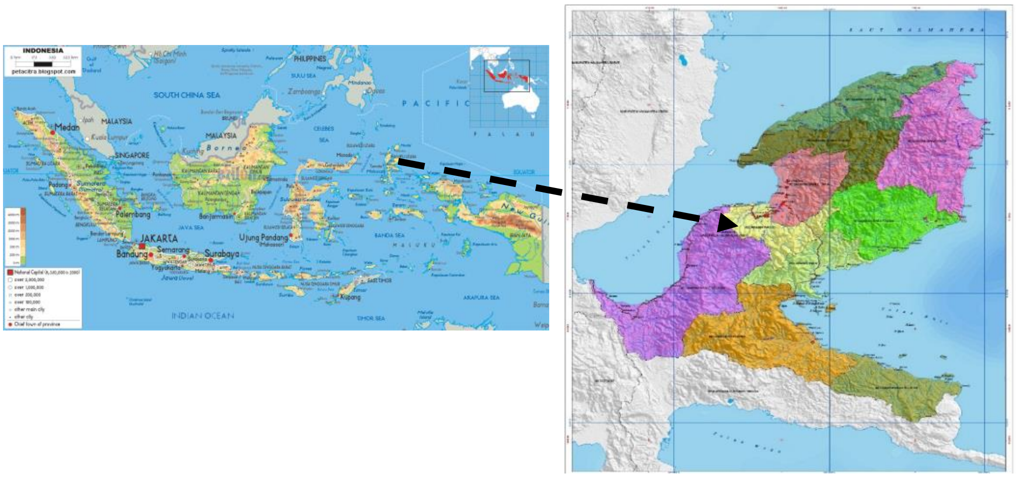

Figure 1. Sampling location of material

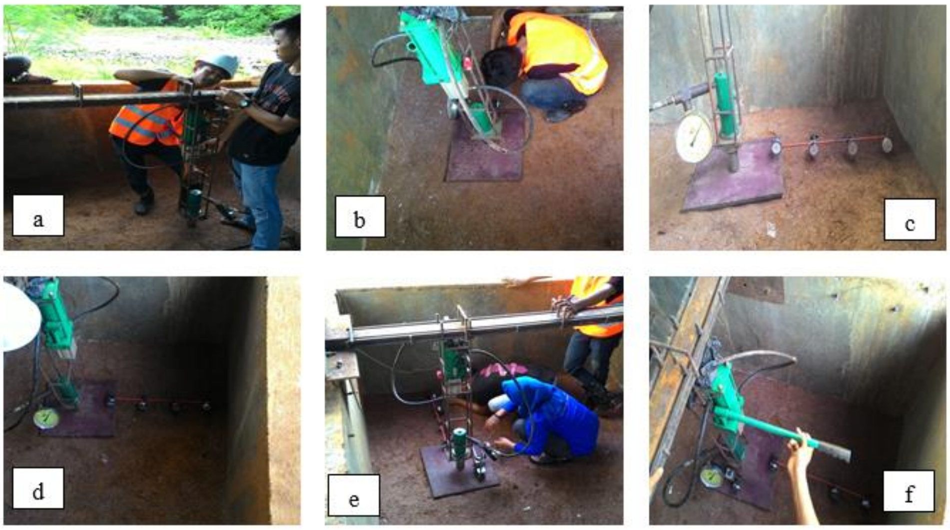

Figure 2. Model testing procedure; a) installation of test apparatus, b) dial gauge installation, c and d) hydraulic setting, e) dial reading, and f) loading test

3. Results and Discussions

Soil characteristics was obtained from laboratory test of physical and mechanical properties are shown in Table 1, chemicals properties from SEM/EDS test are shown in Table 2 [15], and minerals content from XRD test as shown in Figure 3 and Table 3 [15].

Table 1. Results of physical and mechanical properties of soil

Soil Characteristics	Unit	Alluvial Soil	Laterite Soil
Specific Gravity (Gs)	-	2.61	2,66
Water content (w)	%	34.19	18,86
Sieve analysis			
a. gravel	%	-	-
b. sand	%	31.20	8,25
c. Silt/clay	%	68.80	91,75
Atterberg limits			
a. Liquid limit (LL)	%	67.81	67,77
b. Plastic limit (PL)	%	34.28	36,86
c. Index plasticity (PI)	%	33.53	30,91
Standard Proctor compaction			
a. Maximum dry density ($\gamma_{d\ maks}$)	kN/m^3	16.19	16,89
b. Optimum moisture content (w_{opt})	%	27.45	16,53
Unconfined compression strength (q_u)	kN/m^2	42.84	75,61
California Bearing Ratio (CBR)			
a. CBR unsoaked	%	6.57	22,80
Direct shear test			
a. Cohesion (C)	kN/m^2	14.29	16,70
b. Internal friction angle (θ)	(^{0})	12	19

Soil classification			
a.	USCS	CH	CH
b.	AASTHO	A-7-6	A-7-6

Table 2. Results of chemical composition of laterite soil

Element (%)	Laterite Soil
MgO	1,28
Al_2O_3	8,45
SiO_2	3,71
K_2O	-
TiO_2	-
FeO	84,88
SO_3	-
CaO	-
MnO	-
NiO	1,38

Based on Table 1 is known that soil classification of alluvial and laterite soil according to USCS dan AASTHO are CH and A-7-6 respectively. This indicates that alluvial and laterite soil is clay soil with high plasticity. To reduce soil plasticity, it is necessary to improve the soil in order to increase soil performance, especially for laterite soil. Subsequently, from Table 2, the chemical composition of laterite soil is dominated by 84,88% FeO, 8,45 Al_2O_3, and 3,71 SiO_2. While based on Table 3, the minerals contents of laterite soil is dominated by Illite-Montmorilonite, Kaolinite, and Hematite.

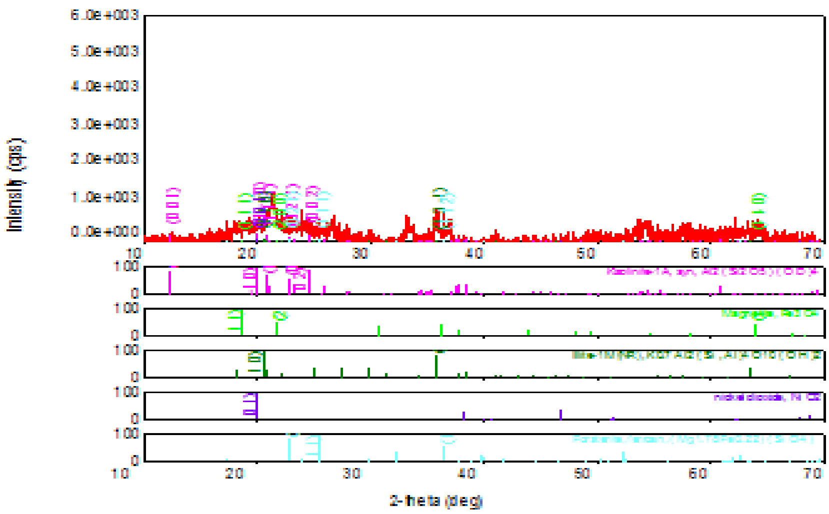

Figure 3. Result of XRD test of laterite soil

Table 3. Minerals content of laterite soil from EDAX test

Mineral Content (%)	Laterite Soil
hematite HP, iron(III) oxide	1
Kaolinite	67
Illite-montmorillonite (NR)	18
rutile HP	11
Magnesium Silicate	3

Static loading test was conducted on lime treated laterite soil of 3, 5, 7, 10% lime addition. The model was cured for 28 days before testing. Furthermore, result of data analysis determined the relationship of lime effect on subgrade modulus and elasticity modulus of model, as shown in Figure 4. Based on Figure 4, it can be seen that the relation is linier, the increasing of lime addition cause the increasing of both subgrade and elasticity modulus. This result in line with laboratory strength test, and increasing of subgrade and elsticity modulus sigificantly which is four times of elasticity modulus and three times of subgrade modulus than untreated soil. This indicates that the lime addition very affected to increasing performance of laterite soil.

The increasing of soil performance accurs due to pozzolanic reaction between soil and lime that yield pozzolanic strength gain. This reaction forms a bond between water, lime, and silica mineral of soil (C-S-H) [12-14]. This condition also seen from chemical characteritic using SEM/EDS photomicrograph as shown in Figure 5 [15]. Based on this figure, it can be seen that untreated laterit soil has higher micropore structure, while treated laterite soil has floculated and agglomertion structure which is formed cemented gel of calsium silacate hydrate (C-S-H) which cover the pore, so micropore getting smaller and soil fabric more dense.

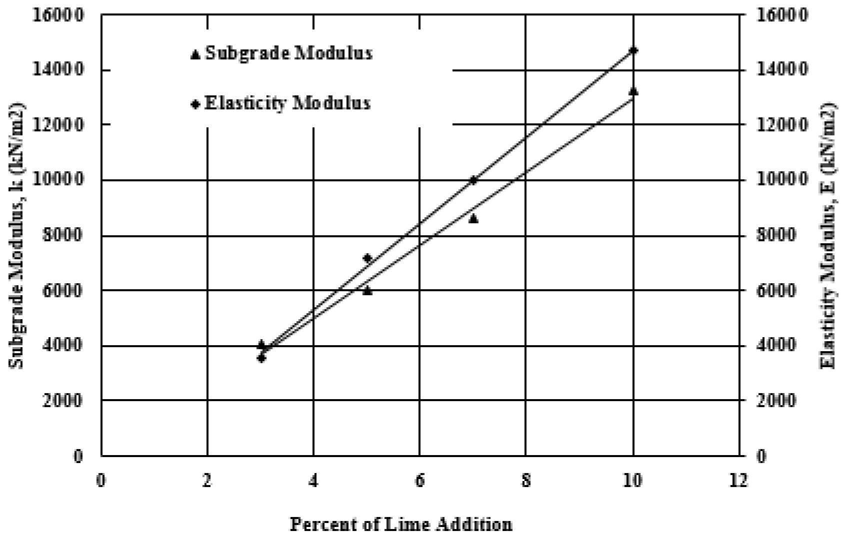

Figure 4. The relationship of soil subgrade and elasticity modulus on percent of lime addition

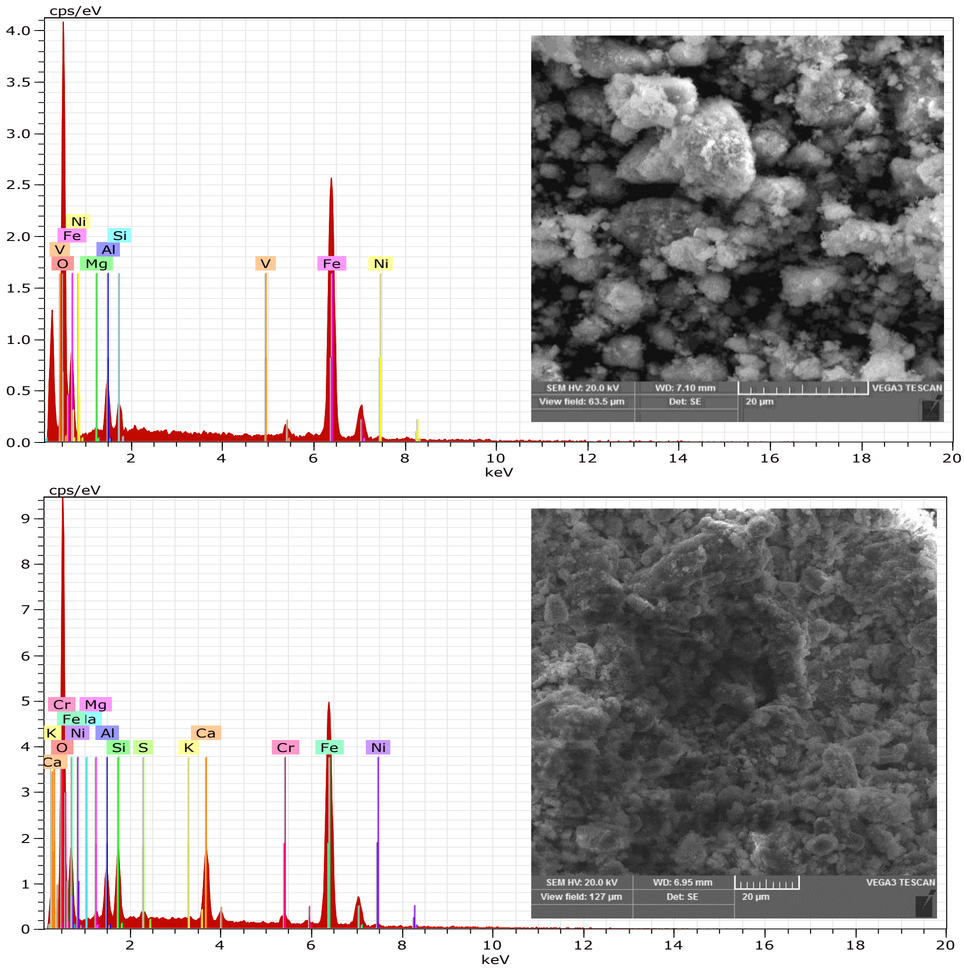

Figure 5. Results of SEM photomicrograph; a) untreated soil; b) treated soil

Subsequently, the results of model loading test obtained the correlation of lime addition, loading pressure, and vertical deformation as in Table 4. from these table, it can be determined vertical deformation model of lime treated laterite soil . The relationship of vertical deformation on dial reading, as seen on Figure 6. Based on this figure, it can be seen the vertical deformation occurs during loading. It is intended to obtain the percent of lime that qualified for lime treated base layer. Maximum vertical deformation on maximum load 35 kN has 9.68mm of untreated soil and 9.21mm of 3% lime, 5.72mm of 5% lime, 3.48mm of 7% lime, and 2.74mm of 10% lime.

Table 4. Vertical deformation of lime treated laterite soil

Percent of lime	Loading Pressure, q (kN/m²)	Vertical Deformation (10^{-3} m)
3	330	8,2
5	362,5	6,0
7	387,5	4,5
10	437,5	3,3

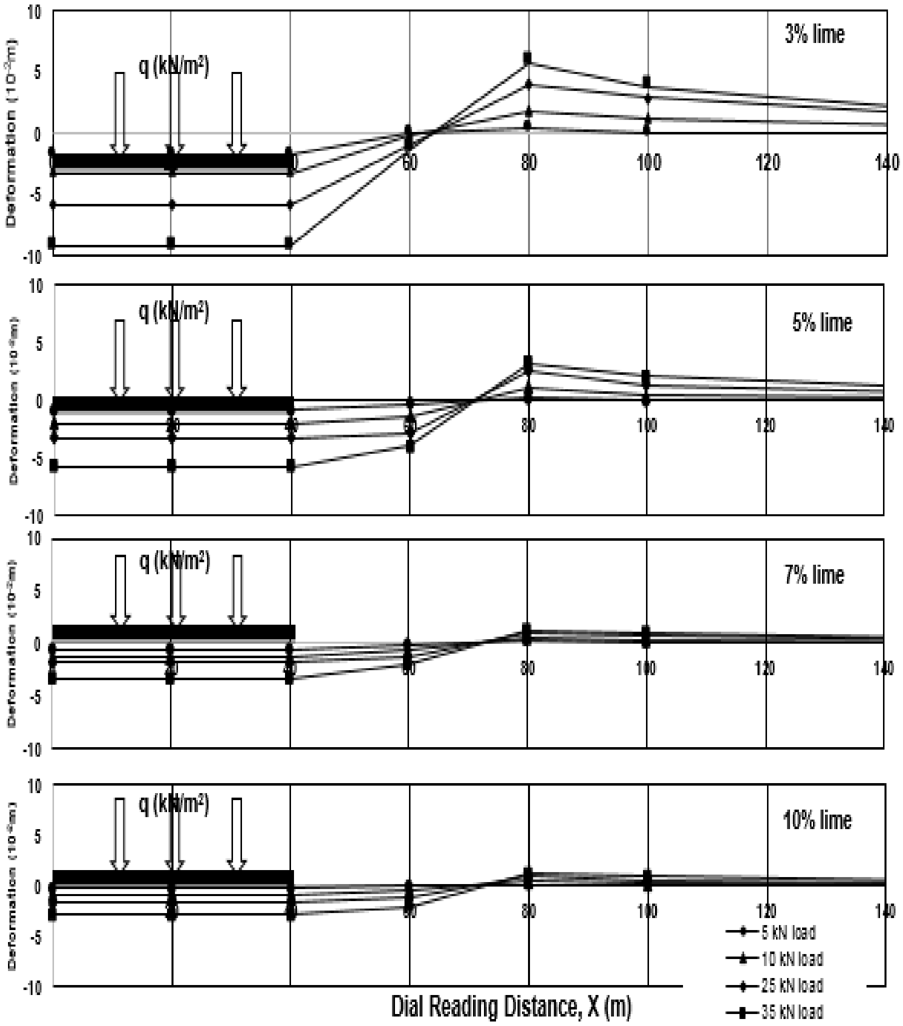

Figure 6. Vertical deformation model of lime treated laterite soil

The results on Figure 6, indicated that vertical deformation occurs on lime treated laterite soil qualified for road base foundation layer in 7-10% lime addition with deflection 3.42mm and 2.90mm respectively, which is maximum requirement of 4.16mm (standard deflection L/240). These results also satisfy that lime treated laterite soil is very potential to be used as a road base foundation layer. Furthemore, in order to make this test more convincing then validation of the experimental results was performed. Validation with numerical analysis using finite element method. Parameters input of numerical analysis obtained from the results of laboratory experimental data analysis. The result of validation as shown in Figure 7. Based on this figure, the validation results of experimental and numerical analysis show the good accuracy.

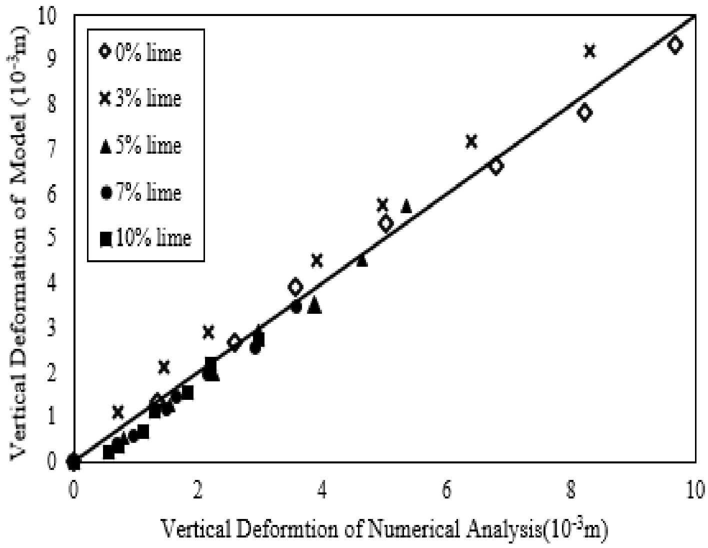

Figure 7. Validation of vertical deformation of model test and numerical analysis

4. Conclusions

Effect of lime on vertical deformation of laterite Halmahera soil was investigated. Increasing of lime addition up to 10%, cause increasing of sugrade modulus three times and elasticity modulus four times than untreated laterit soil. While vertical deformation reduced three times than untreated soil. Vertical deformation of lime treated laterite soil qualify for base foundation layer of 7-10% lime addition. Validation of experimental data analysis using numerical analysis confirm that lime treated laterite soil very potential to be used as road base foundation layer indicated by the validation results which do not show significant difference.

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5. References

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