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# Effect calcium hydroxide (traditionally called slaked lime) to stabilization of laterite soil

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**Abstract.** Inadequate road infrastructure conditions make the airway a mainstay for the transportation of people and goods, including basic needs in several Papua areas. This study aims to determine the value of elastic modulus and poison ratio that has been stabilized with hydrated lime using curing water and air for 7 days. The method used in this research is experimental method in laboratory. The test object dimension used is cylinder 53 x 106 mm. The soil samples used in this soil stabilization study were taken from Tanah Merah Bovendigul District. Clay and lime soil mixtures are prepared by using moisture content of 35%. The results test shows that the average value of elastic modulus (vertical and horizontal) on curing of water and air is 122.82 MPa each; 92.23 MPa and 51.11 MPa; 424,43 MPa. While the average value of poison ratio is respectively of 0.2 and 0.1.

## 1. Introduction

In Indonesia there are several rocks that contain carbonate compounds, including: limestone, limestone clams and limestone magnesia. Limestone is one of the industrial excavation materials with a very large potential with reserves estimated at more than 28 billion tons which are spread throughout the regions in Indonesia. According to Papua Province Mining Data and Information in 2001, Papua Province itself has limestone potential, and there are still around Keerom Regency, Sarmi Regency and Fak-Fak Regency, Papua Province. The basic soil conditions in Tanah Merah (Bovendigul) district are dominated by soft clay soils. This makes a problem that is often encountered if you have to build civil construction on soft clay because of its high compression capacity. To overcome this problem, the method commonly used is soil improvement.

Soil improvement methods are well known and can be grouped into 2 (two) groups, namely mechanical and chemical methods. Mechanical soil improvement methods have been developed, including preloading and installation of micro piles, stone columns, and geotextiles. The chemical method is with lime, cement, husk ash and fly ash. This research is motivated by an increase in the subgrade layer of road sections in Tanah Merah Regency by using a mixture of clay or laterite soil and lime which has been processed into burnt lime (calcium hydroxide, CaOH2) which is expected to be an efficient and economical alternative material, for use in areas that lack adequate coarse aggregate sources. This study aims to analyze the modulus of elasticity and poison ratio of a mixture of laterite and burnt lime

## 2. Materials and Method

### *2.1 Location and Type of Research*

This type of research used in this study is an experimental study and literature review. This research was conducted at the Eco Material Research Laboratory of the Department of Civil Engineering, Gowa Faculty, Hasanuddin University. The time of the study was carried out for approximately 3 months.

### *2.2 Research Methods and Variation of Test Objects*

The research carried out was an experimental test and a literature review on stabilizing soft soils using burnt lime as a stabilizing material. The material used in the form of laterite soil originating from Bovendigoel Regency, Papua Province and limestone obtained from PT Torea, Fak-Fak Regency, West Papua Province. Preparation of clay soil material is done by drying the clay soil under dry surface conditions or under SSD conditions. Whereas for CaCO3 limestone rocks are calcined by heating them at a temperature of $9000^0$C for 4 to 5 hours to obtain lime (CaO) which is then doused with water to form Ca(OH)2 or hydrated lime. Then do the assessment and testing of compressive strength (Compressive Strength) which is used to analyze the value of the modulus of elasticity and poison ratio after the specimen undergoes a process of immersion in water and air curing for 7 days. The number of specimens made is 30 which is used to determine the optimum lime content while the test specimens used for testing the compressive strength with variations in water immersion and for the compressive strength of the original soil are 15 specimens.

### *2.3 Method of Collecting Data*

Collecting data in this study began with examining the characteristics of the mixed material and meeting the required specifications, then a combined aggregate proportion was made using the trial and error method. After a "Trial and Error" of a mixture of clay and lime goes out, the optimum composition (clay and lime escapes sieve No. 200) is 1: 1 in weight for 1 cylindrical specimen diameter of 5.3 cm with a height of 10, 6 cm with a mixture of 35% water content. To obtain the design of a mixture of lime and clay, the volume and weight of each material used is determined. The size of the specimens made are cylinders measuring 53 x 106 mm each of 3 pieces. Fig. 1 shows the compressive strength test settings, modulus of elasticity and poison ratio performed in the laboratory.

After the mixture composition design is made, the next step is to examine the characteristics of the mixture of clay and lime in the form of specific gravity and sieve analysis. The specimens are made from clay and lime which has been tested according to the standard mixed based on the results of the design of the mixture with a ratio of 1: 1 with a moisture content of 35%. Test specimens that have been made are then subjected to treatment of test specimens namely water and air curing for 7 days.

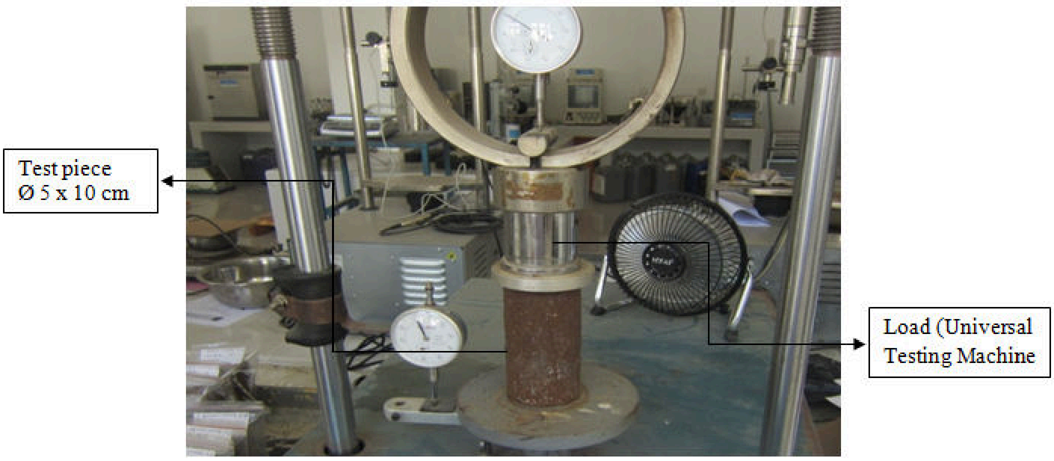


**Figure 1.** Equipment of Compressive Strength, Elasticity and Poison Ratio Test in Laboratory

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*2.4 Data Analysis Method*

Data collection in this study began with testing the material characteristics in the form of physical and chemical characteristics consisting of clay and limestone. Testing of physical and chemical characteristics is carried out by referring to existing specification standards such as the Indonesian National Standard (SNI) and ASTM (American Standard Testing Material).

## 3. Result and Discussion

*3.1 Material Characteristics*

Tests carried out include testing the physical characteristics of clay soil and limestone, where limestone consists of limestone before calcined and limestone after calcined. The clay soil used comes from Quary Waropko located in the Waropko District, Bovendigoel Regency, Papua Province and Lime Material from Quarry PT. Torea, Fak-Fak Regency, West Papua Province. Table 1 shows the physical characteristics of laterite soils used in this study.

**Table 1.** Physical properties of laterite soil.

| No | Materials Characteristics | Interval | Check-up result |
|---|---|---|---|
| 1 | Soil Classification | A-1 – A-7 | A-7 |
| 2 | Sieve analysis | >36 % (No. 200) | 39 % |
| | Waterberg limit | | |
| | Liquid limit (LL) | 30-110 % | 56.75 % |
| 3 | Plastic limit (PL) | 25-40 % | 35.56 % |
| | Shrinkage limit (SL) | 25-29 % | 27.65 % |
| | Plasticity index (PI) | >17 | 21.19 % |
| 4 | Specific gravity | 2.58-2.75 | 2.607 |
| 5 | Compaction | | $\gamma$dry = 1508 gr/cm$^3$<br>$W_{opt}$ = 25,24 % |

Examination of the physical characteristics of clay is carried out to determine the feasibility of clay soil used in research, considering that laterite soil is the main material in this study. The results of the sieve analysis test showed that the soil passed the sieve No. 200 (0.075 mm) greater than 36%, the soil can be classified into groups A-4; A-5; A-6; A-7. Liquid limit (LL) = 56.75%; > 41% then the land is included in group A-5. Pastity index (PI) = 21.19% then it belongs to the A-5 group (PI <10%) and A-7 (PI> 11%). The land can be classified into groups A-7-5 (PL> 30%) and A-7-6 (PL <30%). With a plastic limit (PL) = 35.56%; <30% then the land is included in groups A-7-5. Clay soils used in this study were in groups A-7-5 and included in the classification of clay soils with high plasticity.

Based on book 7 Road Layers (Layers of Limestone Foundations) Dirjen Bina Marga in 2006 that the land used for lime stabilized soil foundation is land classified as clay and includes expansive soils. Thus the soil used in this study must be stabilized with lime. Limestone is used in this study as a stabilizing agent for clay soil. Testing the physical characteristics of limestone is done in 2 stages, namely before calcined and after calcined. Table 2 shows the physical characteristics of limestone before and after calcination.

**Table 2.** Results of examination of physical characteristics of limestone before and after calcination.

| No. | Material Characteristics | Check-up result | |
|---|---|---|---|
| | | Before calculated | After calculated |
| 1 | Specific gravity | 3,638 | 2,308 |
| 2 | Sieve analysis | 50% pass the sieve No. | 30% pass the sieve No. |

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| | | |
|---|---|---|
| | 200 | 200 |

In limestone before calcining, using the same density test method with clay soil test, the value of limestone density is 3,638 and the sieve analysis results show that 50% of the limestone escaped sieve No. 200. Based on book 7 Road Layers (Limestone Foundation) Dirjen Bina Marga 2006 that does not require fineness of limestone and limestone used to meet the specifications of the Director General of Highways in 2006. While in limestone after calcination, a specific gravity of 2.308 was obtained and the results of the filter analysis showed that 30% passed the No. filter. 200. In addition, the results obtained in the form of lime tohor ($CaO$) which is still integrated with gravel-shaped aggregates. Furthermore, watering ($CaO + H_2O$) with water to obtain burnt lime ($Ca(OH)_2$) or calcium hydroxide.

*3.2 Mixtures Design of Laterite Soil and Calcium Hydroxide*

The design of clay and lime mixes conducted in this study was carried out by trial and error method, to obtain the optimum mixture composition used. The design of the mixture of clay and lime can be seen in Table 3.

**Table 3.** The design of a mixture of laterite soil and calcium hydroxide.

| Material | Total (1 $m^3$) | Unit |
|---|---|---|
| Soil | 182,7464 | gram |
| Lime | 182,7726 | gram |
| Water | 127,9246 | gram |

The composition of the mixture used is soil that passed through sieve No. 200 which has been known to have an optimum water content of 25.24%, then due to the addition of lime, the total water content of the mixture is 35%. The range of water addition is intended to cause a pozolanic reaction between the content of clay and lime extinguished.

*3.3 Elasticity and Poisson Ratio of Laterite Soil and Calcium Hydroxide*

Table 4 shows the results of modulus of elasticity and poison ratio with water and air curing at the age of 7 days.

**Table 4.** Test results for modulus of elasticity and poison ratio.

| Curing | Test object | $\sigma_{50}$ (MPa) | $\varepsilon_{50}$ | | $E_{50}$ (MPa) | Poisson ratio |
|---|---|---|---|---|---|---|
| | | | V | H | | |
| Water | 1 | 1.22 | 0.01 | 0.002 | 122.00 | 0.200 |
| | 2 | 1.13 | 0.05 | 0.001 | 226.00 | 0.200 |
| | 3 | 1.25 | 0.004 | 0.0009 | 312.50 | 0.225 |
| Air | 1 | 1.57 | 0.008 | 0.001 | 196.25 | 0.125 |
| | 2 | 1.57 | 0.008 | 0.0012 | 176.40 | 0.134 |
| | 3 | 1.57 | 0.008 | 0.0014 | 180.46 | 0.160 |

Exp: V: Vertical; H : Horizontal

It can be seen that in water curing, the stresses formed at 50% elastic modulus in specimens 1, 2 and 3 are 1.22 MPa, 1.13 MPa and 1.25 MPa, respectively. For vertical and horizontal strain in water curing of specimens 1, 2 and 3 are 0.01, 0.002, 0.005, 0.001 and 0.004; 0.0009, respectively. The modulus of elasticity calculated from 50% of the peak stress is 122 MPa, 226 MPa and 312.5 MPa. Whereas in air curing, the stress formed at 50% elasticity modulus in specimens 1, 2 and 3 is 1.57 MPa. For vertical and horizontal strain in air curing specimens 1, 2 and 3 are 0,008; 0,001, 0,008; 0,0012 and 0,008; 0,0014, respectively. The modulus of elasticity calculated from 50% of the peak stress is 196.25 MPa, 176.40 MPa and 180.46 MPa. For poisson test results the ratio of water and air curing specimens 1, 2 and 3 is 0.20; 0.12, 0.20; 0.13 and 0.22; 0.16.

In this research, it can be seen that there are several aspects that cause the modulus of elasticity and poisson ratio to differ between water and air curing specimens. This is because on the surface of the negatively charged clay particles bind the positively charged water molecule causing the water in the clay surface layer or absorption water to increase, the water in the clay surface layer increases causing the distance between the clay particles to get further and this makes the strength of the mixture decrease. Furthermore, as the age of the test specimen increases, the compressive strength also increases because the clay and lime particles begin to react to form a hard phase of $CaCO_3$ and CSH. Referring to a study conducted by Portelinha et al., 2012 which conducted a free compressive strength test on a laterite (red yellow latosol) soil with a 7-day age of 0.3 MPa. This means that the soil used in this study has a free compressive strength greater than 210%.

Several studies have revealed that the addition of lime or the addition of cement or the addition of these two stabilizing materials (lime and cement) can improve and improve the performance of stabilized so that the soil has the properties or carrying capacity of the soil that is better than the carrying capacity of the original soil (Dash et al., 2012; Horpibulsuk et al., 2005; Portelinha et al., 2012; Consoli et al., 2001; Yi et al., 2014; Latifi et al., 2015; Tang et al., 2007; Paul et al., 2013; Todingrara 'et al. ., 2017 and Saing et al., 2017).

## 4. Conclusion

The use of lime has been widely used as a stabilizing agent in soft soils with the aim of improving the performance of soft soils. The mixture of local Papuan clay soil with the addition of lime meets the parameters required by the Ground Composite Cement Base Layer standard according to the Interim special specifications Section 5.4 Ministry of Public Works Directorate General of Highways and has the potential to be applied in the field. The effect of lime on soil stiffness is the more lime is mixed into the clay, the stiffness will be greater so that the loading cycle is more numerous, where the number of loading cycles (cycle) will be equivalent to the age of the road pavement layers.

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