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The Effect of Soft Soil Stabilization By using Lime as the Basic Soil Strength Material for Road in Merauke Regency

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Abstract: ***Part of roads in Merauke Regency are damaged because of the soil supporting power is soft and not enough to get advantages if it is used as sub-grade soil. One of the ways to handle it is to carry out the mechanic as well as mechanic stability by using additional material. This research intends to know the California Bearing Ratio (CBR) value of subgrade, to know the effect of lime content due to the CBR of clay, the CBR value of sub-grade after being added with lime content, and to know the unconfined compressive strength value of sub-grade and soil after being mixed with lime. .The methodology consists of experimental method by using the mix of clay on the road of Kuda Mati-Tanah Wali-Wali, Merauke Regency with the lime from Wakatobi Regency due to the lime percentage variety of 3%, 6%, 9%, and 12%. Then, it is carried out the test of Atterberg limits, density, CBR swelling, CBR soaked, and test of unconfined compressive strength. The test is due to the lime percentage variety as above and the results of unconfined compressive strength value are 2,024 kg/cm^2; 5,434 kg/cm^2; 6,458 kg/cm^2; 7,689 kg/cm^2; and 7,019 kg/cm^2. Results show that the sub-grade on the road of Kuda Mati-Tujuh Wali-Wali is as clay. Lime can change the soil characteristic better and it can increase the CBR of clay soil and increasing the value of soil unconfined compressive strength***

Keywords: stability, clay, soil

.I. INTRODUCTION

Soil is as the important aspect in each civil engineering construction work because almost the whole construction works locating the work structure over the soil. Some problems are appearing due to the low technical characteristic and soil supporting power. Frequently based on the social economic considerations [1][2][3], the construction has to be developed over the clay or expressive soil. economic considerations [1][2][3], the construction has to be developed over the clay or expressive soil.considerations [1][2][3], the construction has to be developed over the clay or expressive soil. Expressive soil is a name that is used for mentioning soil or stone which has the potency of unfolding and reduction due to the effect of water content/ the size of unfolding and reduction is influenced by clay and its water content.

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If the road hardening will be developed over the type of soil, so it will be as a very serious problem due to the characteristic that is easy to unfold and redact as the effect of the change of water content [4].Therefore, it is needed to specially handle such as by carrying out the stability by giving additional material.

The soil supporting capacity is mainly depended on the density of soil mass so the effort to obtain it is by increasing the soil capacity for producing the optimal density such as by carrying out the stabilization [5][6]. National Standard of Indonesia expressed the base soil supporting value by California Bearing Ratio (CBR). The higher CBR value causes the higher capacity of the subgrade supporting and the thicker layer of road hardening structure over it, on the contrary, if the CBR value is lower, so the hardening size is increased or to be well handled accurately Part of roads in Merauke Regency is damaged due to the soil supporting power is soft and not enough to get advantages if it is used as the subgrade. Type of sub-grade in Merauke Regency is generally as clay with big reduced-unfolded. One of the ways to handle the soil type like this is to carry out the chemical stabilization by using additional material or stabilization by lime This research intends to study the possibility of using hydrated lime which is come from Wakatobi Regency. However, the clay is come from one of the quarry in Merauke Regency where is used as the location of case study and it is possible that the soil type like this is in Wakatobi Regency.

II. MATERIALS AND METHODS

A. Material and location of research

Soil sample that is used is clay of the road of Kuda Mati-Tujuh Wali-Wali, Merauke District-Merauke Regency and it is taken as natural soil condition. Type of lime which is used is hydrated lime with the chemical formula as $Ca(OH)_2$ which is as the making result of lime stone from Wakatobi Regency-South-East Sulawesi. This research is conducted in Laboratory of Civil Engineering, University of Musamus, Merauke-Papua-Indonesia.

B. Test and the Method of Mix

This test intends to know the characteristic of index properties of soil and technical characteristic mainly in accepting density energy, supporting strength in CBR value, and compressive strength Mix of materials is carried out in air dry condition by the lime percentage addition on 3%, 6%. 9% and 12% of soil dry weight so there is homogeny and then it is added water due to the optimum water content which has been obtained on the previous density observation on each mix,

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D. Clay

Clay is as soil with very soft aggregate, it has thin and long shape and on the very hard dry condition, there is cracking on some places, and however, if there is wet condition, it becomes soft and sticking. If there is more water content, the soil is changing as mud and it does not have strength anymore [5][9]. According to Das [10], particle of clay is as very active particle electro-chemically and it can only be seen by electron microscopic. According to AASHTO 1998, clay is as soft aggregate with the diameter less than 0.002 mm. According to Terzaghi and Peck, clay is as particles aggregate that has microscopic and sub-microscopic size which is come from the chemical rottenness of stone setting unsure and has plastic characteristic, and however the water content is medium size until

E. Lime

Principally, quicklime consists of CaO. Quicklime is produced from the oxidation of limestone that has the content of $CaCO_3$ on the temperature of 1000^0C and the rest only CaO [9]. The process of the quickly forming is as follow: Ca + CO3 → CaO + CO2. Dead lime is calcium hydroxide, Ca $(OH)_2$ which comes from life chalk such as adding process on life lime. Reaction of hydrate for forming dead lime is as follow: CaO + H_2O → CA $(OH)_2$ + 15.5 kcal

According to Ingels and Matchalf, lime can be used for stabilizing the subgrade, sub-base, and base course. The higher plasticity on wet condition can be improved by adding lime. It is strengthened by Soekoto [5] that soil that is well reacted with lime is clay that has plasticity index more than 50%. Lime that is used for stabilizing soil and lime modification is CaO and Ca $(OH)_2$, Lime is depended on the action to the pozzolonic material in soil, the suitability of using lime for stabilization such as type of plastic clays [11]. According to AASTHO 1998, quicklime and hydrated lime for using as soil stabilization material has to have minimal 90% content of calcium and Mangesian.

F. Stabilization of Clay and Lime

Stabilization of soil and lime is generally the same as soil stabilization with cement like the example for the technique of evaluation and implementation. According to Soekoto [5], stabilization of clay with lime such as to mix soil and lime, and the effect of lime to the most of clay generally as follow:1) To be able to decrease the Plasticity Index (PI) because of the increasing of Plastic Limit (PL) and decreasing of Liquid Limit (LL); 2) Lime and water fasten the breaking of clay and there is happened granuralization of clay aggregate which is caused by being piled some aggregates as the new big aggregate by lime piled power; 3) The characteristic of unfolded and redacted will be less enough; 4) Ability power of holding to the load force Da and the CBR value will be increasing; 5) Capillarity characteristic will be too less 2.7.

G. California Bearing Ratio (CBR)

CBR is one of the methods which are developed in USA for knowing the sub-grade supporting capacity on highway as well as airport. Supporting capacity of sub-grade is as the base for determining the hard layer depth that is made over it. CBR test is as empirical penetration test type and can be applied for some types of heavy clay on designing the depth of hardening construction and airport that consists of subgrade, sub-base, and base course. CBR value is depended on the dry density and groundwater content for obtaining suitable CBR value and it has to be carried out the soil compaction that is suitable with the water content or dry density which is obtained from the density observation in laboratory. CBR is as the ratio value which is needed for pressuring the piston with the circle number of 19.35 cm^2 (3 $inch^2$) straight upright on soil in the certain place with the velocity of 0.127 cm/minute to the needed load for perforating the certain standard load such as the compacted breaking stone, The ratio is produced for the penetration result of 0.1 inch and 0.2 inch and it is taken the biggest one. There are two manners for measuring CBR as follow: 1) CBR for the pressure on penetration of 0.1'' (0.254 cm) to the standard penetration pressure of 1000 LB/inh^2. CBR = (PI/3x1000) x 100% (PI in LB); and 2) CBR for the pressure on penetration of 0.2'' (0,508 cm) to the standard penetration pressure of 1500. LB/$inch^2$. CBR = (P2/3x1500) x 100 % (PI in LB)

According to Rote Note No 29, some values of CBR on some soils in English and there are tested in TRRI with the lowest limit on the interval of CBR value that is presented is the CBR value if the water depth less than 600 mm and the highest limit on the interval is for the CBR value on the groundwater depth more than 600 mm

F. Unconfined Compressive Strength

Procedure of mix design which is used by State Department of Highway and Public Transportation is the AASTHO T-220 which intends to determine the value of unconfined compressive strength from the mix of soil and lime. According to Illinois procedure, the compressive strength value on the mix of soil and lime on adding of 3% has to produce 34.5 N/cm^2 or 50 psi, Transportation Research Board [10] makes a condition for suitable unconfined compressive test for characterizing the strength on the mix of soil and swallowed lime. However, CBR test is not recommended. Swallowing intends to know the strength of soil mix for the improvement being swallowed during 48 hours on the temperature of 48.90°C or 120°F.

III. RESULTSAND DISCUSSION

A.Clay

Result of sub-grade characteristic test is presented as in Table- I,.

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Table- I.. Characteristic of sub-grade

No	Observation	Value
1.	Air dry water content (w)	8.21%
2.	Specific Gravity (Gs)	2.59
3.	Liquid Limit (LL)	60.13%
4.	Plasticity Limit (PL)	37.25%
5.	Plasticity Index (*PI*)	22.88%
6.	Maximum dry vol-weight (ɱd)	1.67g/cm^3
7.	Optimum water content (*w*)	22.40%
9.	Swelling CBR value	3%
10.	Soaked CBR value	4.40%
10.	Un-soaked CBR value	9.28%
11.	Unconfined compressive	2.024

B. Mix of Clay and Lime

Clay is mixed with lime, and then it is tested the Atterberg limits, compaction test, CBR swelling, CBR soaked, and unconfined compressive strength and the result is presented as in Table- II.

Table- II. Test of Atterberg Limits on the mix of clay and lime

No	Lime content (%)	Liquid Limit (LL, %)	Plastic Limit (PL, %)	Plasticity Index (PI, %)
1	3	53.81	38.64	15.17
2	6	51.57	41.44	10.14
3	9	50.99	43.31	7.68
4	12	50.81	45.57	5.24

Result of standard compaction test on the mix of soil and lime is presented as in Table- III.

Table- III. Standard compaction test on the mix of soil and lime

No	Lime content (%)	Dry vol-weight (Md max, gr/cm^3)	Opt. water content (A opt, %)
1	3	1.50	26.35
2	6	1.48	27.35
3	9	1.38	28.10
4	12	1.26	29.00

The value of the CBR swelling value with the caring during 4 days is presented as in Table-IV. Table- V, and VI present the value of CBR each for soaked and not soaked.

Table- IV. CBR swelling value with caring during 4 days on the mix of soil and lime

No	Lime content (%)	Swelling value (%)
1	3	11.5
2	6	1.3
3	9	9.5
4	12	12.8

Table- V. CBR on the mix of soil and lime (not soaked)

No	Lime content (%)	CBR (%)
1	3	21.99
2	6	26.06
3	9	31.93
4	12	29.65

Table- VI. CBR on the mix of soil and lime (soaked)

No	Lime content (%)	CBR (%)
1	3	11.08
2	6	19.22
3	9	26.39
4	12	24.76

Results of unconvinced compressive strength on the mix of soil and lime without swelling are presented as in Table- VII However Table- VIII presents with 3 days swelling.

Table- VII. Unconfined compressive strength value without swelling

No	Lime content (%)	qu (kg/cm^2)
1	3	3.067
2	6	3.605
3	9	2.247
4	12	2.059

Table – VIII. Unconfinced compressive strength value with 3 days swelling

No	Lime content (%)	qu (kg/cm^2)
1	3	5.434
2	6	6.458
3	9	7.689
4	12	7.019

C. The Effect of Lime Adding to the Atterberg Limits Value

Lime adding on the clay which has high plasticity can affect the Atterberg limit value. Both of them can decrease the liquid limit and plastic limit of clay. The higher decreasing on liquid limit of lime content will increase the plastic limit and decrease the index plasticity.

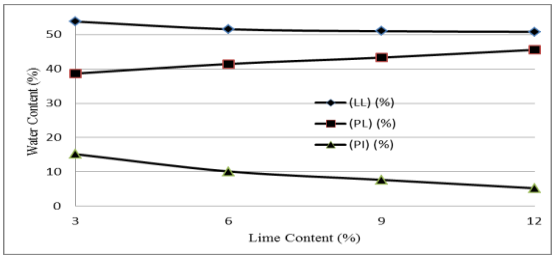

Fig.1. The relation between lime content and Atterberg value

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Fig. 1 as above is presented liquid limit (LL). Liquid limit (LL) is as water content of soil saturated in plastic condition. Due to the observation result, the more increasing of lime content can decrease the liquid limit which the water content is reaching the highest limit on soil for absorbing water, moreover soil will become liquid. The initial condition (0%) of natural soil with the liquid limit of 60.13%, after it is mixed with 3% of lime (end condition) can decrease the liquid limit becomes to 53.81%. This value is continued decreasing due to the increasing of lime content. On Fig. 1, the index plasticity of natural soil is 22.8%, after it is mixed with 3% of lime can decrease the index plasticity into 15.17%. This value is continued decreasing due to the increasing of lime content. The plastic limit on Fig. 1 is 37.25%, after it is mixed with 3% of lime, the plastic limit is increasing to 38.64% due to the lime content.

D. The Effect of Lime Adding to the Maximum Dry Volume Weight and Optimum

Clay that is added with lime will be decreasing the maximum dry volume weight. The maximum dry volume weight on natural soil of 0$ (initial condition) is 1.67 gr/cm^3, after adding 3% of lime adding (end condition), there is decreasing the maximum dry volume weight of 1.50 gr/cm^3; after adding 6% of lime, there is decreasing the maximum dry volume weight of 1.48 gr/cm^3; after adding 9% of lime, there is decreasing the maximum dry volume weight of 1.38 gr/cm^3; the decreasing is happened until the adding 12% of lime and there is decreasing the maximum dry volume weight of 1.26 gr/cm^3. It is due to the usage of lime content will increase the water absorption and the volume weight of lime is also less than volume weight of soil, so by adding lime, it will decrease the maximum dry volume weight [11] as presented in Fig. 2.

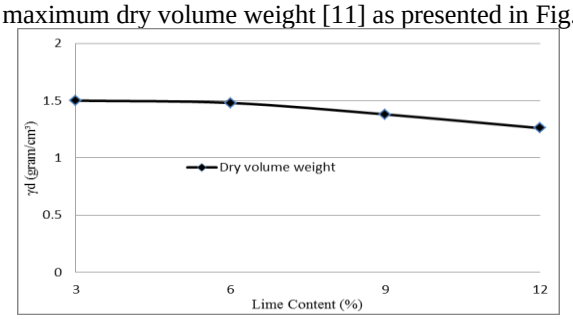

Fig. 2. The relation of lime content and maximum dry volume-weight

After adding 3 until 12% of lime, the optimum water content is increasing as presented in Fig. 3. Clay which is added with lime will be decreasing the optimum water content. The optimum water content on natural soil of 0% (initial condition) is 22.40%. After adding 3% of lime (end condition), the optimum water content is increasing of 26.35%. After adding 6% of lime, the optimum water content is increasing 27.35%. After adding 9% of lime, the optimum water content is increasing of 28.10%. The increasing is happened until adding 12% of lime and the optimum water content is 29.00%. It is due to the usage of lime content will add water absorption and the volume weight of lime is less than volume weight of soil, so the increasing of lime will be decreasing the maximum dry volume weight as presented in Fig. 3

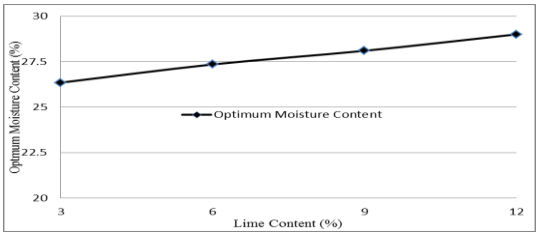

Fig. 3: The relation between lime content and optimum water content

E. The Effect of Adding Lime to the Unfolding Potency

Natural soil which has very high unfolding after being mixed with lime, it can really decrease the unfolding. The decreasing of unfolding value is depended on the lime percentage as presented in Fig. 4, The initial condition of natural soil (0%) has the unfolding of 30%; after it is mixed with 3% of lime (end condition), the unfolding is decreasing to 11.5%; on adding 9% of lime the unfolding is decreasing to 9.5%; on adding 12% of lime, the unfolding is decreasing to 12.8%; and however, on adding 6% of lime, the unfolding is decreasing to 1.3%.

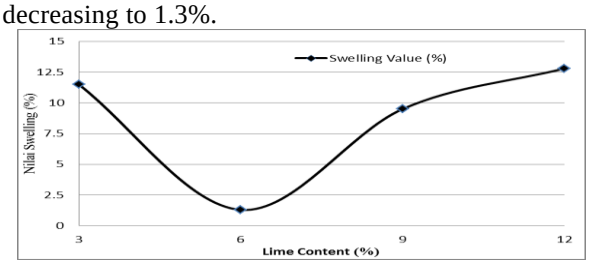

Fig. 4:.The effect of adding lime content to the unfolding potency

F. The Effect of Adding Lime to the CBR Value

F.1. Soaked CBR value

Clay is mixed with lime, and then it is carried out the soaked CBR test. The result is presented as in Fig. 5. Result shows that there is the increasing due to the adding of lime. It is caused by the increasing of lime means that number of Ca and Mg on clay become more and more. By adding water, it will be happened the micro-crystal which can lock mechanically. The reaction is only happened if there is water, but if there is dry, the reaction will stop. Figure 5 presented that on initial condition of natural soil (0%) is 4.40%; on adding 3% of lime (end condition) there is significantly happened the increasing of 11.8%; gor adding 6% of lime, the increasing is 19.22%; on adding 9% of lime, the increasing is 26.39%. This is highest increasing of CBR. On the adding 12% of lime, the CBR value is decreasing; it means that on the adding 9% of lime, the soil supporting strength is not increasing.

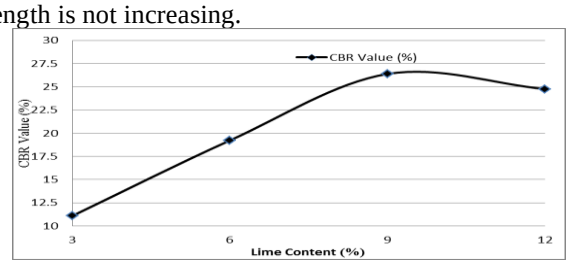

Fig. 5: The effect of adding lime to the soaked CBR value

G. Not Soaked CBR Value

Clay is mixed with lime and then it is carried out the not soaked CBR test. The result is presented as in Fig. 6. Result shows that the increasing of lime causes number of Ca and Mg is more and more. If there is adding water will be happened the micro-crystal that can lock mechanically. The reaction is only happened if there is water, but if there is dry, the reaction will stop. Figure 6 presented that on initial condition of natural soil (0%) is 8.80%; on adding 3% of lime (end condition) there is significantly happened the increasing of 21.99%; or adding 6% of lime, the increasing is 26.06%; on adding 9% of lime, the increasing is 26.39%. This is highest increasing of CBR. On the adding 12% of lime, the CBR value is decreasing; it means that on the adding 9% of lime, the soil supporting strength is not increasing.

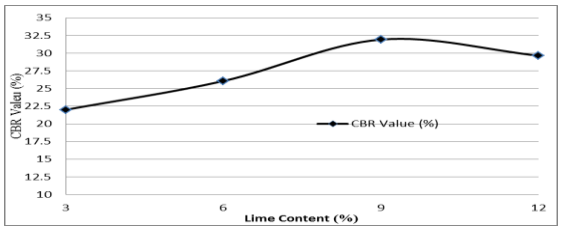

Fig. 6: The effect of adding lime content to the not soaked CBR value

H.The Effect of Adding Lime to the Unconfined Compressive Strength

The adding of lime to the clay can increase the unconfined compressive strength. Fig. 7 presented the compressive strength which is affected by the swelling time. Result of unconfined compressive strength (qu) on natural soil of 0% (initial condition) is 2.0241 kg/cm^2. After adding 3% of lime *end condition), the compressive strength is 3.0674 kg/cm^2. After adding 6% of lime *end condition), the compressive strength is 3.605 kg/cm^2 After adding 9% of lime *end condition), the compressive strength is 2.247 kg/cm^2 After adding 12% of lime *end condition), the compressive strength is 2.059 kg/cm^2, because the mix between soil and lime has not been happened the well reaction. By adding lime more than 9% without swelling, there is not happened the increasing. It can be moaned that by adding lime, it will need more time to react as presented in Fig. 7. Compressive strength test on the mix of soil and lime without swelling indicates the real characteristic of strength because the test is carried out fluctuation, so the condition of soil is still weak.

By swelling during 3 days which the soil and lime is given time to react so there is happened the changing of cat-ion, fluctuation, and agglomeration, so the mix of 3% lime will cause the compressive strength is increasing to 5.434 kg/cm^2. On adding 6% of lime, the compressive strength is increasing to 6.458 kg/cm^2. On adding 9% of lime, the compressive strength is increasing to 7.689 kg/cm^2. It means the given time is enough to react. On adding 12% of lime, the compressive strength is increasing to 7.019 kg/cm^2.It means that the more lime content to be added, the compressive strength is decreasing. The more lime is added, it needs more time to reach the cementation so the real characteristic can be known

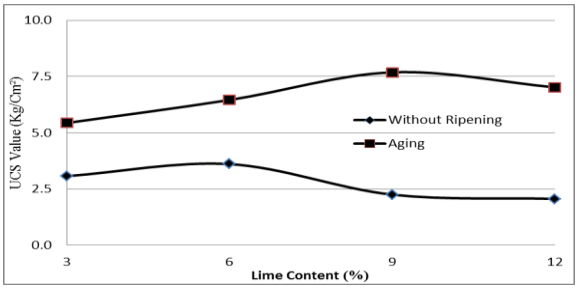

Fig. 7. The effect of swelling time on the mix of soil and lime to the unconfined compressive strength

IV. CONCLUSION

Based on the research result and the discussion as above, it is concluded as follow: Sub-grade on the road of Kuda Mati-Tujuh Wali-Wali is clay because according to AASHTO the type of clay is A 7-5, but according to Unified is CH (inorganic clay with high plasticity or flak clay) with the plasticity index of 22.88%; CBR value of 4.40%; and compressive strength of 2.024 kg/cm^2. Lime can change the characteristic of soil to become better. The decreasing of liquid limit and plasticity index, and to increase the compressive strength of clay. The decreasing of liquid limit (LL) and plasticity index (PI), and the increasing of CBR value is depended on the number of lime that is added. The composition of lime content which can be used is 3%, 6%, and 9% because it can increase the soil supporting power. The lime adding of 3%, 6%, 9%, and 12% can increase the CBR value of 11.08%; 19.22%; 26.39%; and 24.76%. However, the lime adding of 3%, 6%, 9%, and 12% can increase the unconfined compressive strength of 5.434 kg/cm^2; 6.458 kg/cm^2; 7.89 kg/cm^2; and 8.258 kg/cm^2

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