Experimental Study of Clay Stabilization with Quick Lime Activated by Gum Rosin and Iron Oxide

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Abstract

This study is intended to increase the bearing capacity of expansive clay as subgrade of highway. Compressive strength of compacted original soil is 0.27 kg/cm^2, and laboratory CBR value (unsoaked) is 8.9%, therefore carried out stabilization with quicklime, activated by gum rosin and iron oxide. Design mix composition resulting proportions on weigh, 100 quick lime : 10 gum rosin : 8 iron oxide which is then named KA for stabilizers. Samples are made with variation KA 5%, 10%, 15%, and 20% of the dry weight of the soil, and then tested with UCS, CBR, and Hydraulic Compressibility. Test results show that soil + 20% KA at 28 days curing, the UCS value is 117.78 kg/cm^2. On 7 days curing, soil + 5% quicklime obtained CBR value is 14.82%, and soil + 5% KA obtained CBR value is 45.06% (increased by 300%). Hydraulic compressibility test result show that the soil sample is impermeable. The activation of gum rosin and iron oxide improve the performance of lime on soil stability significantly, so that the expansive clay achieve technical specification as subgrade of highway.

Keywords — *activation, gum rosin, iron oxide, quicklime, stabilization.*

I. INTRODUCTION

The soft soil in Indonesia about 10% of land area, located in various region (Utomo 2007). The soft soil tends to spread in the lowland wich places the concentration of human activity where most cities in the word are built for natural reasons. Lowlands generally consist of alluvial soils with low carrying capacity (Utomo 2004), but must bear the heavy construction load. Therefore, in the expansive clay is done stabilization efforts to increase its carrying capacity and durability to meet the technical specifications as a subgrade materials of highway. Previous research states that in the clay with lime stabilization was identified that the pure argillite underwent a slight decrease in its cohesion due to do dissolution of its clayey particles (Cuisinier et all. 2009). The morphological analysis suggested that's gel is formed from a result of the decomposition of the progressive clay particles in the soil reacted with the calcium ions from the lime, while XRD analysis provided no strong evidence in the formation of new phases (Wild et all. 1986).Soil-lime mixing results in cation exchange, causing flocculation and agglomeration of soil particles, effectively increases the strength, durability, and workability the soil. Such treatment also improves soil compressibility, nonetheless, but lime stabilization has a number of inherent disadvantages, such as carbonation, sulfate attack, and environmental impact (Jawad et all. 2014).

Optimum lime content in the range of 5% for black cotton soil stabilization, for various lime contents and curing temperatures, it was observed that the maximum portion of strength was obtained in initial curing period of 7 days (Nasrizar et all. 2010). After a 7 day curing period, test results show that the optimum lime content for soil stabilization is 5% (Ciancio et all. 2013). Stabilization of lime 10% at 28 days curing period increase the carrying capacity of the laterite soil three times higher the laterite soil before stabilization. The soil modulus increases as the lime level increases and curing time (Saing, Z., et all. 2017). The pavement layers construction of soil-lime was flooded every rainy season, In the fourth year, stability decreased because of puddles, decrease the carrying capacity and increase soil plasticity (Adha 2009). Expansive soil stabilized with lime and dregs ash produced maximum density at 4% lime content, unconfined strength up to ash 10%, on the higher ash content the lime is not capable of binding the silicate and aluminate present in the ash.The pozzolanic reaction occurs only when there is water, and if no water then the silicate and aluminate in the ash do not mean anything so that the stabilization process is not occurring (Hatmoko and Lulie 2007). Clay is stabilized with lime and rice husk ash,the highest CBR values were achieved at 6% lime content and 4% rice husk ash content, concluded that the mixture of lime and rice husk ash is not always able to increase the value of CBR, for CBR soaked or CBR unsoaked (Ariyani et all. 2007).

The desiccation cracks in compacted Akaboku soils. Polypropylene (C_3H_6) fiber wash used as an additive material for a soil sample. The percentages of fiber used were varied as 0,0%, 0,2%, 0,4%, 0,6%, 0,8%, 1,0%, and 1,2% (by dry weight of samples). Compacted under the conditions of maximum dry density and optimum water content. The test results: percentage change in volume of compressed soil sample decreases with the addition of fiber, thereby decreasing the strain of volumetric shrinkage significantly (Harianto, T. et all. 2008). Clay soil stabilized 10% fly ash 0.5% of palm oil fiber (POF) improve the soil compressive strength of 129%, decrease the hydraulic conductivity value 850.4%,lowered liquid limit of 33.48% to 24.5%,lowered swelling potential by 8% to 1.5%, lowered the crack intensity factor (CIF) from 1.96% to zero crack (Nurdin, S., et all. 2016).The behavior of fatigue interaction-palm fibers in the soil-cement as an elastic foundation pavement. Reinforcement palm-sugar 0.50% increase resilience modulus degradation of 6,50%due to palm-sugar fiber interaction on cement-soil (Suroso, P., et all. 2016).

Bili-Bili dam's dredging sediment which was stabilized by portland cement type 1at 28 days curing can increase the compressive strength (qu)for 5% cement content reaches 5.15 kg/cm2and for cement content of 20% reach 82.22% (Yusuf, H., et all. 2012).Addition of 20% stabilizer (quicklime activated gum rosin and iron oxide) on silty clay with a 28 day curing increased the compressive strength (qu)from 6.93 kg/cm2 (for soil compacted without stabilizers)to 160.24 kg/cm2 (for soil + 20% stabilizer)or an increase of 2,212% (two thousand two hundred and twelve percent),and decrease the water absorption content from 23.17% to 4.06% (Sofwan, et all. 2016).

Previous studies on soil-lime or soil-cement stabilization indicating the need for further research, mainly on aspects of stability and durability. In this study, soil-lime stabilization was performed by adding gum rosin and iron oxide as an activator. Gum rosin is not soluble in water but capable of absorbing water molecules, potentially as ion exchangers and has the ability to penetrate soil molecular structure that tends to be solid. Has a high degree of viscosity and strong adhesion between the particles.It has high levels of carbon content (Doelen at all. 1998 in Mulyono 2004). The iron oxide can react with calcium carbonate into iron oxide carbonate, can affect the aggregate between soil particles and cation exchange capacity (Cornell & Schertmann 1996), may indicate pH conditions, redox potential, moisture and soil temperature (Rossel et al 2009).Flocculation of the solution can be neutralized by adding material which contains acids (H + ions) (Mitchell 1976). The degree of acidity can decrease the level of permeability so the ground is more stable (Nordstrom 2000).

II. METHODOLOGY

The soil grain has a high carrying capacity and excellent resistance, but at certain moisture content loses its cohesion properties thus lowering the carrying capacity and durability, therefore stabilizing the soil with chemicals should consider chemical reactions as a function of strengthening the inter-grain attraction in wet or dry conditions and has resistance to chemical reactions that damage. Quicklime (CaO) as a stabilizer, gum rosin (C19H24) and iron oxide (Fe2O3) as activator, to improve lime performance on the stabilization of expansive soils to be applied as subgrade material of highway. Mixed designs produce proportions by weight ratio 100 Quicklime : 10 Gum rosin : 8 Iron oxide which is then name KA for stabilizers. Then tested Unconfined Compression Strength (UCS), California Bearing Ratio (CBR), and Hydraulic Compressibility. In UCS test used composition 5%, 10%, 15%, 20% KA, and 5% CaO, on a curing duration of 0 days, 7 days, 14 days, and 28 days. In the CBR test used the composition of 5% KA and 20% KA, also 5% CaO, on a curing duration of 0 days and 7 days. In Hydraulic Compressibility test used composition 5% and 20% KA with a diameter sample 250 mm high 100 mm put into a tube and filled with water on it, then pressed 100 kPa for 60 minutes, 150 kPa for 60 minutes, 200 kPa for 60 minutes. The percentage is weight percent to the dry weight of the soil.

The test is done in the soil mechanics laboratory Department of Civil Engineering Hasanuddin University Makassar, Gowa Engineering campus. Standard testing refers to American Standard Testing and Material (ASTM) and Indonesia National Standard (SNI).

III. RESULT AND DISCUSSION

A. *Properties of the original soil*

From the results of testing the atterberg limits obtained liquid limit (LL) = 70.86% and plasticity index (PI) = 39.46%. According to Unified Soil Classification System (USCS), soil classification is classified as a type of inorganic clay with high plasticity (CH). From the results of the sieve analysis obtained the distribution of soil grain size, quantitatively dominated by clay fraction of 62,58%, followed by the silt fraction of 34.75%, and a sand fraction of 2.67%, so that this soil sample can be categorized as silty clay. The unconfined compressive strength of the original soil compacted without the stabilizer is 0.27 kg / cm2.

B. *UCT Test soil stabilized by KA, and soil stabilized by CaO.*

TABLE 1- UCS test results on KA-stabilized soil, and CaO-stabilized soil.

No.	Weight Ratio			qu (kg/cm2)			
	Clay	KA	CaO	0 day	7 day	14 day	28 day
1	100	5	-	0.62	2.03	13.56	40.18
2	100	10	-	0.98	7.523	22.03	61.79
3	100	15	-	1.22	12.385	35.99	87.29
4	100	20	-	1.51	17.38	50.27	**117.78**
5	100	-	5	0.88	3.01	10.30	18.86

Source: Primary data of research, 2017.

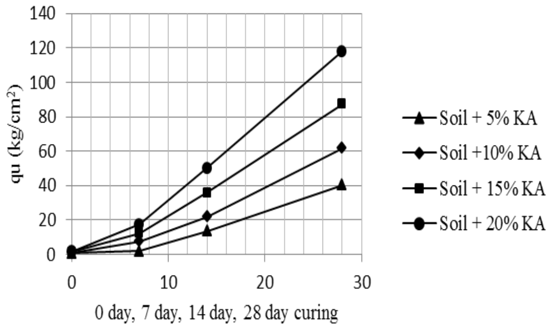

Fig 1 : Correlation qu and period, for variation of KA content

Fig 1 shows that for a variety of KA content, the free compressive strength continues to increase along with the addition of the curing period. That compressive strength testing (qu) for 20% KA until the 28 days curing period, produce unconfined compressive strength value (qu) 117.78 kg / cm2, or 436 (four hundred and thirty-six) times of compacted original soil without stabilizers. Activation of gum rosin and iron oxide significantly improves the behaviour of lime on improving the bearing capacity.

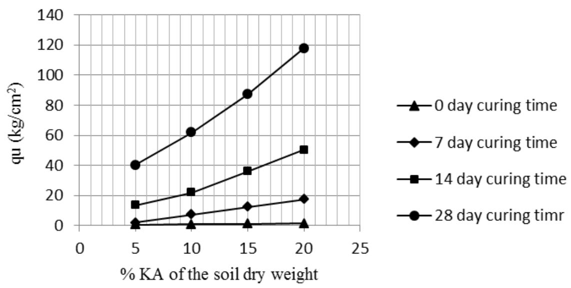

Fig 2 : Correlation qu and KA content with various of curing time

Fig 2 shows that the variation of the curing period, unconfined compressive strength continues to increase along with the addition of KA content up to 20 percent of the dry weight of the soil. Thus activation of gum rosin and iron oxide significantly improves lime behavior in soil stabilization functions.

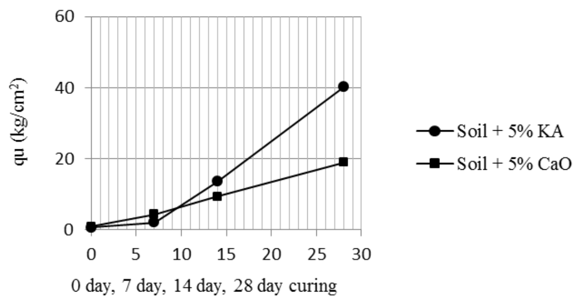

Fig 3 : The correlation qu and the curing period, the comparison between 5% KA and 5% CaO

Fig 3 shows that a 28-day at curing period, press strength of soil stabilized with 5% CaO = 18.86 kg / cm2, for soil stabilized with 20% KA = 40.18 kg / cm2. That for a 5% composition against the dry weight of the soil at 28 days' of curing period, gum rosin and iron oxide activation improved lime performance on the strengthening of the qu value of 2.5 times.

C. CBR Test of soil stabilized with KA, and soil stabilized with CaO.

TABLE 2
CBR Test of soil stabilized by KA, and soil stabilized by CaO.

Sample	0 day		7 day curing	
	ω%	CBR %	ω%	CBR %
Original soil	31,27	8,90	-	-
Soil + 20% KA	19,50	63,21	14,44	75,05
Soil + 5% KA	24,63	38,29	22,46	45,06
Soil + 5% CaO	29,09	12,16	28,07	14,82

Source: Primary data of research, 2017.

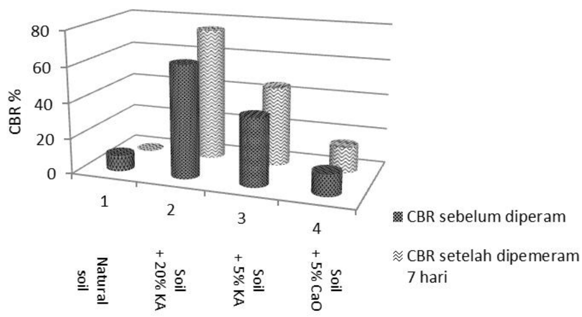

Fig 4 : Correlation of CBR and curing period.

Fig 4 shows that at 0 day position, original soil CBR = 8.90%,CBR of Soil + 5% CaO = 14.82%, CBR of Soil + 5% KA = 45.06%or 3 times the CBR of Soil + 5% CaO.As for soil + 20% KA, CBR it reached 63.21%.After 7 days of curing, CBR of soil + 5% CaO = 12.16%, CBR of soil + 5% KA = 38.29% or 3 times CBR of soil + 5% CaO.As for soil + 20% KA, CBR it reached 75,05%. In the composition of 5% to dry weight of expansive soil, activation of gum rosin and iron oxide improved the behavior of lime on the soil CBR value is 3 times the CBR value of expansive soil stabilized without activator.

D. Hydraulic Compressibility.

TABLE 3
Test Result of Hydraulic Compressibility

Sample	Weight of sample (gram)			
	Before test	After test		
		100 Kpa	150 Kpa	200 Kpa
Soil + 20% KA	9007	9838	10078	10110
Soil + 5% KA	8872	9855	10119	10158

Source: Primary data of research, 2017.

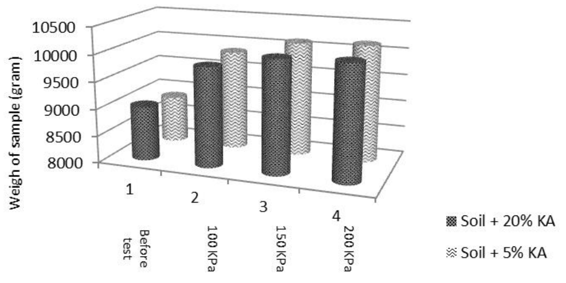

Fig 5 : Weight of sample on pressure variations

Fig 5 show that sample of Soil + 20% KA before tested its weight = 9.007 gram, after being pressured 100 kPa for 60 minutes its weight = 9.838 gram (increased 831 gram), after increasing the pressure to 150 kPa for 60 minutes its weight = 10.078 gram (increased 240 gram), after increasing the pressure to 200 kPa for 60 minutes its weight = 10.110 gram (increased 32 gram). Sample of Soil + 5% KA before tested its weight = 8.872 gram, after being pressured 100 kPa for 60 minutes its weight = 9.855 gram (increased 983 gram), after increasing the pressure to 150 kPa for 60 minutes its weight = 10.119 gram (increased 264 gram), after increasing the pressure to 200 kPa for 60 minutes its weight = 10.158 gram (increased 39 gram). Until the end of the test there is no water dripping below the sample, and if the calculated, water absorbed only 60% (<1,0) of the water content of the sample before curing (water content of the sample before curing is 19%). The results of the hydraulic compressibility test <1.0 indicate that clay soil stabilized with lime and activated with gum rosin and iron oxide are impermeable.

IV. CONCLUSION

1. For various variations of KA levels, the free compressive strength continues to increase as the addition of the period of curing. For 20% KA of the dry weight of the soil at 28 days period the free compressive strength value (qu) was 117.78 kg / cm2 or 436 times qu of compacted original soil. The activation of resin resin and iron oxide significantly improves chalk behavior on the increase of support capacity.
2. On 28 day curing period, for the compressive strength of soil that the stabilized with 5% CaO = 18.86 kg/cm2, for soil that the stabilized with 5% KA = 40.18 kg / cm2. Activation of gum rosin and iron oxide to quicklime improve the behavior of lime on the strengthening of the compressive strength of soil of 2.5 times greater than soil stabilization with quicklime without an activator.
3. The compressive strength testing (qu) for 20% KA until the 28 days curing period, produce unconfined compressive strength value (qu) 11.55 Mpa = 117.78 kg / cm2, or 436 (four hundred and thirty six) times qu original soil compacted without stabilizers.
4. After 7 days of curing,CBR of soil + 5% CaO = 12.16%, CBR of soil + 5% KA = 38.29% or 3 times CBR of soil + 5% CaO. In the composition 5% of the dry weight of expansive soil, activation of gum rosin and iron oxide could be improve the behavior of lime on the CBR value is 3 times the CBR value of expansive soil that the stabilized without activator.
5. The results of the hydraulic compressibility test <1.0 indicate that clay soil stabilized with lime and activated with gum rosin and iron oxide are impermeable.

Activation of gum rosin and iron oxide improves lime behavior significantly on soil stabilization, so that expansive clay reaches technical specification as subgrade of highway.

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