MECHANICAL CHARACTERISTIC OF FERRO LATERITE SOIL WITH CEMENT STABILIZATION AS A SUBGRADE MATERIAL

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ABSTRACT

This study aimed to determine and evaluated the mechanical characteristic of the potential ferro laterite soil with cement stabilization to be used as base material. Ferro laterite soil obtained from three different sampling sites at the East Halmahera Regency. The sampling process of conventional excavation on the surface, soil sample is inserted into the sample bag and labeling as LH1 for first location, LH2 for the second location, and LH3 for a third location. Furthermore, soil prepared for testing the physical properties. The sampling results were tested for physical properties of the soil according to ASTM and SNI standardization, involved testing; moisture content, particle size distribution, specific gravity, and the limits of Atterberg, as well as compaction test. Making of the soil test specimen is done by mixing the ferro laterite soil with the addition of cement in a composition of 3%, 5%, 7%, and 10% on the initial condition of maximum density and optimum moisture content standard Proctor test results. Cylindrical test specimen with dimensions H = 2D, then cured for 3, 7, 14, and 28 days before being tested for soil compressive strength with UCS testing. The test results showed that the ferro laterite soil stabilization with cement increases the compressive strength for the three types of ferro laterite soil that is significantly until the curing time of 28 days (73-357 kPa, 79-588 kPa, 62-450 kPa, respectively for LH1, LH2 and LH3), resulting with an increase in the percentage of cement addition. Based on these test results, the ferro laterite soil has the potential to be used as road base material and construction material, but it is necessary to test in detail the physical model (prototype) prior to implementation in the field.

Key words: Mechanical characteristic, ferro laterite soil, cement stabilization, subgrade material.

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1. INTRODUCTION

Indonesia by geographically and geologically, is an area rich in minerals, especially metal formed from ultramafic rocks, causing the spread of laterite soil in almost every area. Distribution of ferro laterite soil on the island of Halmahera in North Maluku Province is very dominant in the east. Halmahera ferro laterite soil is soil that forms in the tropics or sub-tropics with a very high level of weathering on mafic and ultramafic rocks which implies dominated by ferrous metals.

Laterite soil contains clay minerals are relatively high mainly illite and montmorillonite [1], so the potential for damage is greater if the construction work carried out on the soils like this. Clay minerals and metals are high, it can be used for all types of construction, industry, and others. Need to study the characteristics of the soil and the possibility of repair before use, one potential use is as a subgrade material. Laterite soil is the result of very high weathering, soil group, formed from the concentration of hydrated iron oxide and aluminum [2]. The soil type has the characteristics of a hard, impenetrable, and very difficult to change if dry conditions [3]. Laterite has a wide range of red, yellow to brown, fine grain with a grain size of the soil residual light texture has a nodular shape and cemented well [4].

The composition of elements and compounds contained in laterite soil that is common in Indonesia, including oxygen, magnesium, aluminium, silicon, sulfur, calcium, vanadium, manganese, iron, and nickel. While the mineral content contained in laterite soil consists of hematite, kaolinite, illite, montmorillonite, rutile, forsterite, andalusite, magnetite, magnesium silicate, and nickel dioxide. Physical characteristics in nature in general, is often called the soil of red-brown color is formed in humid, cold, and perhaps a puddle. This soil has a depth profile, easy to absorb water, has a moderate content of organic matter and pH neutral to acidic with a lot of metal content, particularly iron and aluminium, as well as good use as a base material to absorb water and the texture is relatively solid and sturdy. Physical properties of laterite soil vary greatly depending on the mineral composition and particle size distribution, granulometri can vary from subtle to gravel depending on the origin and formation process that will affect Geotechnical properties such as plasticity and compressive strength. One of the advantages of laterite not swell with water, depending on the amount of clay mineral content.The soil with a very high content of clay mineral montmorillonite is a separate issue if these soils was used for Geotechnical works, both as a construction material and subgrade. To cope with the condition of the soil as this can be done by the method of soil improvement in several ways such as; mechanical repairs (compaction), enhanced by drying (dewatering), improvement (soil stabilization) by chemical means or by the method of soil reinforcement. Related Research of laterite soil and laterite soil stabilization have been done, particularly in countries such as Asia and Africa [1], [5], [6], [7], [8], [9], [10], [11], [12], [13].

2. MATERIAL AND METHOD

The material used in this study is ferro lateritic soil from eastern Halmahera Island, with three different sampling locations. Subaim location with coordinates 1°3'46,24"N and 128°8'28,56" E, Buli location on coordinate 0°55'13,29 "N and 128°21'5,15" E, and Maba location with coordinate 0°40 ' 17.80” N and 128°16'51,20 "E (Fig. 1). Soil sampling with conventionally processing using crowbars and shovels, then the soil sample was placed in a sample bag and wrapped in plastic to maintain the original moisture content, and then labeled initials correspond to sampling location of LH1 to samples from first location, LH2 for sample from second location, and LH3 to samples from third location (Fig. 2).

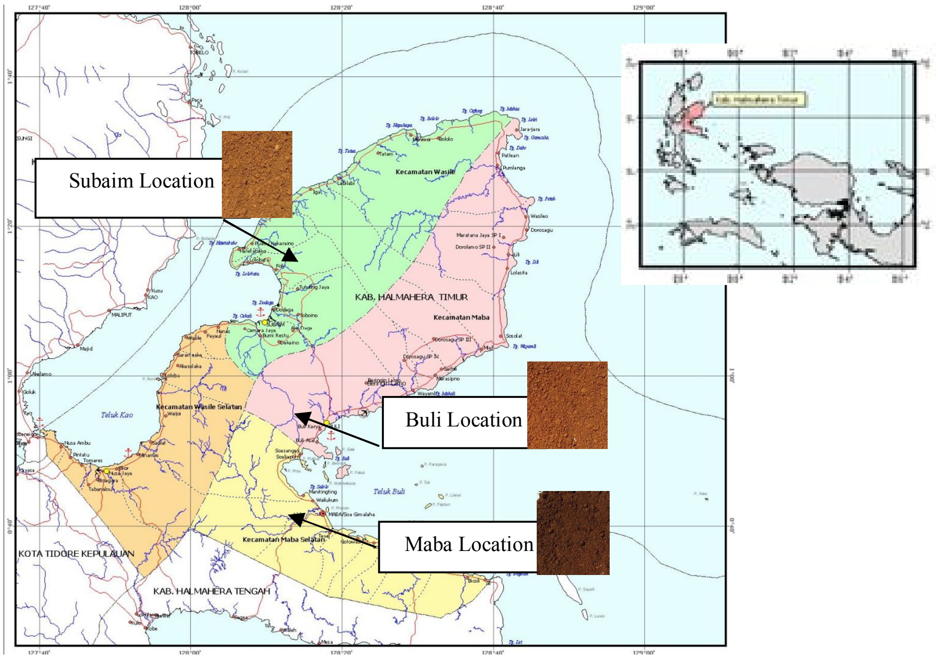

Figure 1 Location of ferro laterite soil sampling and soil type

Figure 2 The typical of ferro laterite soil sampling: LH1 for Subaim location, LH2 for Buli location,and LH3 for Maba location

This study is an experimental research conducted in the laboratory to determine the characteristics of lateritic soil as base material. Laboratory tests to determine the physical properties include moisture content, soil consistency and specific gravity. While testing the mechanical properties include compaction test, compressive strength test, and bearing capacity test. Soil consistency using the Atterberg limit tests, compaction tests then conducted using standard Proctor compaction test, the result of compaction test that used as a basis for sample preparation. Soil strength used unconfined compression test, bearing capacity of soil used CBR test, and microstructure tested using XRD test, and SEM-EDS test.

The tools used previously inspected and calibrated conditions and capabilities. Procedures of working tools to be studied carefully for accuracy, and capacity of the device should be well understood in order to avoid mistakes during testing. soil samples were prepared in accordance with standard procedures in each test. The tools will be used, previously inspected the conditions. capability and calibrated beforehand. The procedures and works mechanism to be studied carefully, ability, accuracy, and capacity of the device should be well understood in order to avoid mistakes during testing. Soil samples were prepared in accordance with standard procedures in each test.

Ferro laterite soil was added with water and weighed in the composition according to the results of compaction and cured for 24 hours until it reaches an equilibrium condition before the test. Sample were made in a cylindrical shape with size H = 2D, made by mixing ferro laterite soil with water in optimum moisture content condition, and inserted into a mold that has been lubricating oil, then compaction with 25 times blows for each section. Sample was cured for 3, 7, 14, and 28 days before being tested.

3. RESULT AND DISCUSSION

Index properties testing program were concerned with; specific gravity, water content, density, Atterberg limit, and grain size analysis. The Laboratory testing performed prior is the basic testing for original soil such as soil properties of ferrous laterite soil by use of ASTM and SNI standard test. Testing was conducted for a few sample points and taken randomly (3 different locations). The results of laboratory tests can be seen in Table 1. Based on Table 2, it can be seen that, gradation/grain size test results showed that clay dominated the type of samples is about 91,75 to 94,89% and water content about 18,86 to 22,25%, while the specific gravity is 2,62 to 2,66 and the plasticity index is about 18,06 to 26,77. From these results, based on AASHTO and USCS soil classification that ferro laterite soil is clay with high plasticity.

Table 1 Physical properties of ferro laterite soil

Physical and Mechanical Properties	Ferro Laterite Soil		
	LH1	LH2	LH3
Water content (%)	20,26	22,25	18,86
Specific gravity	2.73	2.62	2.66
% Passing #200	92.32	94.89	91.75
Liquid limit (%)	65.98	68.73	67.77
Plastic limit (%)	47,92	41,96	48,86
Plasticity index (%)	18,06	26,77	18,91
AASTHO soil classification	A-7-6	A-7-6	A-7-6
USCS soil classification	CH	CH	CH
Optimum moisture content (%)	19,45	20,7	20.50
Maximum dry density (ton/m3)	1.769	1.773	1.780
CBR (%) – unsoaked	11,24	21,02	12,33
UCS (kPa)	71,44	128,88	75,61

Laterite soil dominated by clay minerals that have a high plasticity such as mineral montmorillonite (smectite) and illite, can swell when in contact with water in liquid or vapor. This is related to the composition of the base layer mineralogy or montmorillonite mineral unit structure. The structure of the mineral montmorillonite is an element that is formed of alumina octahedral sheet between two sheets of silica tetrahedra. An alumina octahedral structure composed of one atom of aluminum and 6 hydroxyl in which silica tetrahedral octahedral shape consisting of a silicon atom and four oxygen atoms in a tetrahedral shape [5].

Most of the clay minerals have a sheet or layered structures, several them have elongate tubular or fibrous structures. Clay particles behave like colloid, it is a particle whose specific surface is so high that its behaviour is controlled by surface energy rater than mass energy.

From the viewpoints of interparticle forces, these colloidal characteristics of clay particles are similarly charged [6].

Table 2 shows that ferro laterite soil is dominated by montmorillonite and illite to LH1 (65%) and LH2 (48%), while LH3 dominated by kaolinite (76%). This shows that cement stabilization reduced the potentially to swelling of ferro laterit soils. The chemical characteristic can also affect the ferro lateritic soil behavior if treated either mechanically or by stabilization. Chemically ferro laterite soil is dominated by iron (FeO) about 55,10% to 78,52% as shown in Table 3.

Table 2 Mineral content of ferro laterite soil with cement stabilization

Minerals Content (%)	LH1 + Cement (days)				LH2 + Cement (days)				LH3 + Cement (days)			
	7	14	21	28	7	14	21	28	7	14	21	28
hematite HP, iron(III) oxide	7	6	6	5	7	8	38	25	1	4	5	2
Kaolinite	10	10	15	17	6	11	9	5	67	76	70	75
Illite-montmorillonite (NR)	65	59	54	48	42	9	26	18	30	7	2	3
Forsterite	0	0	0	0		25	8	37			4	6
Nickel dioxide	15	16	18	21						11	13	12
Portlandite	2	9	7	9	45	47	18	15	2	2	6	2

Table 3 Chemical properties of ferro laterite soil

Element (%)	LH1 + Cement (days)				LH2 + Cement (days)				LH3+ Cement (days)			
	3	7	14	28	3	7	14	28	3	7	14	28
MgO	2,36	1,02	2,27	2,12	2,61	1,98	0,07	3,21	1,68	1,04	1,49	0,00
Al2O3	4,69	3,58	7,12	4,98	10,18	7,46	3,90	10,07	8.01	7,97	7,39	8,13
SiO2	24,68	20,96	6,09	23,55	6,75	5,35	3,41	8,92	6,03	5,96	7,91	5,87
K2O	0,27	0,35	0,17	0,00	0,32	0,29	0,00	0,00	0,20	0,34	0,25	0,00
TiO2	0,00	0,13	0,20	0,00	0,00	0,39	0,40	0,00	0,00	0,76	0,00	0,00
FeO	55,10	59,60	67,28	56,46	62,44	67,06	78,52	60,53	70,75	67,84	68,87	75,20
NiO	1,23	1,84	2,32	0,00	2,69	2,72	2,62	0,00	0,91	1,25	1,26	0,00
Cr2O3	1,06	1,42	1,49	0,38	1,73	2,18	2,06	1,94	1,81	2,64	2,07	1,68
P2O5	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
SO3	1,14	0,98	1,38	1,33	2,64	1,59	0,80	2.31	0,58	0,58	0,70	0,00
Na2O	1,42	0,83	1,68	1,63	3,47	1,70	0,00	2,51	1,34	1,42	1,19	0,00
CaO	8,04	9,29	10,00	9,57	6,84	9,25	8,22	10,51	8,07	10,18	8,88	9,12

Mechanical characteristics test of ferro laterite soil, which the method for unconfined compressive strength test, in this case, brief results were obtained curing time for unconfined compressive strength are 3 days, 7 days, 14 days, and 28 days as shown in Fig. 3. The maximum density conditions for all soil types with different curing time showed an increasing trend, this was due to the bond between the grains in the soil more stable over time curing up to 28 days. It is seen that the increase in dry density from 1.73 to 1.99 tonnes / m3 with optimum moisture content decreased from 22.14 to 19.98%. The compressive strength of the soil also showed an increasing trend for all kinds of ferro laterite soil, increasing of soil density causing compressive strength increased from 73,20 to 357,47 kPa to LH1, 79,12 to 588,72 kPa for LH2, and 62,89 to 450,55 kPa to LH3, in a mixture of 10% cement with 28 days curing time.

Soil strength LH2 is higher than the two others typical soil, this is due to the condition of maximum density of micro pores become smaller and the bond between water and soil grains getting stronger, thus increasing soil density with increasing curing time lead to increased soil strength (Fig. 3).

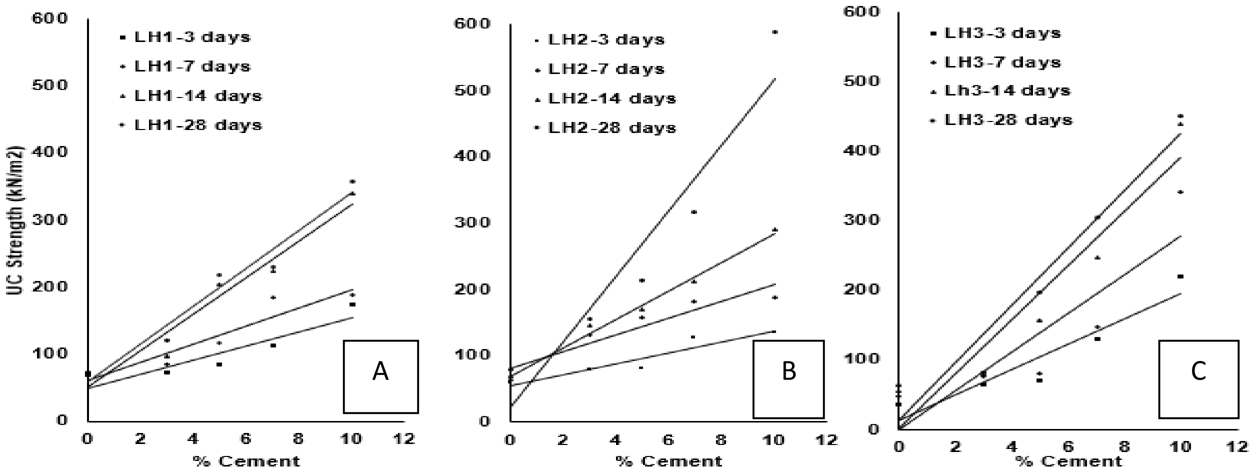

Figure 3 Relationship of soil compressive strength to the percentage of a mixture of cement with a curing time; A) ferro laterite soil LH1, B) ferro laterite soil LH2, C) ferro laterite soil LH3.

Figure 3 shows the relationship between soil strength and percent addition of cement with curing time. The figure show that, the increase of percentage of cement addition and increased curing time lead to increased soil strength, that ferro laterite soil LH2 better than LH1 and LH3. This represents an increase of soil strength is almost six times greater than the strength of the native soil. Increased curing time up to 28 days also increase the strength of the soil, increase soil strength significantly to LH1, LH2, and LH3. Increased curing time not significantly affected on native ferro laterite soil. While on the mixture of soil with cement in particular with 3%, 5%, 7%, and 10%, increase soil strength average of 60% to 10% cement, 50% to 7% cement, 62% to 5% cement and 37% to 3% cement. It is seen that the condition of a mixture of 5% and 10% cement to curing time 28 days to produce the highest soil strength [1] [13].

The result of the CBR and the interpretations are presented in Fig. 4, and Table 4. For standard proctor unsoaked 10% cement to 28 days curing time, increase CBR of 13,33% to 53,33% (LH1), 15,67% to 50,33% (LH2), and 20,00% to 105,00% (LH3). Considering the value, they fall within the CBR value range 20 to >50 for LH1, LH2, and LH3 [14]. Hence, the soils could be useful for subgrade material of road construction.

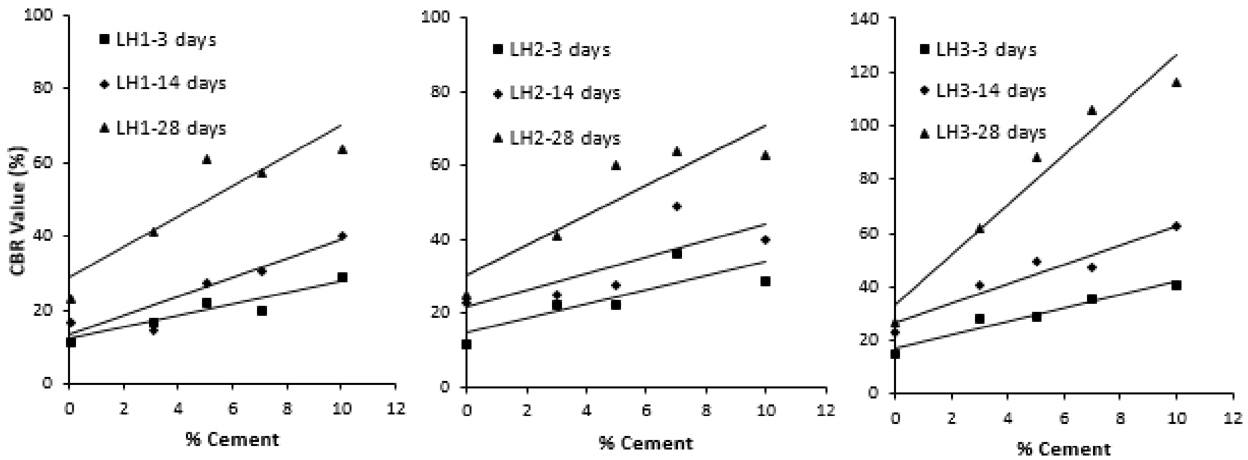

Figure 4 Increasing CBR laboratory of ferro laterite soil with curing time; a) ferro laterite soil LH1, b) ferro laterite soil LH2, c) ferro laterite soil LH3

Table 4 General rating of soil materials using CBR Values

CBR Value	General	Uses	Classification System
0-3	Verry poor	Subgrade	OH,CH, MH, OL
3-7	Poor-fair	Subgrade	OH, CH, MH, OL
7-20	Fair	Subgrade	OL, CL, ML, SC, SM, SP
20-50	Good	Base, subgrade	GM, GC, SW, SM, SP, GP
50	excelent	Base	GW, GM

Increasing the strength of ferro laterite soil is strongly influenced by the content of elements and minerals present in the soil. Laterite soil dominated by clay minerals that have a high plasticity such as mineral montmorillonite (smectite) and illite, can swell when in contact with water in liquid or vapor. This is related to the composition of the base layer mineralogy or the mineral montmorillonite unit structure. The structure of the mineral montmorillonite is an element that is formed of alumina octahedral sheet between two sheets of silica tetrahedra. An alumina octahedral structure composed of one atom of aluminum and 6 hydroxyl in the which the silica tetrahedral octahedral shape consisting of a silicon atom and four oxygen atoms in a tetrahedral shape [5]. Most of the clay minerals have a sheet or layered structures, have them several elongate tubular or fibrous structures. Clay particles behave like colloids, it is a specific whose particle surface is so high that its behavior is controlled by the surface energy rater than mass energy. From the viewpoints of interparticle forces, reviews these characteristics of colloidal clay particles are similarly charged [6]. In microstructure condition, the maximum density of ferro laterite soil, bonding clay mineral particles are increasingly unstable, the addition of lime resulting condition is getting smaller micropores, thereby reducing the weak areas. The metal element content of iron in ferrous minerals in the soil also resulted in a ferro laterite particle bond is getting stronger, so that the conditions of 28 days cured the bond is more stable, which causes increased soil strength (Fig. 5).

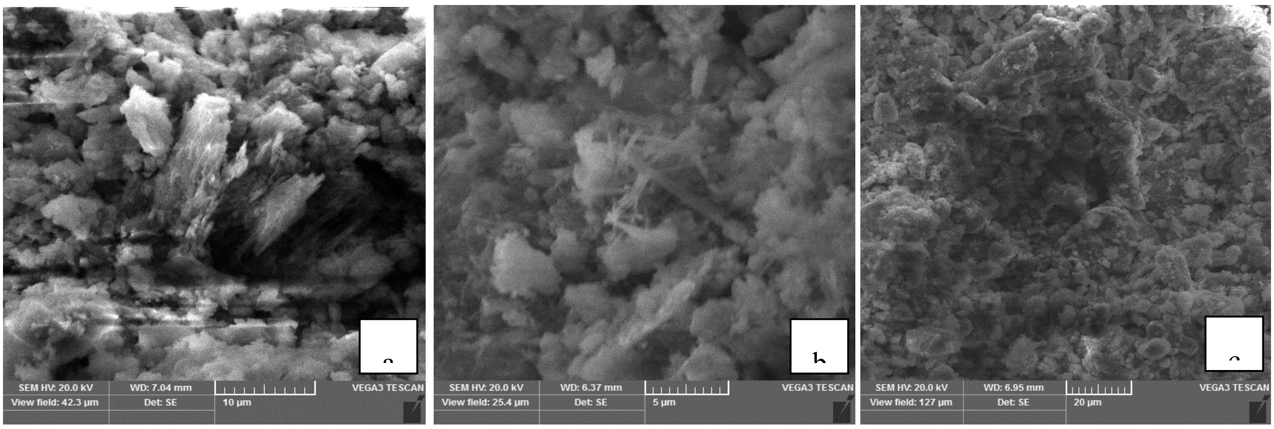

Figure 5 SEM microphotograph of ferro laterite soil with 10% cement stabilization to 28 days curing time; (a) LH1, (b) LH2, (c) LH3

4. CONCLUSIONS

In this paper, three different ferro laterite soils related to the effect of curing time on strength behavior for subgrade material utilization was studied. The main aim was to determine and evaluated the strength behavior of ferro laterite soil to be used as subgrade material. Based on physical properties, sample of the ferro laterite soil was A-7-6 for AASHTO soil classification system and CH for USCS soil classification system.

The UCS and CBR data for curing time 28 day indicated a significant increasing strength of LH1, LH2, and LH3. Also, it was found that increasing of curing time then increasing of density and soil strength due increase the bearing capacity of the soil. Furthermore, based on CBR value, the soils could be useful for subgrade material of road construction, but it is necessary to test in detail the physical model (prototype) prior to implementation in the field.

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