The Effect Of Nickel Slag Addition On The California Bearing Ratio (CBR) Value Of Soaked Laterite Soils In Central And South Kalimantan Provinces

El Efecto De La Adición De Escoria De Níquel En El Valor CBR (California Bearing Ratio) De Los Suelos Sobresaturados De Laterita De Las Provincias De Kalimantan Central Y Del Sur

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ABSTRACT

Lateritic soil as base fill in road construction often requires extra handling because it does not have adequate strength and stability. These extra handling efforts can be carried out by stabilizing laterite soil by mixing certain ingredients such as lime, cement, or similar materials to boost the ability of the lateritic soil to approach road pavement standards. In this study, the material used to stabilize the laterite soil was nickel slag waste. The test was conducted out using an experimental approach in the laboratory with variations of a mixture of laterite soil and nickel slag waste of 0%, 5%, 10%, 15%, 20%, and 25%. The Atterberg test, Grain Distribution, and Specific Gravity (GS) were used in this study to assess the physical qualities and features of native soils from Central and South Kalimantan. In addition, the California Bearing Ratio (CBR) Soaked was tested on each version of the mixture with the increase in Soaked CBR value in Central Kalimantan soil from 2.53% to 5.87%, and the resulting increase in Soaked CBR value in South Kalimantan soil from 2.8% to 6.08%.

***Keywords**: lateritic soil, nickel slag, land stabilization, CBR soaked.*

RESUMEN

Los suelos lateríticos como basamento en la construcción de viales requieren a menudo un cuidado especial por sus falencias intrínsecas en lo que a fortaleza y durabilidad se refiere. Esto puede llevarse a cabo mediante la inclusión de aditivos estabilizadores en la mezcla tales como cal, cemento y sus similares con el fin de alcanzar los estándares de pavimentación adecuados. En el presente estudio el material usado para estabilizar el suelo laterítico fue las escoria residual de níquel. Las pruebas fueron llevadas a cabo mediante pruebas de laboratorio escalonadas con contenidos de 0%, 5%, 10%, 15%, 20%, y 25% de escoria con respecto al volumen total de suelo laterítico. Se emplearon las pruebas de Attemberg, de Distribución Granular y de Gravedad Específica (GS) para evaluar las cualidades físicas y características intrínsecas de los suelos nativos de las regiones central y sur de Kalimantan. Además se comprobó el CBR (California Bearing Ratio) para comprobar los niveles de saturación de la mezcla con incrementos de saturación CBR en el rango del 2,53% al 5,87% en el caso del Kalimantan Central y del 2,8% al 6,08% en el del Kalimantan del Sur.

***Palabras Clave**: suelo laterítico, escoria de níquel, estabilización de suelos, sobresaturación CBR.*

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1. INTRODUCTION

In Indonesia, road infrastructure development played a critical role as a determinant of economic and construction growth. Lateritic soil, used as a base fill in road building, is frequently insufficiently strong and stable to withstand traffic or vehicle loads. According to United States Department of Agriculture, lateritic soil is a soil that formed in tropical or sub-tropical area with high corrosion level in mafic to ultramafic rocks which dominated by iron content (Ko, 2014). This soil contains a high concentration of clay minerals, particularly illite and montmorillonite, which could result in a significant risk of construction damage. However, it can be stabilized if the lateritic soil is combined with other elements to improve its ability to approach the standard of road construction.

In Central and South Kalimantan Province, there is still a problem of lateritic soil as a subgrade pile which can be seen in figure 1 below:

Figure 1: *Lateritic soil as a subgrade road condition*

Based on the figure 1 above, it is required to stabilizing the lateritic soil so that it does not cause damage to the road construction structure due to chemical or mechanical reactions when employed as a subgrade. Soil stabilization or enhancement can be accomplished by mixing different elements with the original soil to get a more accurate composition. It is different with previous studies mentioned that the stabilization of lateritic soils used more mixed materials such as lime, cement, and sand, in this study the material used to stabilize lateritic soils was nickel slag waste. Efforts to utilize waste from nickel ore processes can be an alternative in order to reduce the exploitation of natural resources that is currently happening. Nickel slag is a waste material from the nickel ore smelting process and in general slag has physical characteristics that resemble natural aggregate. Every year there are at least 1 million tons of slag produced domestically (Marga, 2018). This number will increase every year because the number of nickel smelters in Indonesia will increase in number due to the effects of the Indonesian government's policy which has officially banned the export of nickel abroad since January 1, 2020 as outlined in the regulation of the Minister of Energy and Mineral Resources Number 11 of 2019.

CBR Parameter is necessary to determine the strength of the subgrade or landfill. According to research Muhammad Rizqi Ramadhani (2022) show the positif tren for CBR value, where a large increase in CBR values is seen in the sample test of microorganism effective addition (ME) 40% until 21 days ripening is 7,41% of not submerged condition and 6,11% of submerged condition.

Research by Ardiyanti & Andajani (2014) conducted mixing expansive soil with steel slag waste in order to increase the California Bearing Ratio (CBR) value of the soil. The results of the CBR test with immersion for 24 hours found that the CBR value of the original soil which was 2.16% increased as the addition of steel slag by 5%, 10%, 15% and 20% resulted in a CBR value of 2.49% respectively, 4.87%, 7.84% and 12.18%.

Chaiyaput & Ayawanna (2021) conducted a study on the effect of iron slag for laterite soil mixture from Thailand as a material in the subbase pavement structure with the addition of slag composition of 5 to 12%. The results of this study indicate an increase in the value of CBR (California Bearing Ratio) in Thai laterite soils which continues to increase with increasing levels of iron slag. Meanwhile, there was a decrease in the liquid limit and plasticity index which caused a decrease in the development index of laterite soils containing iron slag.

It is hoped that the results of this study will reveal the various characteristics and behavior of laterite soil mixed with nickel slag waste in a certain composition so that it can be useful for civil construction works in the future. In addition, this research will be useful in increasing knowledge about nickel slag which is expected to replace the use of construction materials derived from natural resources.

2. RESEARCH METHOD

This research was carried out in the Lambung Mangkurat University's Civil Engineering Soil Mechanics Laboratory by conducting a series of tests on samples made of a mixture of Laterite soils from Central and South Kalimantan with nickel slag waste from PT. Growth Java Industries that passed the No. 40 filter. The study sample was then put through its paces in the lab, with varied quantities of nickel slag added. The purpose of this research is to evaluate the physical qualities and features of the original laterite soil used as subgrade in Central and South Kalimantan, as well as the value of the California Bearing Ratio (CBR) submerged (Soaked) after mixing changes. This research was carried out in the even semester of the 2021/2022 academic.

The variables used in this study are:
a) The laterite soil used came from Pelarantan Village, Cempaga Hulu District, East Waringin City Regency, Central Kalimantan Province and from Gunung Kupang, Cempaka District, Banjarbaru City, South Kalimantan Province.
b) The nickel slag used comes from the smelter PT. Growth Java Industry is located in Cilegon City, Banten Province and is a material that passes the No. 40 filter.
c) Variations of nickel slag mixture used in this study were 0%, 5%, 10%, 15%, 20% and 25%.

The data collection method used is an experiment where the author conducts research directly on the sample. The tests are in the form of:
a) Real Soil Physical Test
Soil physical testing consists of:
i. The Atterberg test consists of several tests, namely the Liquid Limit (LL) test and the Plasticity Limit (PL) test to get the Plasticity Index (PI) value.
ii. Specific Gravity
iii. Granule Distribution

b) CBR Soaked
This test includes the measurement of the CBR value in the laboratory for compacted soil based on the compaction test. The standard used in this test is SNI 1744-2012.

The tools used in this research are:
a) Real Soil Physical Test Equipment
i. Liquid Limit (LL) test equipment includes: Sieve no 40, glass plate, cap, 1 set of liquid limit test equipment, spoon / spatula, grooving tool, cup, scale, oven. Then the Plasticity Limit (PL) test includes: Glass plate, cup, scale, cap and oven.
ii. Specific Gravity (Sg) test equipment includes: 100 ml pycnometer, thermometer, scales, oven, desiccator, funnel, pipette, and electric furnace.
iii. The tools used in the grain analysis are: A set of sieves (No.8, No.16, No.20, No.40, No.80, No.100, No.120, No.200, and pan), Sieve tool shaker Container container (cup), Oven, and Scales.
b) CBR Soaked
The CBR Soaked test was carried out using the following tools: Mold with several sizes, Spacer dish, hammer, 10 lb surcharged load, CBR gauge," and No 4 sieves, soaking bucket, swelling gauge and other equipment.

The test materials used in this test are:
a) Laterite Soil
The soil used is a laterite type soil originating from the Pelarantan village location, Cempaga Hulu District, East Waringin City Regency, Central Kalimantan Province and Mount Kupang, Banjar Baru City, South Kalimantan Province, with disturbed conditions (disturb).
b) Nickel Waste (Slag)
Nickel slag waste comes from the smelter of PT. Growth Java Industry, Cilegon City, Banten Province which passed the No. filter. 40 for the Soaked CBR test.

Testing Step

The testing procedure in this study are:

a) Preparation of materials to be used in this study, namely native soil with disturbed conditions and nickel slag that has passed through filter No. 40.

b) Preparation of a mixture of laterite soil and nickel slag with mixed proportions of 0%, 5%, 10%, 15%, 20% and 25%.

c) Conducting the Atterberg limits test, namely testing to find the PI (Plasticity Index) value according to the provisions, including: LL (Liquid Limit) test to determine the liquid limit, PL (Plastic Limit) test to determine the plastic limit so that PI (Plasticity) with ASTM D 2487-06 regulation (ASTM, 2000).

d) Perform a soil density test (Specific Gravity) as much as ± 10 grams of each 3 pycnometers for the test object, namely with a mixture of clay + steel waste (0%, 5%, 10%, 15%, 20%, 25%).

e) Sifting the sample of the test object using a set of No. 8, No. 16, No. 20, No. 40, No. 80, No. 100, No. 120, and No. 200 sieves and testing the hydrometer analysis with SNI 3423:2008 regulation (BSNI, 2008).

f) After that, conduct a soil compaction test which aims to determine the value of γd maximum and W_{opt} of the original soil test before conducted a nickel slag mixing.

g) Soaking for 4 days (96 hours) on each variation of the mixture of test objects and conducting a CBR test to get the CBR Soaked value.

h) Analyze the test results data on the sample with each calculation method and make conclusions.

Data Analysis Techniques

From laboratory testing, data on the physical properties and characteristics of laterite soils from 2 locations without mixing and the CBR value of Soaked with nickel slag waste were obtained which will be analyzed so as to produce statements about:

a) How is the comparison of laterite soils characteristics from Central Kalimantan and South Kalimantan.

b) What is the behavior of the physical properties of the laterite soils of Central Kalimantan and South Kalimantan.

c) What is the optimal percentage of nickel slag addition to stabilize laterite soils from Central Kalimantan and South Kalimantan.

d) How is the comparison of the effect of the addition of nickel slag on the CBR value of Soaked lateritic soils in Central Kalimantan and South Kalimantan.

Research Flowchart

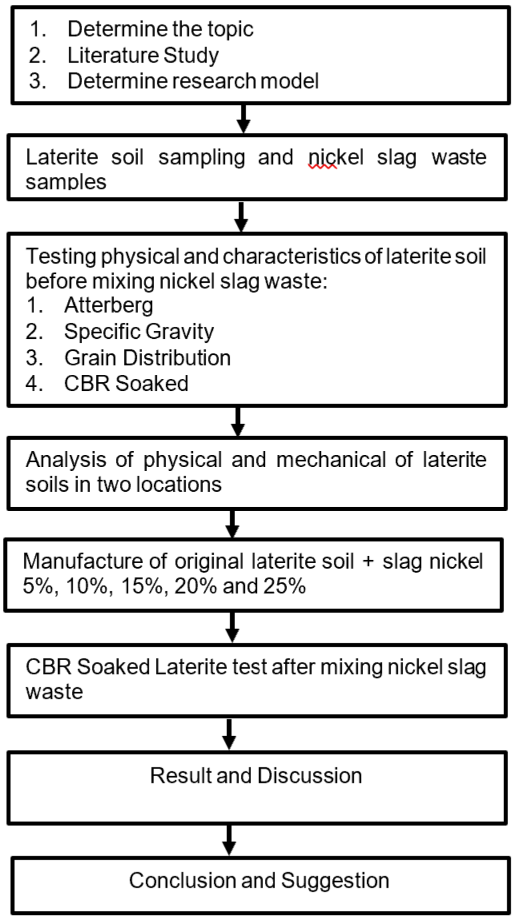

Figure 2: *Research Flowchart*

3. RESULTS AND DISCUSSION

3.1. Characteristics of the original soil

3.1.1. Laterite soil of Central Kalimantan

The type of soil material used in this test is lateritic soil obtained from Pelantaran village, Cempaga Hulu District, East Waringin City Regency, Central Kalimantan Province. In determining the type of classification of a soil sample, there are several tests that must be carried out first in order to obtain a standard value according to the classification of each soil type. After conducting several series of tests in the form of the Atterberg test, sieve analysis and specific gravity in the laboratory were obtained the value in the Figure 3 and Table 1 below:

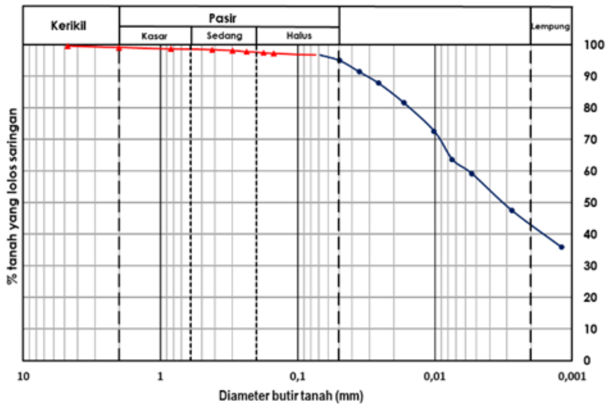

Figure 3: *Graph of grain size distribution of latrite originating from Central Kalimantan*

Table 1: *Results of testing physical characteristics on laterite soils originating from Central Kalimantan*

Nomor Sample			
Soil property	Specific Gravity (Sg)		2,660
Grain Distribution	Gravel (>2mm)	%	0,93
	Rough sands (0,6 – 2,00 mm)	%	0,57
	Medium sand (0.2-0.6mm)	%	0,93
	Small sand (0.05-0.2mm)		
	Silt and Clay (0.002-0.05mm)	%	4,45
	Clay (<0.002mm)	%	51,48
	No. 10 (2.00mm)		41,63
	No. 40 (0.425mm)	%	99,07
	No. 200 (0.0075mm)	%	98,38
		%	96,70
Limit of Atterberg	Liquid limit (LL)	%	55,63
	Plastic Limit (PL)	%	22,02
	Plastic Index (PI)	%	33,62
	Classification		CH
Compact	Optimum water content	%	22,03
	Maximum fill weight (γd maks) kg/cm^3		1,64

The results of the examination of specific gravity (Gs) carried out on laterite soils were taken on an average of 2.660. This value indicates that the lateritic soil sample in Pelantaran village, Central Kalimantan is included in the inorganic silt group.

Test results Filter analysis and hydrometer analysis on native laterite soils with disturbed conditions originating from Central Kalimantan showed that the lateritic soils had a percentage of passing sieve No. 200 of 96.70% (more than 50% of soils that passed sieve No. 200). This shows that laterite soils originating from Central Kalimantan are generally classified as dominant fine-grained soils (silt and clay) when referring to the USCS table. Therefore, in classifying the lateritic soils, it is necessary to help by using the Atterberg limits test.

Based on the results of tests in the laboratory in the form of testing the limits of consistency in the laboratory, it was found that the results of the Liquid Limit (LL) and Plasticity Limit (PL) examinations on the sample were 55.63% and 22.02% respectively so that the Plasticity Index (PI) value was obtained. by 33.62%. Furthermore, the Liquid Limit (LL) and Plasticity Index (PI) values of the laterite soil are used to determine the symbol for soil classification using a plasticity diagram according to the USCS soil classification method as shown in Figure 4.

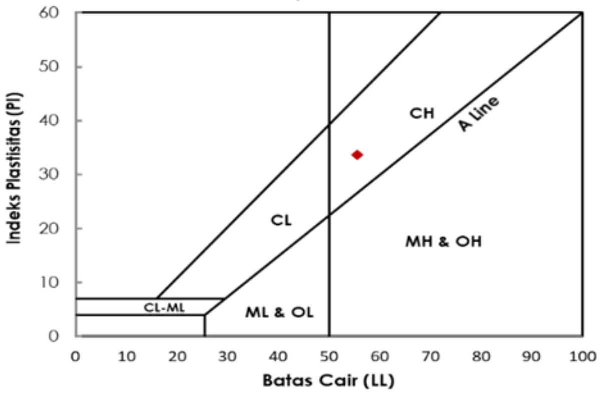

Figure 4: *Diagram of soil classification according to USCS system in Pelantaran village, Central Kalimantan*

Based on the plastic diagram can be concluded that laterite soil in central Kalimantan is included classification of Clay-High (CH) or high plastic inorganic clays (fat clays).

3.1.2. Laterite soil in South Kalimantan

The type of soil material used in this test is lateritic soil obtained from Mount Kupang, Cempaka District, Banjarbaru City, South Kalimantan Province. In determining the type of classification of a soil sample, there are several tests that must be carried out first in order to obtain a standard value according to the classification of each soil type. After carrying out several series of tests in the form of the Atterbergh test, sieve analysis and specific gravity in the laboratory were obtained the value in the figure 5 and table 2 below:

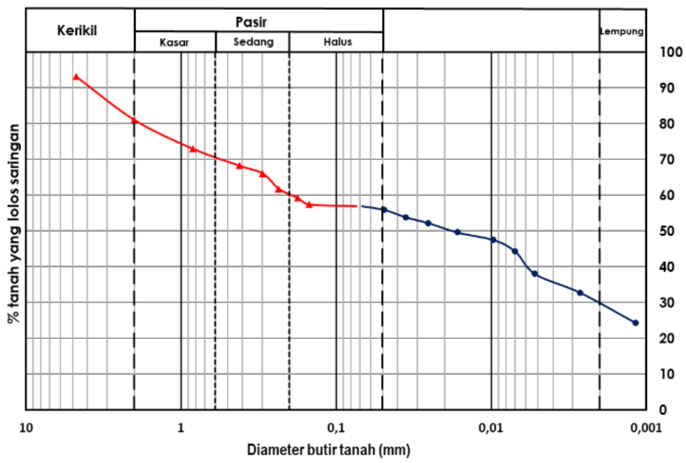

Figure 5: *Graph of grain size distribution of latrite originating from South Kalimantan*

Table 2: *Results of testing physical characteristics on laterite soils originating from South Kalimantan*

Nomor Sample			
Soil property	Specific Gravity (Sg)		2,670
Grain Distribution	Gravel (>2mm) Rough sands (0,6 – 2,00 mm) Medium sand (0.2-0.6mm) Small sand (0.05-0.2mm) Silk and Clay (0.002-0.05mm) Clay (<0.002mm) No. 10 (2.00mm) No. 40 (0.425mm) No. 200 (0.0075mm)	% % % % % % % %	18,96 10,41 10,11 5,72 16,35 28,46 81,04 68,26 56,91
Limit of Atterberg	Liquid limit (LL) Plastic limit (PL) Plastic Index (PI) Classification	% % %	46,65 25,21 21,45 CL
Compact	Optimum water content Maximum fill weight (γd maks) kg/cm^3	%	21,60 1,67

The results of the examination of specific gravity (Sg) carried out on lateritic soils so that the average taken is 2,670. This value indicates that laterite soil samples from South Kalimantan belong to the inorganic silt group.

Test results Filter analysis and hydrometer analysis on disturbed lateritic soil originating from South Kalimantan showed that the lateritic soil had a percentage of 56.91% passing sieve No. 200 (more than 50% of soil that passed sieve No. 200). This shows that laterite soils originating from South Kalimantan are generally classified as dominant fine-grained soils (silt and clay) when referring to the USCS table. Therefore, in classifying the lateritic soils, it is necessary to help by using the Atterberg limits test.

Based on the results of tests in the laboratory in the form of testing the limits of consistency in the laboratory, it was found that the results of the Liquid Limit (LL) and Plasticity Limit (PL) examinations on the sample were 46.65% and 25.21% respectively so that the Plasticity Index (PI) value was obtained. by 21.45%. Furthermore, the Liquid Limit (LL) and Plasticity Index (PI) values of the laterite soil are used to determine the symbol for soil classification using a plasticity diagram according to the USCS soil classification method as shown in Figure 3.

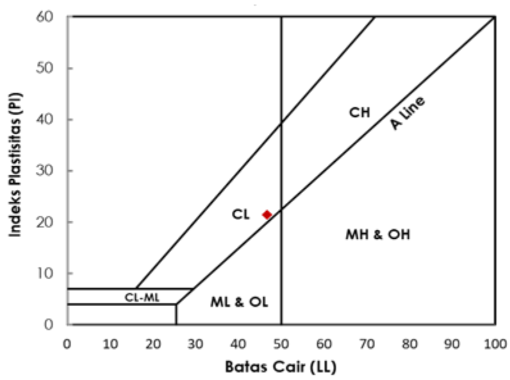

Figure 6: *Diagram of soil classification according to USCS system in Pelantaran village, Central Kalimantan*

Based on the plastic diagram can be concluded that laterite soil original in Pelantaran village included classification of Clay of low plasticity (CL) or low plastic inorganic clays.

Comparison of original soil characteristic in Central Kalimantan and South Kalimantan

Based on the results of the tests and calculations that have been carried out on the two samples, the results can be compared that the lateritic soils of the two samples are both classified as inorganic silt according to ASTM D-854-02 rules based on their specific gravity values. While the classification of the two samples based on the USCS got the results that both of them have different classifications where the Central Kalimantan soil sample is included in the Clay High with a PI value of 33.62% while the South Kalimantan soil sample is included in the Clay of low plasticity (CL) with a PI value of 21,45%.

CBR Soaked Test Results

CBR Soaked testing was carried out with 5 variations on 2 soil samples with the addition of nickel slag of 5%, 10%, 15%, 20% and 25%, the test results shows in the table 3 below:

Table 3: *CBR Soaked Test Result*

Mix percentage		CBR Value	
Original soil	Nickel Slag	South Kalimantan	Central Kalimantan
100%	0%	2,8%	2,53%
95%	5%	4,93%	4,77%
90%	10%	5,05%	4,91%
85%	15%	5,38%	5,11%
80%	20%	5,74%	5,38%
75%	25%	6,08	5,87%

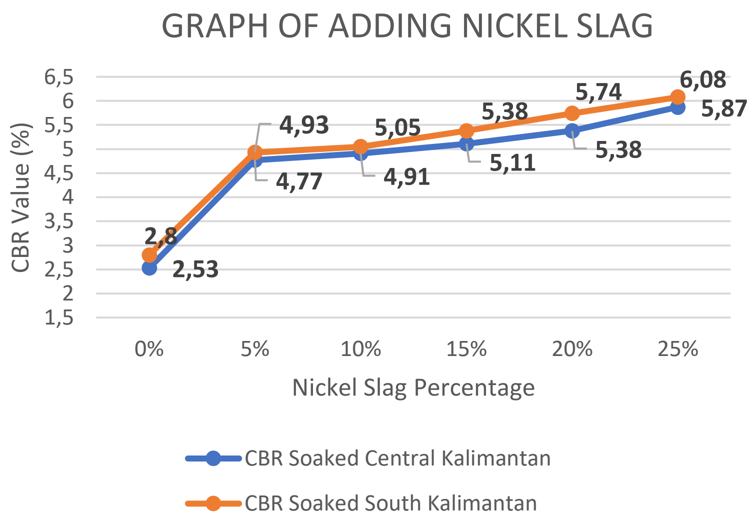

Figure 7*: Graph of comparison of CBR Soaked value*

Based on Figure 7, it can be seen that the addition of nickel slag waste has an effect on increasing the CBR value of Soaked according to the added percentage. At the 5% variation of nickel slag addition, the CBR Soaked value in both sample locations was assessed to increase very significantly. At a variation of 5% to 10%, the CBR value of Soaked in both locations also increased, but was more gentle than the previous condition where the Central Kalimantan sample obtained an increase of 0.14% while the sample from South Kalimantan obtained an increase of 0.12%. In the variation of 10% to 25%, the CBR value of Soaked in both locations increased more than the variation of 5% to 10%, but not as much as the 5% variation, which increased significantly.

When viewed at the same variation, the CBR value of Soaked lateritic soil from South Kalimantan tends to be slightly higher than the CBR value of Soaked laterite soil from Central Kalimantan. This is supported by the characteristics and physical properties of laterite soils from Central Kalimantan which tend to be lower.

4. CONCLUSIONS

Based on the testing and discussion that explained by previous point, the conclusion is below:

a) Lateritic soil from Central Kalimantan and South Kalimantan is included classification of inorganic silk soil based on the specific gravity value 1.66 for lateritic soil Central Kalimantan and 1.67 for lateritic soil South Kalimantan.

b) In both lateritic soil samples, there are differences in soil physical where laterite soil from Central Kalimantan is included in the Clay High (CH) classification with a Plasticity Index (PI) value of 33.62% while laterite soil from South Kalimantan is included in clays of low plasticity. (CL) with a Plasticity Index (PI) value of 21.45%.

c) After carrying out the CBR test on variations in nickel slag mixture of 0%, 5%, 10%, 15% 20% and 25%, it can be concluded that the best addition of nickel slag in this study to increase the CBR value of Soaked laterite soil is 25% where at Laterite soils from Central Kalimantan obtained a CBR value of 5.78% while on laterite soils from South Kalimantan it was 6.08%.

d) An increase in the CBR value of Soaked on laterite soils from Central Kalimantan and South Kalimantan along with the increase in the level of nickel slag waste.

e) After the addition of nickel slag waste by 25%, laterite soil from South Kalimantan has increased so that it produces a CBR soaked value of 6.08% and has met the requirement as base embankment soil according to the regulations of the Ministry of Public Works and Public Housing (PUPR) of the Republic of Indonesia, Binamarga Division 3 2018 Revision 2, meanwhile in Central Kalimantan laterite soil after the addition of nickel slag by 25%, it increases resulting in a CBR soaked value of 5.78%, this is close to the standard value as road embankment.

5. SUGGESTION

It is necessary to do a further research with the addition of nickel slag waste with a percentage greater than 25% considering that with a mixed variation of 0% - 25%, the CBR Soaked value continues to increase as the nickel slag content increases. This research also necessary to conduct further research on stabilization using nickel slag waste mixing materials with other soil types.

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