Shear Strength Behavior of Lateritic Soil with Nickel Slag Mixture

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Abstract: ***Laterite soil is an embankment soil that is often used because it is easy to find and is widely found in South Kalimantan. However, this land has many shortcomings to be used as embankment soil. This is because the lateritic soil has a clay content and a high Plasticity Index (PI) value. So the quality is still questionable to be used as landfill. To overcome this, it is necessary to improve or stabilize the lateritic soil. In this study, the lateritic soil was stabilized by the addition of slag nickel. This study aims to determine the physical characteristics of laterite soil after being given a mixture of nickel slag addition, this study also aims to determine the effect of the percentage of nickel slag on primary consolidation (Sc) of laterite soil. As well as knowing the effect of the percentage of nickel slag on the parameters of shear strength in the form of cohesion (c) and shear angle (ϕ). Consolidation and shear strength specimens were made with 90% of the optimum moisture content. The variations of the nickel slag mixture used in this study were 0%, 5%, 10%, 15%, and 20% of the weight of the soil used. Based on the results of data analysis, the addition of a mixture of nickel slag in each sample variation can reduce the plasticity index value of the lateritic soil. In addition, the addition of nickel slag also affects the value of the primary consolidation settlement value (Sc) of the laterite soil. The addition of the percentage of nickel slag also affects the parameters of the shear strength of the soil, for the cohesion value (c) of the laterite soil experiences a value that decreases with the increase in the percentage of nickel slag. Meanwhile for the shear angle (φ) of the laterite soil, the value increases with the increase in the percentage of nickel slag.***

Keywords: laterite soil, nickel slag, plasticity index, consolidation of laterite soil, shear strength of laterite soil

1. Introduction

Soil which is the base layer of construction will be strong or safe if it has a carrying capacity greater than the load it receives. However, it is not uncommon to find native soil that has low bearing capacity and does not allow it to carry the load on it. This is the reason for the need to fill soil on top of the original land using soil that has adequate carrying capacity potential. The embankment soil that is often used is lateritic soil type because it is easy to find and widely available in Kalimantan. However, this type of embankment still raises the question of whether its composition is suitable for use as subgrade. This is because there is a lot of damage or landslides in civil engineering works in South Kalimantan that use lateritic soil as embankment. To overcome this, it is necessary to repair or stabilize the lateritic soil. In this study, the lateritic soil was stabilized by the addition of nickel slag.

2. Theoritical Study

Laterite

Laterite soil is a soil formed in the tropics or subtropics with a high level of weathering in alkaline to ultramafic rocks which are dominated by iron metal content (Febriani, 2014). Laterite soils consist of a variety of red, brown to yellow waste soils, fine grained waste soils with a light texture, nodular grain shape, and well cemented (Lambe and Whitman, 1979). The physical properties of lateritic soils in nature are generally red to brown soils that are formed in a humid, cold environment and can allow water logging. In addition, lateritic soils also readily absorb water, have moderate organic matter content and a neutral to acidic pH with high metal content (especially iron and aluminum), and are good foundation materials due to their relatively dense texture (Saing, 2017).

Nickel Slag

Slag is an industrial waste generated during metal smelting. Slag in the form of residue or waste in the form of lumps such as metal, has poor quality because it is mixed with other substances that are difficult to separate (Sugiri, 2005). Nickel slag has a granular shape similar to natural aggregate, namely natural sand and gravel/split (Ferhi, 2019).

Consolidation

Consolidation is a process of reducing the volume or reducing the pore voids of low - permeable soil caused by loading, where the process is influenced by the speed or time of squeezing of pore water out of the soil cavity (Hardiyatmo, 2002). Primary consolidation (Sc) is part of soil compaction due to the flow of pore water from soil cavities until all dissipation processes are complete.

Direct Shear

Direct shear test is the easiest and simplest test of soil shear strength parameter. Vertical and horizontal loads acting on the tool will cause stress on the soil. These stresses are in the form of major principal stresses and minor principal stresses which can cause the soil to experience shear stresses that form an angle to the shear plane. On the other hand, the intermediate principal stress is not taken into account because it still acts uniformly on all sides but does not cause deformation. (Nurdian, 2015).

3. Research Methodology

The testing steps carried out in this study were as follows:

1) Sampling of laterite soil in Sungai Ulin, Banjarbaru City, South Kalimantan and taking nickel slag Growth Java Industry which is located at Jl. Sunan Demak No.8, Kepuh, Kec. Ciwandan, Cilegon City, Banten.

2) Testing of the physical properties of laterite soils (water content test, volume weight, specific gravity, sieve analysis, hydrometer analysis and atterberg limit) and mechanical properties of laterite soils (compacting, consolidation and direct shear tests) were carried out at the Soil Mechanics Laboratory, Faculty of Engineering, ULM Banjarbaru.
3) The test of sieve analysis, hydrometer analysis and Atterberg limit with *slag* of 0%, 5%, 10%, 15%, 20% of the weight of the laterite soil used.
4) Preparation of consolidation test specimens and direct shear tests with *slag* of 0%, 5%, 10%, 15%, 20% of the weight of the laterite soil used. Density to make the specimen for consolidation and direct shear test in this study was 90% of the optimum moisture content.
5) Consolidation testing and direct shear testing were carried out at the Soil Mechanics Laboratory, Faculty of Engineering, ULM Banjarbaru.

4. Results and Discussion

Results of Physical and Mechanical Properties Testing on Original Laterite Soils

Test results on physical and mechanical properties on native laterite soils presented in Table 1.

Table 1: Results of Testing for Physical Properties of Original Laterite Soil

Name of Sample				Laterite Soil from Sungai Ulin
The Physical Properties of Soil	*Soil Properties*	Spesific Gravity (Gs)		2.65
		Water Content (W)	%	31.41
		Volume Weight (γ)	gr/cm³	1.92
	Grain Size Distribution	Gravel (>2mm)	%	5.26
		Course Sand (0,6-2,00mm)	%	7.08
		Medium Sand (0,2-0,6mm)	%	10.65
		Fine Sand (0,05-0,2mm)	%	9.32
		Silt and Clay (0,002-0,05mm)	%	36.64
		Clay (<0,002mm)	%	31.05
		No. 10 (2,00mm)	%	94.74
		No. 40 (0,425mm)	%	86.01
		No. 200 (0,0075mm)	%	69.56
	Atterberg Limits	Liquid Limit (LL)	%	60.27
		Plastic Limit (PL)	%	28.71
		Plasticity Index (PI)	%	31.56
		Classification		CH

Based on sieve analysis and hydrometer analysis, it shows that laterite soil originating from the Ulin River has a percentage value of grains that pass the No. sieve.200 by 69.56% (greater than 50% of the soil that passed the No.200 sieve). This shows that lateritic soils originating from this area can generally be grouped into fine - grained dominant soils (silt and clay) when referring to the USCS soil classification table method. From the results of testing in the laboratory, Plasticity Index (PI) value is 31.56%. From these values it can be concluded that the soil belongs to the *Clay - High* (CH) group or inorganic clay with high plasticity/ *fat clays.*

Mechanical tests carried out in this research test were compaction test, consolidation test, and direct shear test. The results of testing the mechanical properties of lateritic soil on the Ulin River obtained the parameters that can be seen in Table 2 below.

Table 2: Results of Testing the Mechanical Properties of the Original Laterite Soil

Name of Sample				Laterite Soil from Sungai Ulin
The Mechanical Properties of Soil	*Compaction*	Optimum Moisture Content (OMC)	%	22.81
		Maximum Dry Weight (γdmaks)	gr/cm³	1.65
	Consolidation	Compression Index (Cc)		0.21289
		Consolidation Coefficient (Cv)	cm²/sec	0.00018814
		Swelling Index (Cs)		0.024145
		Primary Consolidation (Sc)	cm	0.04860
	Direct Shear	Shear Angle	°	16.87
		Cohesion	kg/cm²	0.2628

Results of Testing the Limits of Consistency (*Atterberg Limit Test)* with Variation of Nickel Slag

Tests for the limits of consistency (*atterberg limit test)* carried out in this study include the liquid limit test and the plastic limit test, so that the value of the plasticity index (PI) can be obtained. Relationship between variations in the nickel slag and the value of the plasticity index (PI) can be seen in Figure 3 below.

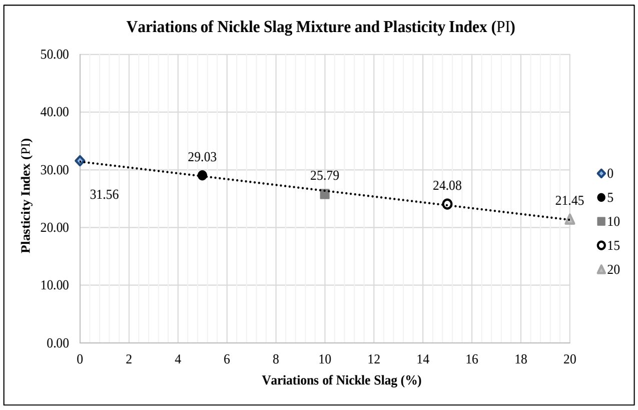

Figure 3: Graph of Relationship of Variation Nickel Slag to Plasticity Index (PI) Value

Based on the graph above, it can be seen that the plasticity index (PI) value decreased with increasing variation of nickel slag.

Clay high plasticity clay low plasticity (CL) along with the increasing percentage of nickel slag in the soil sample. Therefore, it can be concluded that nickel slag can be used to control the plastic properties of the laterite soil.

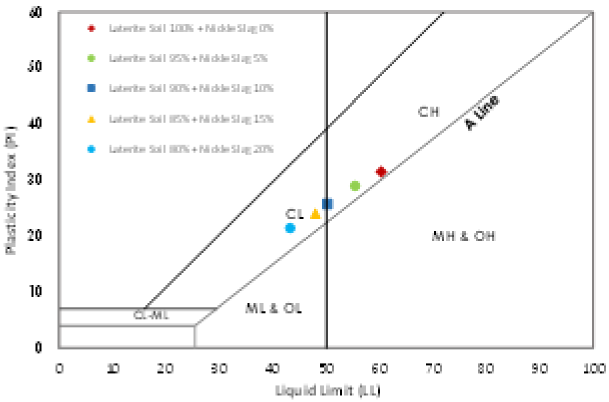

Figure 4: USCS Plasticity Diagram for Laterite Soil with Variation of Nickel Slag

Test Results of Grain Size Analysis with Variation of Nickel Slag

This grain size analysis test is in the form of sieve analysis and hydrometer analysis. The results of the analysis of the grain size analysis of laterite soils with variations in the nickel slag can be seen in Table 4 and Figure 5 below.

Table 4: Results of Grain Size Analysis with Variations in Nickel Slag

Grain Size Distribution		100% Laterite + 0% Nickle slag	95% Laterite + 5% Nickle slag	90% Laterite + 10% Nickle slag	85% Laterite + 15% Nickle slag	80% Laterite + 20% Nickle slag
Gravel (>2mm)	%	5,26	5,28	5,25	5,33	5,23
Coarse Sand (0,6-2,00mm)	%	7,08	9,86	9,88	9,98	9,87
Medium Sand (0,2-0,6mm)	%	10,65	10,73	11,58	13,48	14,14
Fine Sand (0,05-0,2mm)	%	9,32	9,54	9,97	10,40	15,01
Silt and Clay (0,002-0,05mm)	%	36,64	36,41	35,65	33,65	37,48
Clay (<0,002mm)	%	31,05	28,18	27,66	27,14	18,26
No. 10 (2,00mm)	%	94,74	94,72	94,75	94,67	94,77
No. 40 (0,425mm)	%	86,01	81,11	81,58	81,53	82,64
No. 200 (0,0075mm)	%	69,56	68,11	66,38	62,97	57,66

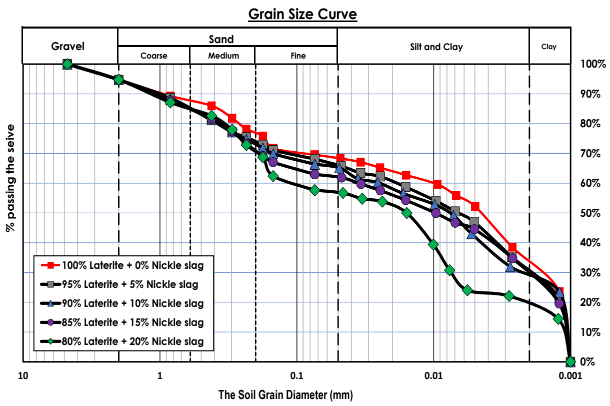

Figure 5: Graph of Grain Size Analysis with Variations in Nickel Slag

Based on the results of this test, it can be seen that with the increase in the percentage of nickel slag, there is a change in soil gradation. The percentage of soil that passes the No.200 sieve is decreasing because nickel slag increases the size of the large gradation, so that the soil particles that pass the No.200 sieve are getting smaller. The decrease was due to the larger soil grains after being mixed with nickel slag, this was due nickel slag to the larger nickel.

Results of Consolidation Testing with Variations of *Slag* Nickel

The results of the analysis of consolidation test that have been carried out in the laboratory can be seen in Figure 6.

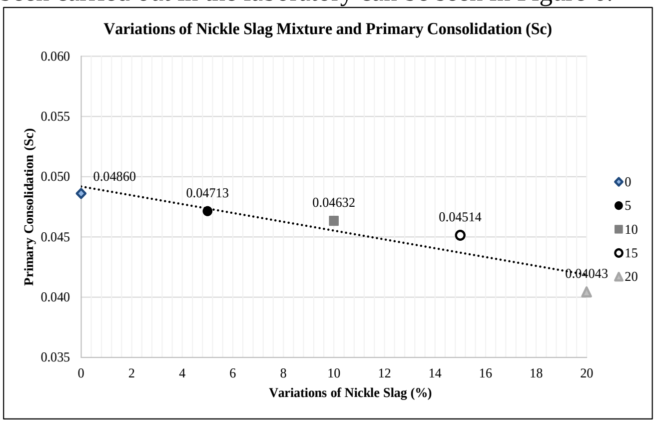

Figure 6: Graph of Relationship of Variation Nickel Slag to Decline Value of Primary Consolidation (Sc)

The relationship of variation of nickel slag to primary consolidation decrease value (Sc) is shown in Figure 6. Based on the graph, it can be seen that the higher the percentage nickel slag, the value of primary consolidation decrease.

Results of the Direct Shear Test Mixed Variations Nickel Slag

The results of the analysis of the direct shear test that have been carried out in the laboratory can be seen in Figure 7 and Figure 8.

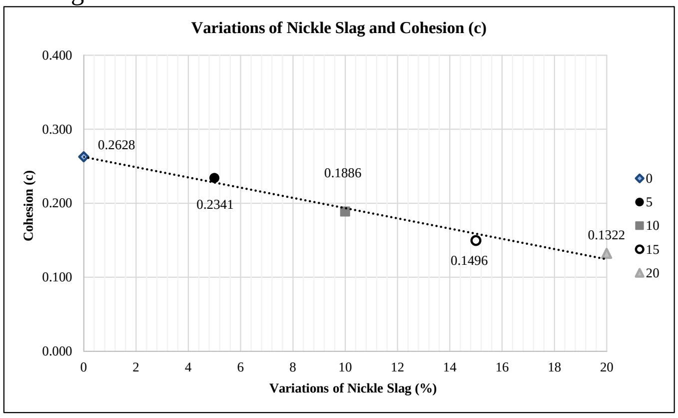

Figure 7: Graph of the Relationship between Nickel Slag Soil Cohesion Value (c)

The relationship between variations innickel slag and soil cohesion value (c) can be seen in Figure 7. Based on the graph, it can be seen that as the percentage of the mixture increases, the cohesion value will decrease.

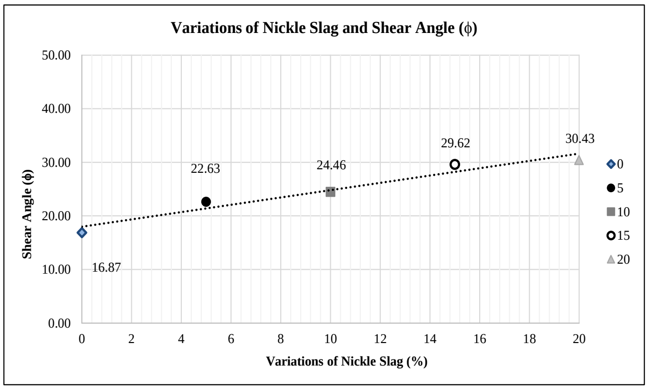

Figure 8: Graph of Relationship of Variation Nickel Slag to Soil Shear Angle Value (φ)

Mixture nickel slag to soil shear angle value (φ) can be seen in Figure 8. Based on the graph, it can be seen that the value of soil shear angle increases with time mixture nickel slag.

5. Conclusion

Based on the results and discussion, the following conclusions were obtained:

1) The plasticity index (PI) of the soil decreased by 10.11%. The plasticity index value was originally 31.56% in the 100% variation of laterite soil with a mixture of 0% nickel slag, to 21.45% in the 80% variation of laterite soil with a mixture of 20%nickel slag.
2) The results of the grain size analysis showed that as the nickel slag in laterite soils, the fine grained soils decreased.
3) The value of primary consolidation (Sc) decreased along with the increase in the percentage of nickel slag.
4) Based on the direct shear test, the value of soil cohesion (*c*) decreased by 0.1306 kg/cm^2. From the original 0.2678 kg/cm^2 on a variation of 100% laterite soil with a mixture of 0% nickel slag, to 0.1322 kg/cm^2 on a variation of 80% laterite soil with 20% nickel slag.
5) The value of the soil shear angle (ϕ) increased by 13.56^o. From the original 16.87^o in the variation of 100% laterite soil with a mixture of 0%nickel slag, to 30.43^o in the 80% variation of laterite soil with a mixture of 20% nickel slag.

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