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THE EFFECT OF ADDED COARSE SAND FRACTION ON LATERITE SOILSHEAR STRENGTH

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ABSTRACT

Laterite soil is the most common type of embankment soil used for road construction in Kalimantan. This is because laterite soils are easy to find and widely available in several locations in South Kalimantan. However, this soil has many drawbacks, one of which is that it has a high plasticity index to be used as embankment, both for ordinary embankments and selected embankments. Therefore, it is necessary to improve or stabilize the soil so that the laterite soil can meet the requirements or specifications as embankment soil. In previous studies, the addition of a mixture of sand to laterite soils tends to decrease the value of the plasticity index.

This study aims to determine the characteristics of laterite soils and the effect of adding a mixture of sand and plasticity to the shear strength of laterite soils by using a direct shear test apparatus. The specimens were made by testing the standard type of compaction and the value of 90% of the maximum density. The variation of the Sand mixture used is 0%; 7%; 14%; 21%;and 28%.

Based on the USCS classification system, the soil for the three preliminary test locations is classified as CH (clay-high) group, while according to the AASHTO classification system, Landasan Ulin and Mandiangin location are classified as group A-7-5 and Sungai Ulin location is classified as group A-7-6 (clayey soils). There was a decrease in the value for the shear strength parameter of the laterite soil from the peak condition to the residual condition. The addition of a mixture of sand in each variation of the sample can reduce the PI value along with the addition of sand. In addition, the addition of sand also changes the parameters of the shear strength of the laterite soil. All samples of laterite and sand mixture variations have a value liquidity index < 0 which indicates that the soil is in a solid or semi-solid condition, while a value consistency index > 0 indicates that the soil is in a solid or semi-solid condition. The higher the value of the plasticity index of a soil, the higher the cohesion value of the soil and the lower the value of the internal shear angle. The more addition of a mixture of sand can reduce the plasticity index and soil cohesion and can increase the value of the internal shear angle. It can be said that the addition of a mixture of sand can reduce the plasticity index of the soil and affect the parameters of the shear strength of the soil in both peak and

residual conditions.
Keywords: shear strength, residual shear strength, laterite soil, sand, plasticity index

1. INTRODUCTION

Soil is an important component in a building construction. Where the land used must comply with technical specifications or requirements and be able to support the construction load and the load on the building. Often found subgrade conditions that are unstable and have low bearing capacity so that they are unable to with stand the load on it. This can be overcome by stockpiling the soil on top of the subgrade by using soil that has adequate bearing capacity. Generally, in South Kalimantan, the embankment soil used to construct buildings or roads is laterite soil. This soil contains relatively high clay minerals so that the potential for damage is relatively large if construction work is carried out on this soil because it has high plasticity and plasticity index (PI) value. Based on scientific research by Ilmi (2021), which examined the characteristics of laterite soils in Cempaka District, Banjarbaru City, South Kalimantan, it was found that the plasticity index (PI) value was 34.51%. According to the 2018 General Specifications from Bina Marga, the laterite soil tested is not yet suitable for use as ordinary or preferred embankment material because it includes soils that have high plasticity and a plasticity index (PI) value of more than 6%. Therefore, it is necessary to make improvements to the laterite soil to make the soil better and to meet the technical requirements or specifications before being used as fill material. In South Kalimantan itself, various damaged road conditions are often encountered due to unstable soil conditions. The delay in repair efforts to deal with these problems results in greater damage and can result in landslides on the road.

2. LITERATURE REVIEW

Soil Classification system is a system of arranging several different types of soil but having similar properties into groups and subgroups based on their use (Das, 1995). The classification system was created to provide information about the characteristics and physical properties of the soil. Soil classification is also useful for a more detailed study of the density of the soil and the need for tests to determine the technical properties of the soil such as compaction characteristics, soil strength, density and so on (Bowles, 1991). The soil classification systems that have been commonly used are the Unified Soil Classification System (USCS) and the American Association of State Highway and Transporting Official (AASHTO).

1) USCS Classification System

   In the USCS classification system, a soil is classified into two main categories, namely, coarse-grained and fine-grained soils. Coarse-grained soils consisting of gravel and sand that are less than 50% of the total weight of the soil sample pass the No. sieve. 200 and fine-grained soils having more than 50% by weight of the soil sample pass through the No.sieve. 200.

2) AASHTO Classification System

   AASHTO classification system divides soils into 7 major groups, namely A-1 to A-7 including their sub-groups. Soil is classified based on two criteria, namely the percentage of soil particle size that passes the No. sieve. 200 and the value of soil plasticity (LL and PI). Groups A-1, A-2, A-3 are groups of coarse-grained soils where the percentage of grains that pass the No. sieve. 200 at 35% or less. Then the group A-4, A-5, A-6, A-7 is a soil group where the percentage of grains that pass the No. sieve. 200 by 35% or more, generally the soil in this group is silt and clay.

Laterite soil or often called red soil is soil that is formed in tropical or sub-tropical areas with a high level of weathering in alkaline rocks to ultramafic rocks which are dominated by iron metal content (Febriani, 2014). Laterite soils consist of a variety of residual soils that have red, brown, and yellow, fine-grained residual soils with a light texture (Lambe, 1979). This soil has a deep profile, easily absorbs water, has a moderate organic matter content and a neutral to acidic pH with a lot of metal content, especially iron and aluminum (Saing, 2017).

Sand is a type of non-cohesive (soil cohesionless soil). Non-cohesive soils have properties loose intergranular. Non-cohesive soils do not have a boundary line between plastic and non- plastic states, because this type of soil is not plastic for all water content values (Bowles, 1986). According to the AASHTO classification system, sand is the part of the soil that passes the No. sieve. 10 (2 mm) and retained on the No. sieve. 200 (0.075 mm) (Das, 1995). Meanwhile, according to the USCS classification system, soil is classified into coarse-grained (gravel and sand) if less than 50% passes the No. sieve. 200 (mm) (Hardiyatmo, 2002).

The shear strength of a soil mass is the internal resistance of the soil per unit area to failure or displacement along the shear plane in the soil (Das, 1995). To analyze the soft soil shear strength is defined as having a soft consistency (12.5-25 kPa) and very soft < 12.5 kPa (Bowles,1989).

The value of the parameters of the shear strength of the soil can be determined by testing in the laboratory, namely mainly by carrying out two main tests, the direct shear test and the triaxial test (Das, 1995).

According to Hardiyatmo (2002), several things related to soil shear strength are: Shearstrength ofstrength of

a. Fine-grained soil is related to parameter c (cohesion)
b. Shearcoarse-grained soil is related to parameter (shear angle)
c. Shear strength of soil from a mixture of fine soil and Coarse soil is related to the parametersc (cohesion) and (shear angle).

Mohr-Coulomb's Law (1776) states that the soil shear strength (τ), has a functional relationship with soil cohesion (c), and the friction (ϕ) between the particles expressed in the following equation:

$$\tau = c + \sigma \tan \phi$$

where:

τ = shear strength (kg/cm^2)

c = cohesion of soil (kg/cm^2)

σ = normal stress (kg/cm^2)

ϕ = angle of friction (°)

3. RESEARCH METHODOLOGY

The stages of testing carried out in this study are as follows.

1) Test preparation by preparing tools and materials.
2) Sampling of laterite soil and sand in the field. Laterite soil sampling was carried out in two stages. The first stage of sampling of undisturbed and disturbed laterite soil at locations in South Kalimantan, namely Landasan Ulin, Mandiangin, and Sungai Ulin for preliminary test samples. This second stage of sampling is for disturbed laterite soil samples in the Sungai Ulin which will be used as material for the test object. The stabilizing material used is sand taken from the Sungai Barito.
3) Preliminary testing for laterite soils of Landasan Ulin, Mandiangin, and Sungai Ulin included testing of water content, volume weight, specific gravity, sieve analysis, hydrometer analysis, Atterberg limits, compaction, and shear strength. For sand, sieve analysis was carried out.
4) Analysis of the results of preliminary testing of the Landasan Ulin, Mandiangin, and SungaiUlin laterite soils.
5) Analysis of grain size analysis and Atterberg boundaries of Sungai Ulin laterite soil samples with a variation of 0% sand mixture; 7%; 14%; 21%; and 28%.
6) Making specimens for testing the shear strength of laterite soil samples from Sungai Ulin with a variation of 0% sand mixture; 7%; 14%; 21%; and 28% using a maximum density of 90% of the optimum moisture content (OMC). The results of the data analysis obtained from this shear strength test include the relationship between the influence of the

addition of a mixture of sand on the value of the parameters of the shear strength of laterite soil, Atterberg limits, liquidity index, and consistency index as well as the value of the plasticity index on the shear strength parameter of the soil.

4. RESULTS AND DISCUSSION

The type of soil material used was laterite soil. Before mixing the specimens, physical properties were tested on the laterite soil, which consisted of testing the water content, volume weight test, specific gravity test, soil grain size analysis, and Atterberg limits. The results of the physical properties test can be seen in Figure 1 and Table 1 below.

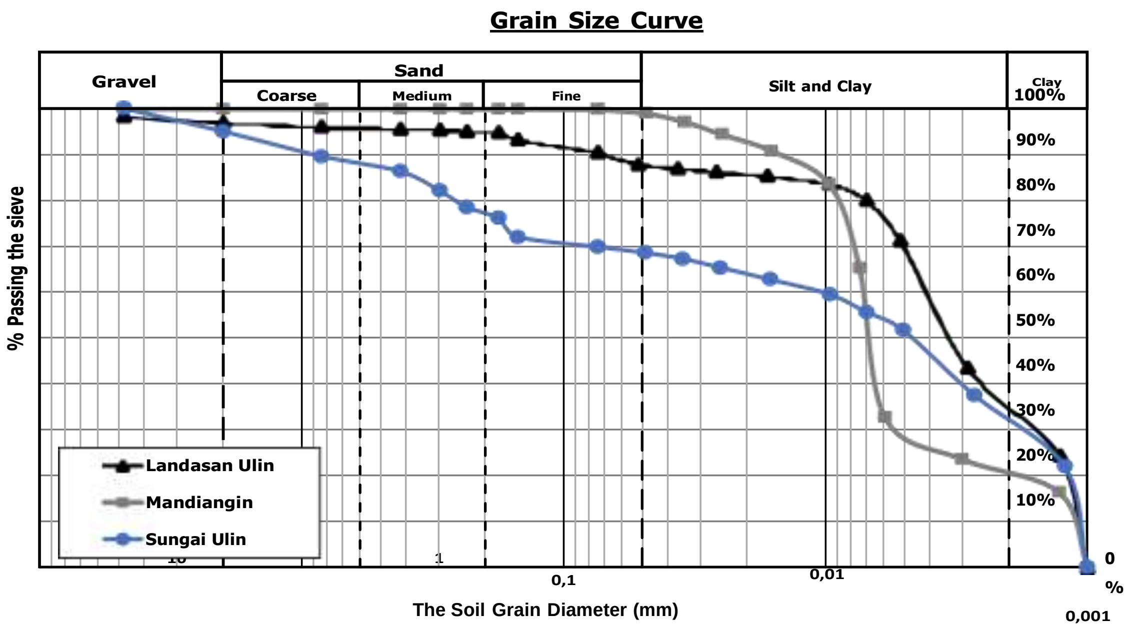

Figure 1. Graph of Grain Size Distribution of Landasan Ulin, Mandiangin, and Sungai Ulin Laterite Soils

Table 1. Results of Physical Properties of Landasan Ulin, Mandiangin, and Sungai Ulin Laterite Soils

The Physical Characteristic of Soil	Sample Location			**Landasan Ulin**	**Mandiangin**	**Sungai Ulin**
	Depth			**1,00 - 1,40 m**		
	Soil Proerties	Water Content (W)	%	37,82	54,03	25,59
		Volume Weight (γ)	gr/cm³	1,82	1,63	1,92
		Specific Gravity		2,63	2,64	2,65
	Grain Size Distribution	Gravel (>2,00 mm)	%	2,93	0,01	4,96
		Coarse Sand (0,60-2,00 mm)	%	1,13	0,03	7,08
		Medium Sand (0,20-0,60 mm)	%	0,89	0,06	10,65
		Fine Sand (0,05-0,20 mm)	%	7,45	1,85	9,40
		Silt and Clay (0,002-0,05 mm)	%	53,60	78,06	38,16
		Clay (<0,002 mm)		33,99	19,97	29,76
		No. 10 (2,00 mm)	%	97,07	99,99	95,04
		No. 40 (0,425 mm)	%	95,71	99,94	86,32
		No. 200 (0,0075 mm)	%	90,64	99,85	69,86
	Atterberg Limits	Liquid Limit (LL)	%	81,43	74,34	52,85
		Plastic Limit (PL)	%	33,91	32,67	23,68
		Plasticity Index (PI)	%	47,52	41,67	29,16
		Soil Activity Value		1,398	2,087	0,980
		USCS Classification		***CH***	***CH***	***CH***
		AASHTO Classification		***A-7-5***	***A-7-5***	***A-7-6***

Based on the test results of grain size distribution for laterite soils from Landasan Ulin, Mandiangin, and Sungai Ulin, the percentage of grains passing the No. sieve. 200 which indicates a number greater than 50%, when referring to the USCS soil classification system, the three samples can be classified as fine-grained soils (silt and clay) and the figure is greater than 35% which, when referring to the AASHTO classification system, the three the soil fromthis location is classified as silt and clay.

Based on the value of the plasticity index (PI) from the test results of the

Atterberg boundaries, it can be seen that the location that has the smallest plasticity index (PI) value of the three locations is laterite soil from the Sungai Ulin. Knowing the liquid limit value (LL) and plasticity index (PI) can be used to determine the soil classification system. Based on the USCS classification system, the ground for the three locations were included in the group of Clay-High (CH) or inorganic clay with high plasticity and for the AASHTO classification system for location Landasan Ulin and Mandiangin belong to a group of A-7-5 because the value of PI ≤ LL - 30 and the location of the Sungai Ulin is classified as group A-7-6 because the PI value > LL – 30 (clayey soils). Based on the comparison value of the plasticity index and clay content, the soil activity values for the Landasan Ulin and Mandiangin locations indicate that they are classified as active clays (montmorillonite) while for the Sungai Ulin are classified as normal clays (illite).

The results of testing the physical properties of the Sungai Barito Sand, namely the sieve analysis test, can be seen in Figure 2 and Table 2 below.

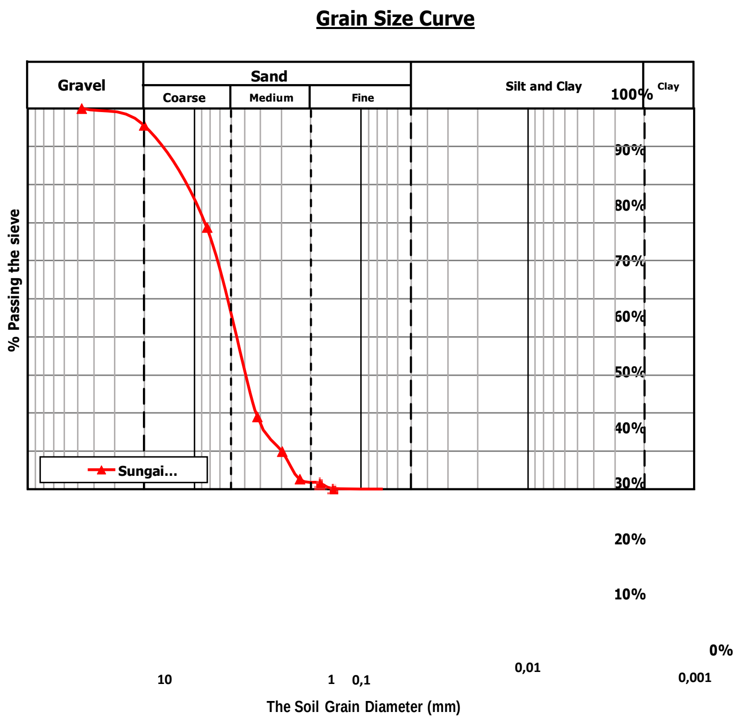

Figure 2. Graph of Grain Size Distribution of Sungai Barito Sand

Table 2. Results of Physical Properties Testing of Sungai Barito Sand

Grain Size Distribution		Sungai Barito Sand
Gravel (>2,00 mm)	%	4,43
Coarse Sand (0,60-2,00 mm)	%	51,75
Medium Sand (0,20-0,60 mm)	%	41,68
Fine Sand (0,05-0,20 mm)	%	0,00
Silt and Clay (0,002-0,05 mm)	%	0,00
Clay (<0,002 mm)		0,00
No. 10 (2,00 mm)	%	95,57
No. 40 (0,425 mm)	%	18,57
No. 200 (0,0075 mm)	%	0,00

The results of the grain size distribution test for the Sungai Barito sand retained in the No. sieve. 10 is 95.57%, retained in the No. sieve. 40 is 18.57%, and retained in the No. sieve. 200 is 0%. Based on Table 4.2 regarding the results of the physical properties of the Sungai Barito Sand above, the sand from that location is classified as coarse sand because of the dominance of the percentage that passes the No. sieve. 4 and retained in sieve No. 10 is the largest, which is 51.75% of the total weight of the total sample weight.

Preliminary Shear Strength Test Results

The results of the shear strength test for the undisturbed samples from the Landasan Ulin, Mandiangin, and Sungai Ulin produce shear strength parameters for peak conditions and residual conditions which can be seen in Table 3 below.

Table 3. Results of Laterite Soil Preliminary Shear Strength Test

Location	Peak Cohesion (kg/cm^2)	Residual Cohesion (kg/cm^2)	Peak Internal Shear Angle (°)	Residual Internal Shear Angle (°)	Peak Shear Strength (kg/cm^2)	Residual Shear Strength (kg/cm^2)
Landasan Ulin	0,1619	0,1048	16,88	10,93	77,2665	49,1747
Mandiangin	0,0567	0,0352	14,11	12,16	57,3837	49,1769
Sungai Ulin	0,1485	0,0892	21,47	16,44	105,7039	79,2814

Based on the direct shear strength test results, it can be seen that the location that has the largest cohesion value for peak and residual conditions is the Landasan Ulin location, while the location with the largest internal shear angle value for peak and residual conditions is the Sungai Ulin location. The difference in the value of the soil shear strength parameter from each location is due to the difference in the volume weight of each soil. In addition, the grain size distribution of the particles contained in each sampling location is also the cause of the difference in the results of the shear strength of the soil.

To determine the grain size distribution, sieve analysis and hydrometer tests were carried out for each variation in the percentage of the Sand mixture. The results of the analysis of the grain size distribution analysis for each sample variation can be seen in Figure 3 and Table 4 below.

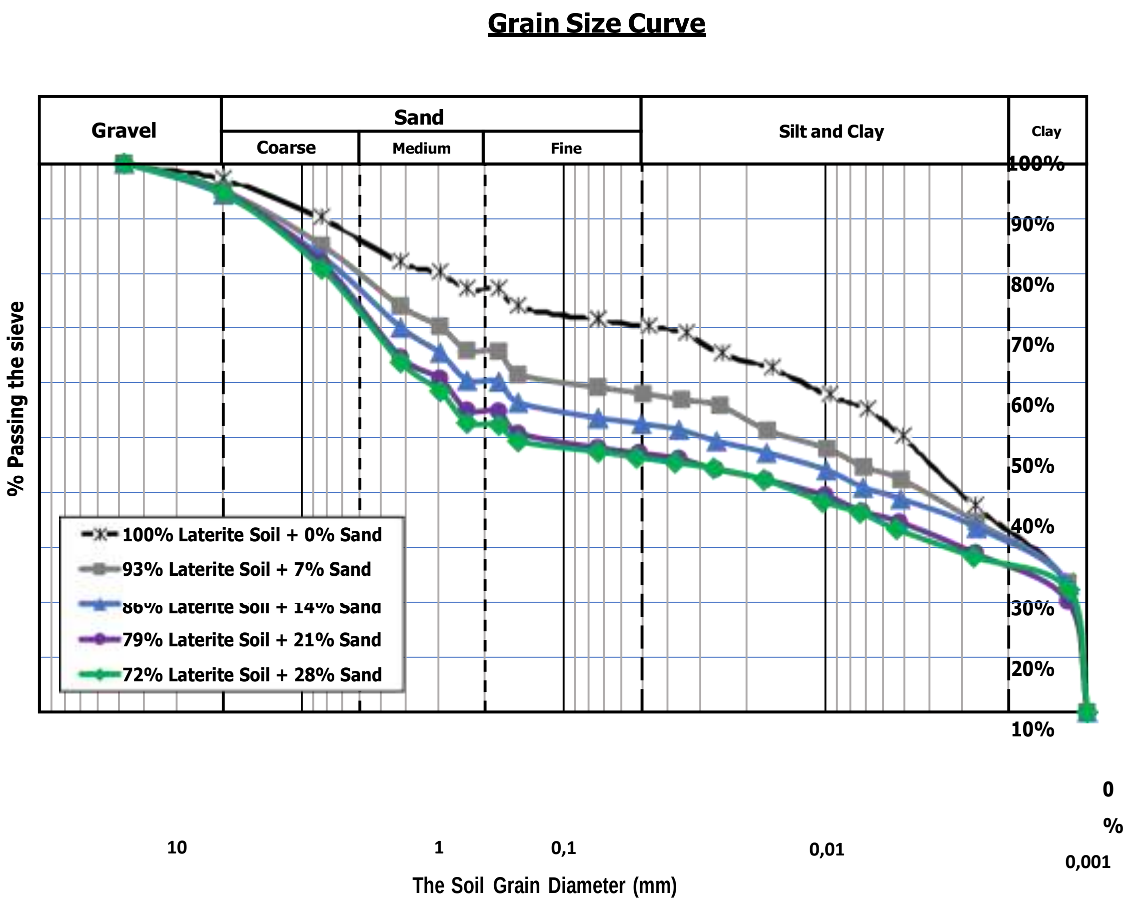

Figure 3. Graph of Grain Size Distribution of Laterite Soil with Mixed Sand

Table 4. Results of Analysis of Grain Size Distribution of Laterite Soil with Mixed Sand

Grain Size Distribution		100% Laterite Soil + 0% Sand	93% Laterite Soil + 7% Sand	86% Laterite Soil + 14% Sand	79% Laterite Soil + 21% Sand	72% Laterite Soil + 28% Sand
Gravel (>2,00 mm)	%	2,60	4,93	5,73	5,07	5,37
Coarse Sand (0,60-2,00 mm)	%	11,18	15,57	17,70	21,62	22,35
Medium Sand (0,20-0,60 mm)	%	8,90	13,70	16,22	18,40	19,73
Fine Sand (0,05-0,20 mm)	%	7,47	8,37	8,39	8,26	6,66
Silt and Clay (0,002-0,05 mm)	%	39,01	28,43	23,62	22,13	20,67
Clay (<0,002 mm)		30,83	28,99	28,34	24,53	25,21
No. 10 (2,00 mm)	%	97,40	95,07	94,27	94,93	94,63
No. 40 (0,425 mm)	%	82,20	73,93	70,10	64,70	63,77
No. 200 (0,0075 mm)	%	71,73	59,10	53,53	48,10	47,40

Based on the test results of the grain size distribution analysis that has been carried out, the percentage weight retained by sieve No. 200 for each variation in a row is 71.73%; 59.10%; 53.53%; 48.10%; and 47.40% and it is also seen that there is an increase for coarse-grained soils and a decrease for fine-grained soils due to the addition of a mixture of sand. This is because the percentage of sand mixture into the lateritic soil replaces the fine grains contained in the sample which results in the reduced content of fine grains in the form of silt or clay.

To determine the atterberg limits, awere tested liquid limit and plastic limit for each variation in the percentage of the sand mixture that would produce a liquid limit value (LL), the plastic limit. (PL), and the plasticity index (PI). The results of testing the limits of consistency for each sample variation can be seen in Table 5 below.

Table 5. Results of Atterberg Limit Test of Laterite Soil with Sand Mixture

Atterberg Limits		100% Laterite Soil + 0% Sand	93% Laterite Soil + 7% Sand	86% Laterite Soil + 14% Sand	79% Laterite Soil + 21% Sand	72% Laterite Soil + 28% Sand
Liquid Limit (LL)	%	60,27	57,78	52,54	49,32	45,06
Plastic Limit (PL)	%	28,71	28,17	26,09	25,89	25,00
Plasticity Index (PI)	%	31,56	29,61	26,45	23,43	20,06
Soil Activity Value		1,0237	1,0214	0,9333	0,9552	0,7957
USCS Classification		***CH***	***CH***	***CH***	***CL***	***CL***
AASHTO Classification		***A-7-6***	***A-7-6***	***A-7-6***	***A-7-6***	***A-7-6***

Based on the Table 4. above the values obtained liquid limit (LL) decreased from 100% variation laterite soil with a mixture of sand initially

0% 60.27% to 45.06% on 72% variation laterite soil with a mixture of 28% sand. The same thing also happened to the plastic limit value, which decreased from a variation of 100% laterite soil with a mixture of 0% sand which was originally 28.71% to 25.00% at a variation of 72% laterite soil with a mixture of 28% sand. The decrease in the value of the liquid limit and plastic limit affects the value of the plasticity index. The decrease in the value of the liquid limit and plastic limit affects the value of the plasticity index. The value of plasticity index (PI) decreased from a variation of 100% laterite soil with a mixture of 0% sand which was originally 31.56% to 20.06% in a variation of 72% laterite soil with a mixture of 28% sand. Based on the comparison value of the plasticity index and clay content, the soil activity values for each variation were classified as normal clays (illite). The value of soil activity is strongly influenced by the value of the soil plasticity index (PI), where the higher the PI value, the higher the value of soil activity.

The results of the direct shear strength test at the peak and residual conditions for each sample variation can be seen in Table 6. below.

Table 6. Results of the Direct Shear Strength Test for Peak at Peak and Residual ConditionsLaterite Soil with Sand Mixture

Variation Sample	Peak Cohesion (kg/cm²)	Residual Cohesion (kg/cm²)	Peak Internal Shear Angle (°)	Residual Internal Shear Angle (°)	Residual Strength Ratio (%)
100% Laterite Soil + 0% Sand	0,1879	0,1237	16,94	13,69	65,83%
93% Laterite Soil + 7% Sand	0,1750	0,1112	20,07	16,29	63,54%
86% Laterite Soil + 14% Sand	0,1421	0,0952	21,29	17,56	67,00%
79% Laterite Soil + 21% Sand	0,1373	0,0844	24,83	22,49	61,47%
72% Laterite Soil + 28% Sand	0,1290	0,0775	27,09	25,97	60,08%

Based on Table 6. above, it is known that the soil still has residual strength after failure. The percentage of residual strength possessed by each sample variation ranged from 60.08 to 67.00%. The value of the soil shear strength parameter obtained at the residual condition is smaller than the peak condition because the soil condition cannot return to its original state. In addition, there was a change in the shear strength test parameters for each sample variation.

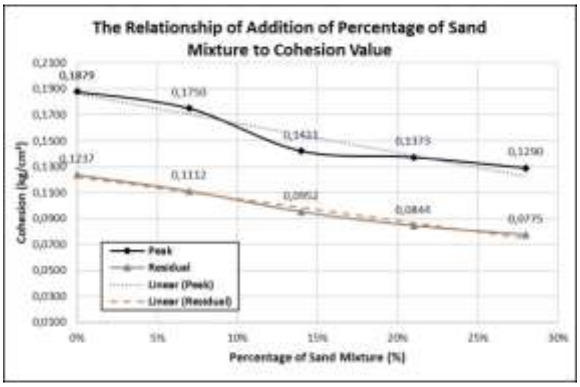

Figure 4. Graph of Relationship of Addition of Percentage of Sand Mixture to Cohesion Value

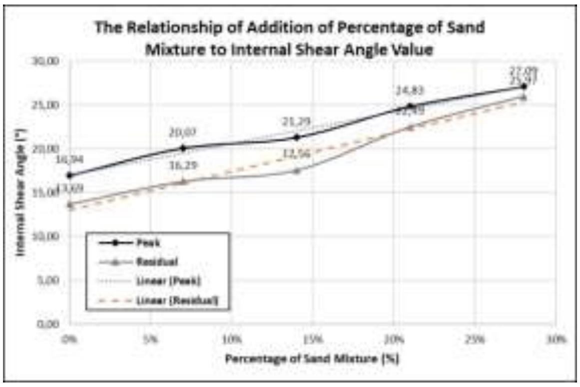

Figure 5. Graph of Relationship of Addition of Percentage of Sand Mixture to Internal Shear Angle Value

Based on Figure 4. above, it can be seen that the cohesion value decreases along with the increase in the percentage of the Sand mixture, both in peak conditions and residual conditions. Inversely proportional to cohesion, in Figure 5. it can be seen that the value of the internal shear angle increases with the increase in the percentage of the Sand mixture, both at peak and residual conditions. Knowing the value of soil cohesion and internal shear angle in both peak and residual conditions can determine the value of the shear strength of the soil. The calculated value of shear strength can be seen in Table 7. and is presented in graphical form in Figure 6. below.

Table 7. Recapitulation of Direct Shear Strength Results Peak Conditions and Residual Laterite Soil with Sand Mixture

Variation Sample	Peak Shear Strength (kg/cm²)	Residual Shear Strength (kg/cm²)
100% Laterite Soil + 0% Sand	50,4445846	40,3158563
93% Laterite Soil + 7% Sand	60,4584808	48,3293177
86% Laterite Soil + 14% Sand	64,4397386	52,3095280
79% Laterite Soil + 21% Sand	76,4828681	68,3959014
72% Laterite Soil + 28% Sand	84,5274300	80,4464590

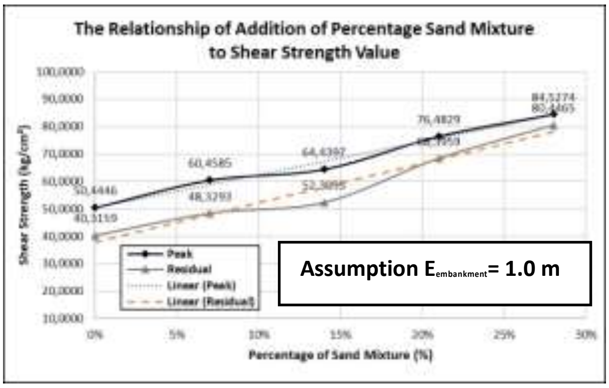

Figure 6. Graph of Relationship of Addition of Percentage of Sand Mixture to Shear StrengthValue

Based on the results of the shear strength test at peak and residual conditions presented in Table 7. it can be seen that the strength value increases with the increase in the percentage of the sand mixture, both at peak conditions and residual conditions. From Table 7. and the graph in Figure 6. also shows that the sample that experienced the addition of sand as much as 28% had a shear strength in the residual condition that was greater than the peak condition shear strength for the original soil sample (without the addition of sand).

Based on the data obtained in the Atterberg limit test for each sample variation, then the changes that occur can be presented in graphical form in Figure 7, Figure 8, and Figure 9. below.

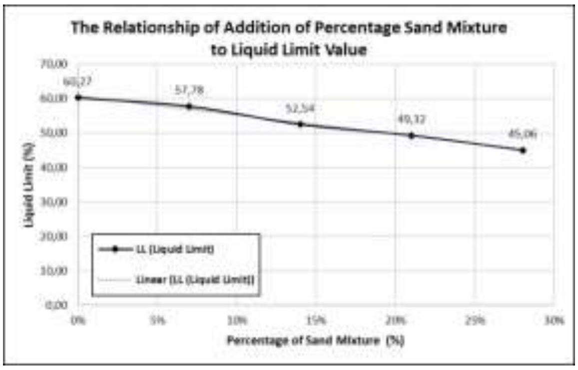

Figure 7. Graph of Relationship of Addition of Percentage of Sand Mixture to Liquid Limit Value

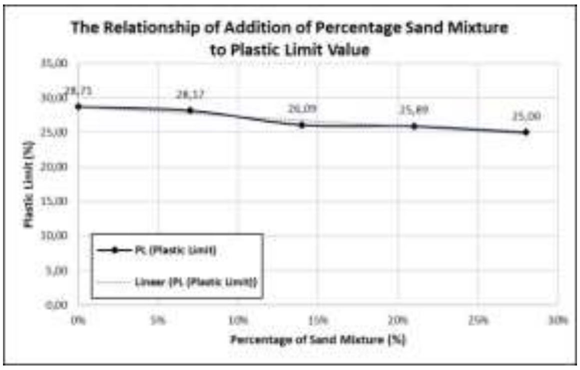

Figure 8. Graph of Relationship of Addition of Percentage of Sand Mixture to Plastic Limit Value

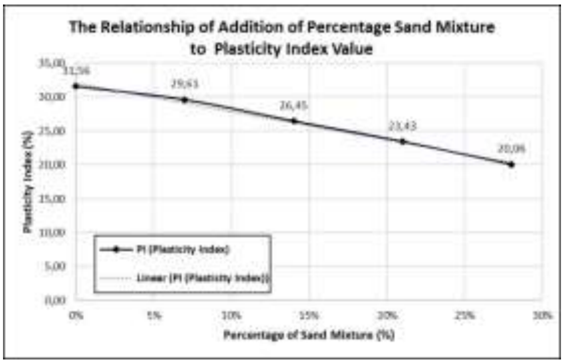

Figure 9. Graph of Relationship of Addition of Percentage of Sand Mixture to Plasticity Index Value

The addition of a mixture of sand in each sample variation with a percentage of 0%; 7%; 14%; 21%; and 28% causing a decrease in the value of the liquid limit and plastic limit in each sample variation that affects the value of the plasticity index. This is because the sand fills the soil cavities and makes the soil denser. Sand can also make the water content needed by the soil to be more to change the soil from a semi-solid state to a plastic state.

Based on the data obtained in testing the consistency and shear strength limits for peak and residual conditions in each sample variation, further analysis will be carried out on the relationship between the influence of the plasticity index value on the soil shear strength, which is presented in Table 8. and in the form of a graph in Figure 10. and Figure 11. below.

Table 8. Results of Analysis of Plasticity Index and Parameters of Soil Shear Strength

Variation Sample	PI (%)	Peak Cohesion (kg/cm²)	Residual Cohesion (kg/cm²)	Peak Internal Shear Angle (°)	Residual Internal Shear Angle (°)
100% Laterite Soil + 0% Sand	31,56	0,1879	0,1237	16,94	13,69
93% Laterite Soil + 7% Sand	29,61	0,1750	0,1112	20,07	16,29
86% Laterite Soil + 14% Sand	26,45	0,1421	0,0952	21,29	17,56
79% Laterite Soil + 21% Sand	23,43	0,1373	0,0844	24,83	22,49
72% Laterite Soil + 28% Sand	20,06	0,1290	0,0775	27,09	25,97

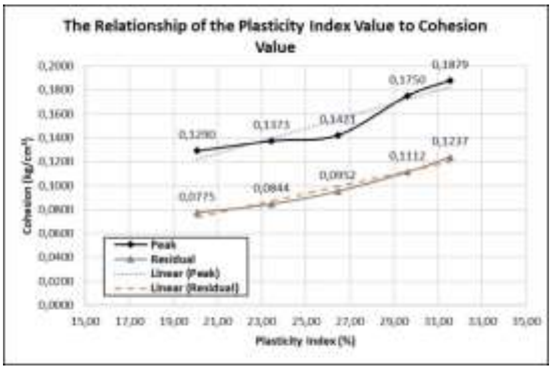

Figure 10. Graph of Relationship between Plasticity Index Values and Cohesion Value

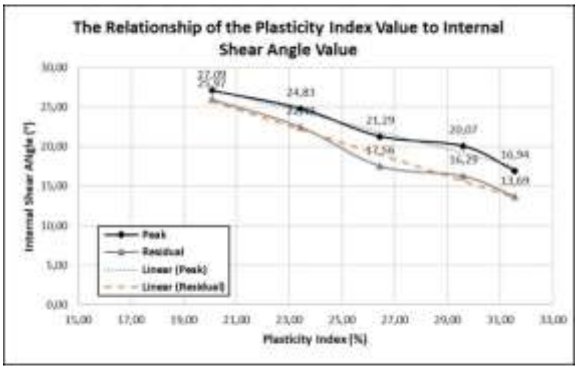

Figure 11. Graph of Relationship between Plasticity Index and Internal Shear Angle Value

Based on the relationship between the plasticity index of the soil and the cohesion value presented in Figure 10., it can be seen in the graph that the higher the percentage of sand added, the smaller the plasticity index value produced. This also occurs in the value of soil cohesion both at peak and residual conditions which have decreased. It can be said that the value of the plasticity index of the soil is directly proportional to the value of soil cohesion. The decrease in the value of soil plasticity index and soil cohesion is due to the addition of the percentage of sand which can reduce the adhesion of grains to the variation of the sample mixture so that the soil becomes less cohesive.

While the relationship between the plasticity index of the soil and the value of the internal shear angle is presented in Figure 11., it can be seen in the graph that the more percentage of sand added, the greater the value of the shear angle in the soil produced both at peak and residual conditions. It can be said that the value of the internal shear angle is directly proportional to the addition of the percentage of sand and inversely proportional to the value of soil cohesion and soil plasticity index.

Values of liquidity index can be known by the comparison between the difference between the original water content and the plastic limit on the plasticity index. While the consistency index is the ratio between the difference between the liquid limit and the original water content of the plasticity index. The sum of the values of the liquidity index and consistency index must produce the number 1. The results of the calculation of the value of the liquidity index and consistency index and their relationship to the percentage of added Sand mixture can be seen in Table 9. and are presented in the graphs in Figure 12. and Figure 13. below.

Table 9. Results of the Analysis of the Relationship between the Addition of the Percentageof Sand to the Values Liquidity Index and Consistency Index

Variation Sample	**LL (%)**	**PL (%)**	**PI (%)**	**W (%)**	**LI (%)**	**IC (%)**
100% Laterite Soil + 0% Sand	60,27	28,71	31,56	22,810	-0,187	1,187
93% Laterite Soil + 7% Sand	57,78	28,17	29,61	22,810	-0,181	1,181
86% Laterite Soil + 14% Sand	52,54	26,09	26,45	22,810	-0,124	1,124
79% Laterite Soil + 21% Sand	49,32	25,89	23,43	22,810	-0,131	1,131
72% Laterite Soil + 28% Sand	45,06	25,00	20,06	22,810	-0,109	1,109

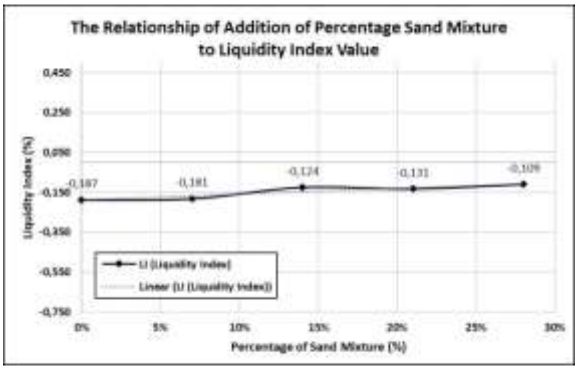

Figure 12. Graph of Relationship of Addition of Percentage of Sand Mixture to Liquidity Index Value

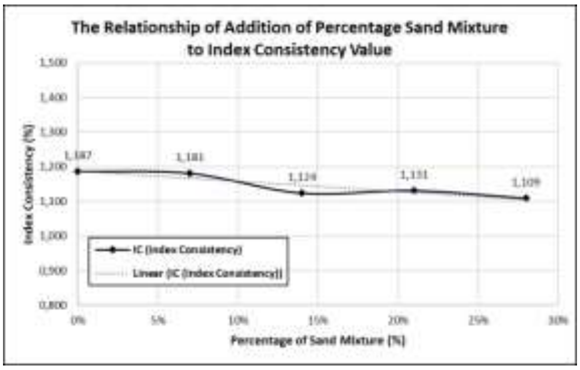

Figure 13. Graph of Relationship of Addition of Percentage of Sand Mixture to Consistency Index Value

Based on the results of the analysis presented in the form of tables and graphs above, it shows that thevalue liquidity index for each sample with a percentage of Sand mixture is 0%; 7%; 14%; 21; and 28% respectively are -0.187%; -0.181%; -0.124%; -0.131%; and -0.109%, where each sample has avalue liquidity index that is smaller than 0. If thevalue of liquidity index a land less than 0, then the soil is in a solid or semi-solid state.

Furthermore, for thevalue consistency index for all sample variations, the percentage of Sand mixture was 0%; 7%; 14%; 21; and 28% respectively amounted to 1.187%; 1.181%; 1.124%; 1.131%; and 1.109%, where each sample has avalue consistency index greater than 0. If thevalue of consistency index a soil is greater than 1, then the soil is in a solid or semi-solidstate.

5. CONCLUSION

1) Based on the USCS classification system, the soils for the three preliminary test locations were classified as CH (clay-high) group, while according to the AASHTO classification system for the Ulin and Mandiangin locations were classified as group A-7-5 and the Sungai Ulin location was classified as group A-7-6. (clayey soils). There was a decrease in the value for the shear strength parameter of the laterite soil from the peak condition to the residual condition. The addition of a mixture of sand in each variation of the sample can

reduce the PI value along with the addition of sand. In addition, the addition of sand also changes the parameters of the shear strength of the lateritic soil.

2) Soil plasticity index (PI) for each sample variation was 31.56%, respectively; 29.61%; 26.45%; 23.43; and 20.06% where this number decreased with the increase in the Sand mixture. Then the liquidity index (LI) for each sample variation is -0.187%; -0.181%; - 0.124%; - 0.131%; and -0.109% where the LI number is less than 0 which indicates that the soil is in a solid or semi-solid state. Meanwhile, the consistency index value for each sample variation is 1.187%, respectively; 1.181%; 1.124%; 1.131%; and 1.109% where the IC number is greater than 1 which indicates that the soil is in a solid or semi-solid state.
3) Based on the grain size gradation curve for each lateritic soil mixture there was a change, an increase for coarse-grained soils and a decrease for fine-grained soils due to the addition of a mixture of sand. The more the addition of the percentage of the Sand mixture, the less the value of the percentage of soil that passes the No. sieve. 200.
4) The effect of variations in plasticity can affect the parameters of the shear strength of the soil. This is indicated by the higher the plasticity value of a soil, the greater the cohesion value of the soil. This is inversely proportional to the internal shear angle, the higher the plasticity value, the lower the internal shear angle.
5) Changes in the grain size distribution in the soil can change the parameters of the shear strength of the soil. It is proven that as the Sand mixture increases, the soil cohesion value decreases. However, it is different from the value of the internal shear angle which is directly proportional to the addition of the Sand mixture. The more the addition of the Sandmixture, the greater the value of the internal shear angle.
6) Both variations in plasticity and grain size distribution can affect the parameters of the shear strength of laterite soils. The variation of

plasticity will increase the cohesion of the soil and the grain size distribution will increase the internal shear angle. Based on this research, it can be seen that the coarser the grain size that dominates, the greater the shear strength of the soil. On the other hand, the finer the grain size that dominates, the smaller the shearstrength of the soil.

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