

STUDY OF SHEAR STRENGTH BETWEEN LATERITE SOIL DUE TO TEMPERATURE INFLUENCE BASED ON LABORATORY SCALE

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Abstract. South Kalimantan is a large wetland with an area of 382,272 hectares (ha). The condition of wetland with soft soil types in this area, especially peat soil can initiate fires during the dry season because the water content in the land decreases drastically. Moreover, fires that occur on peat soil land with road constructions do cause the temperature around the land to increase. The increment of this temperature can affect the physical and mechanical properties of the embankment/laterite soil. Therefore, this study aimed to determine the influence of hot temperatures on shear strength between laterite soils. The materials used were laterite soil samples from quarries in Banjarbaru, South Kalimantan, namely Mandiangin, Cempaka, and Landasan Ulin. The temperature variations applied below 100°C included 27, 50, 60, 70, 80, and 90°C. During the analysis, the method used was a direct shear test in the laboratory. Based on the study conducted, the data analysis results were obtained and presented in a graph. The results showed that the changes in characteristics of laterite soil were due to the influence of hot temperatures. Additionally, the outcome also signified that cohesion value (c) in Mandiangin, Cempaka, and Landasan Ulin laterite soils from a normal temperature of 27 to 90°C increased on average by 11.5, 19, and 53%. The analysis implied that when the soil water content decreased, most of the free water pumped out, leaving capillary water occupying the space between soil grains. Following the discussion, the value of internal friction angle (ϕ) of these laterite soils from 27 to 90°C increased on average by 60.5, 59.5, and 84%. The result showed that when the soil water content reduced and the pore water pressure decreased, increasing effective stress (σ') in the soil. During the analysis, higher effective stress increased frictional resistance between soil grains, and ϕ value also improved. Therefore, soil mechanical properties parameters such as soil shear strength could be increased by adjusting soil temperature.

Keywords: direct shear test, temperature, laterite, shear strength

I. INTRODUCTION

During dry season in South Kalimantan area, frequent fires can cause geotechnical problems in civil engineering projects, particularly when geotextiles are exposed to high temperatures. South Kalimantan has an extensive wetland area covering 382,272 hectares (ha) (Annisa et al., 2021). This wetland features soft soil types, including peat soil, which is prone to fires during dry season due to drastically decreasing water content. When fires occur on peat soil with roads,

the surrounding temperature increases. Moreover, the propagation of hot temperatures can alter physical and mechanical properties of the embankment/laterite soil, including its shear strength.

According to Rusdiansyah in his book “*Perbaikan Karakteristik Tanah Laterit*” (Improvement of Laterite Soil Characteristics), laterite soil forms in tropical or subtropical areas with high weathering rates on basic to ultrabasic rocks rich in iron. The physical properties of laterite soil vary greatly depending on its mineralogical composition and particle size distribution. Additionally, granulometry analysis shows that laterite soil properties can range from fine to gravelly, influenced by its origin and formation process. This variation affect geotechnical properties including plasticity, compressive strength, and shear strength. In South Kalimantan, laterite soil often experiences major deformation during road construction or repair, influenced by compaction level, saturation conditions, and internal structure of the soil structure. The performance of this soil pavement also depends on climate and drainage conditions.

Laterite soil is rich in iron and aluminum oxide, which is formed due to weathering process of rocks in tropical and subtropical areas with high rainfall. This soil is characterized by owned red-to-brown color due to the dominant iron oxide content. Lambe (1979) stated that laterite soil was soil formed due to intensive weathering in tropical and subtropical areas with hot climate conditions as well as high rainfall. Following the discussion, this weathering process causes intensive leaching of silicate elements. Due to the process, the soil becomes rich in iron and aluminum oxide minerals but poor in organic matter, which is easily soluble minerals such as calcium, magnesium, as well as potassium.

Residual shear strength of laterite soil is influenced by wetting and drying cycle which affects its cohesion values and friction angles in this soil (Rusdiansyah, 2021). The study of consolidation tests modified with hot temperatures stated that, as hot temperature increases, the value of the soil volume compression coefficient decreases. Similarly, increasing hot temperature raises the soil permeability coefficient (Rusdiansyah et al., 2021). Sukiman Nurdin's (2023) study observed that increasing temperature and heating time caused a significant decrease in water content, increasing shear strength value of peat soil.

II. MATERIALS AND METHODS

Materials

The soil samples used during this analysis were disturbed samples taken from laterite soil in Mandiangin, Cempaka, and Landasan Ulin areas of South Kalimantan, Indonesia. Figure 1 showed the area where laterite soil samples were collected.

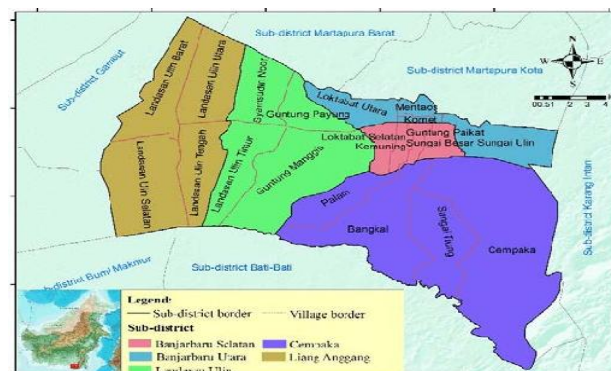


Figure 1. Map of laterite soil sampling area

Table 1 showed the characteristics/physical properties of laterite soil from each area used as a test object.

Table. 1 Characteristics of physical and mechanical properties of laterite soil

Properties	Mandiingin	Cempaka	Landasan Ulin
Water content	2.56	2.54	2.63
Gs	17.15	24.43	16.88
Gravel (%)	2.54	6.23	25.07
Coarse Sand (%)	9.30	6.13	3.09
Medium Sand (%)	8.47	8.53	5.31
Fine Sand (%)	8.18	8.39	13.23
Silt (%)	58.14	58.62	43.87
Clay (%)	13.47	12.11	9.44
Liquid Limit (LL)	49.34	53.16	40.47
Plastic Limit (PL)	23.07	24.21	21.94
Plasticity Index	26.27	27.94	18.53
USCS Classification	CL	CH	CL

Based on Table 1, the parameters used were liquid limit (LL), plastic limit (PL), and plasticity index (PI). For Mandiingin area with 49.34 and 23.07% had a PI of 26.27%. According to Unified Soil Classification System (USCS) classification system, the index fell under Clay-Low (CL) group, which referred to inorganic clay with low to moderate plasticity. Following this discussion, the test results in Cempaka area were obtained sequentially at 53.16 and 25.21%, with a PI of 27.94%. Using USCS classification system, the index for this area was in Clay-High (CH) group or inorganic clay with high plasticity. Moreover, the test values for Landasan Ulin area were consistently 40.47 and 21.94%, having a PI of 18.53%. The index for the area fell in CL group or inorganic clay with low to moderate plasticity following USCS classification system.

Methods

The manufacture of test objects, namely by compaction test, was conducted in this study using standard compaction test method, which was performed on original laterite soil samples. During this process, the optimum water content and maximum dry weight values were obtained. After obtaining the values from the result at each variation of laterite soil sample area, objects were prepared for direct shear test. The density used to manufacture direct shear test objects was 95% of maximum dry weight because it was adjusted to field conditions that did not allow 100% soil density. According to the requirements of SNI 03-2008-1992, the recommended soil density value was 95%. **SNI 1742:2008** also stipulated that field density should have an approval level of not less than 95% of maximum dry density.

During the analysis, the test was conducted using a direct shear tester in soil mechanics laboratory. The temperatures applied in this test were 50, 60, 70, 80, and 90°C. Based on this study, the applied temperature range values referred to a previous investigation conducted by Rusdianyah concerning the magnitude of temperature above 39°C. Following this discussion, the test was performed three times at each sample area, where the average value was obtained, and the results were more accurate. The parameter values obtained from direct shear test included normal stress value (σ_n), shear stress (τ), soil cohesion (c), and also internal friction angle (ϕ) at each test area.



Figure 2. Direct shear test

III. RESULT AND DISCUSSION

Laterite soil shear strength without being affected by temperature

The two soil shear strength parameters, cohesion (c) and internal friction angle (ϕ) were obtained from the tests. During this analysis, the study of residual shear strength of laterite soil under wetting and drying cycles produced cohesion as well as internal friction angle values (Rusdiansyah, 2021). Table 2 showed the results of direct shear test of laterite soil.

Table 2. Direct Shear Strength Test Results of Laterite Soil

Sample Name		Mandiingin	Cempaka	Landasan Ulin
Optimum Water Content (95%)	%	19.40	24.20	14.50
Maximum Dry Weight (95%)	gr/cm ³	1.37	1.33	1.77
Cohesion (c)	kg/cm ²	0.27	0.23	0.28
Internal Friction Angle (ϕ)	°	34.25	32.58	38.38

From the data in Table 2, Mandiingin laterite, with dry density of 95%, including 1.37 gr/cm³ and water content of 19.40%, achieved 0.27 kg/cm² c and 34.25° ϕ , respectively. For Cempaka laterite with dry density of 95%, namely 1.33 gr/cm³ and water content of 24.20%, obtained 0.20 kg/cm² c and 32.58° ϕ , respectively. Moreover, Landasan Ulin laterite with dry density of 95% consisting 1.77 gr/cm³ and water content of 14.50% obtained 0.28 kg/cm² c as well as 38.38° ϕ . Among the three samples, Landasan Ulin laterite had higher c and ϕ values compared to Mandiingin and Cempaka. Additionally, the outcome was due to maximum dry density of Ulin foundation that was higher, where its value was directly proportional to c and ϕ . As the

density of this area became greater, c also increased, while, soil mass became denser, as ϕ became greater.

The shear strength of laterite soil is affected by temperature.

The samples tested using a direct shear tester were laterite soil samples that were compacted by applying standard proctor tester under 95% MDD conditions. The test object was molded using a ring and inserted into a modified casing with a heating element connected to a thermocouple controller. During the examination, cohesion value (c) and internal friction angle (ϕ) were obtained. A graph was plotted based on the results of direct shear test influenced by temperature. Figures 3 and 4 showed the relationship between temperature and cohesion, as well as the correlation concerning temperature and the internal friction angle in the soil.

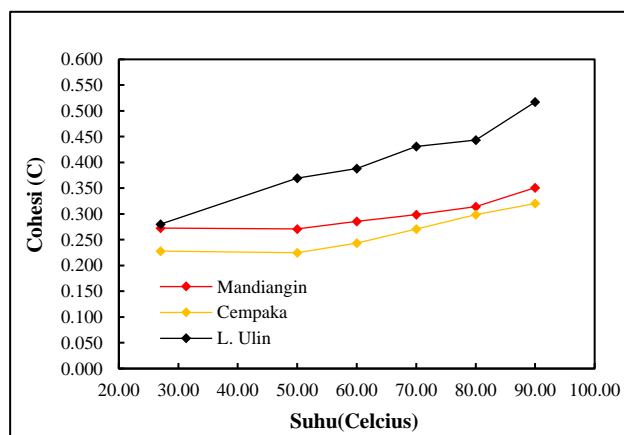


Figure 3 Graph of the relationship between temperature and cohesion

According to direct shear test conducted at temperatures of 27 (normal), 50, 60, 70, 80, and 90°C, soil shear strength parameters including cohesion value and internal friction angle were determined from each test area. For Mandiangin laterite at a normal temperature of 27, 0.27 kg/cm² c and 34.25° ϕ were obtained. Additionally at 50 °C, 0.27 kg/cm² c and 53.14° ϕ were achieved. A total of 0.29 kg/cm² c and 53.70° ϕ at 60°C were obtained during the analysis. Following this discussion, 0.30 kg/cm² c and 54.52° ϕ at 70°C were achieved. About 0.31 kg/cm² c and 55.82° ϕ at 80°C were obtained in this analysis. Lastly, at 90°C, 0.35 kg/cm² c and 57.73° ϕ were achieved during the study.

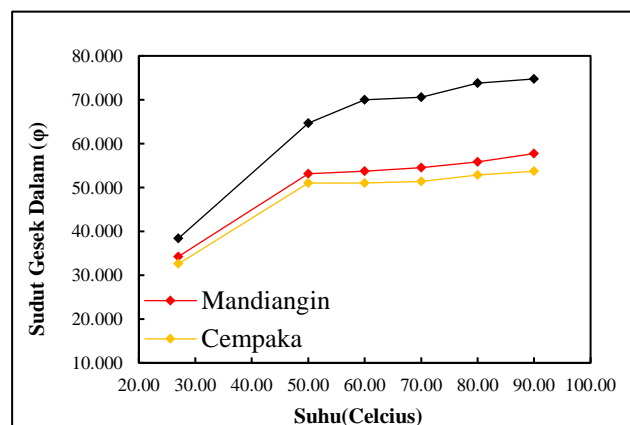


Figure 4 Graph concerning the relationship between temperature and internal friction angle

Shear strength parameters c and ϕ were obtained for Cempaka laterite at various temperature. At 27°C, the values were 0.23 kg/cm² for c and 32.58° for ϕ . As the temperature increased, the following values were achieved, including 0.22 kg/cm² and 51.04° at 50°C. Moreover, 0.24 kg/cm² and 51.04° for c and ϕ , respectively, were achieved at 60°C during the analysis. At a temperature of 70, 0.27 kg/cm² c and 51.35° ϕ were obtained. A total of 0.30 kg/cm² for c and 52.85° for ϕ were gotten at 80°C. Lastly, at 90°C, 0.32 kg/cm², as well as 53.70° for c and ϕ , were achieved in this study.

During the test, shear strength values of Landasan Ulin laterite soil at 27°C were 0.28 kg/cm² for c and 38.38° for ϕ . At 50°C, 0.37 kg/cm² and 64.66° for c as well as ϕ were obtained consecutively during the analysis. Following this discussion, 0.39 kg/cm² c and 70.02° ϕ were achieved. A total of 0.43 kg/cm² and 70.57° for c as well as ϕ were obtained at 70°C when Landasan Ulin laterite soil was examined. c and ϕ with 0.44 kg/cm² as well as 73.82° were also achieved at 80°C. Finally, at 90°C, 0.52 kg/cm² for c and 74.75° for ϕ were obtained.

Figure 3 showed that c was improved along with increasing temperature for Mandiangan laterite, Cempaka laterite, and Landasan Ulin laterite soils. The process occurred because as the soil water content decreased, most of the free water was removed, leaving behind capillary water that filled the space between soil grains. This capillary water created an attractive force (capillary tension) between soil particles, which increased cohesion.

Figure 4 showed that the value of (ϕ) of Mandiangan, Cempaka, and Landasan Ulin laterite soils with increasing temperature also improved. As the soil water content decreased, the pore water pressure also reduced and this process increased the effective stress (σ') in the soil. During the analysis, higher effective stress improved the frictional resistance between soil grains allowing the value of ϕ to increase. Shear strength value (τ) also automatically improved with an increment in c and ϕ . Therefore, an increase in soil temperature improved the parameters of its mechanical properties, such as shear strength. The results followed previous studies which stated that increasing soil temperature improved the parameters of the mechanical properties of the soil, such as compressibility, known as compression index (C_c), consolidation coefficient (C_v), and swelling index (C_s) (Rusdiansyah & Markawie, 2021).

CONCLUSION

In conclusion, several assumptions were drawn based on the results and wetting in the following manner.

1. From tests of laterite soil samples in three quarries, the initial water content values were obtained from 16.88% to 24.43%. The specific gravity obtained from Mandiangan, Cempaka, and Landasan Ulin laterites soil were 2.56, 2.54, and 2.63, respectively. Moreover, the three laterite soils were classified as clay-silt soils.
2. Gradation of these soil grains was dominated by clay-silt (> 70%). In comparison, Landasan Ulin laterite had a clay-silt content of 56.64% and a higher gravel content of 25.07%.
3. Based on USCS classification, Mandiangan laterite soil was inorganic clay with low to medium plasticity (CL), and Cempaka was also included in the inorganic clay group with high plasticity (CH). At the same time, Landasan Ulin was classified as low to medium plasticity (CL).
4. c in Mandiangan, Cempaka, and Landasan Ulin laterite soils from a normal temperature of 27 to 90 experienced an average increase of 11.5, 19, and 53%.

5. The value of ϕ of these soils from a normal temperature of 27 to 90, experienced an average increase of 60.5, 59.5, and 84.
6. Hot temperatures affected c and ϕ of the soil, which was signified by increasing temperature, value of c as well as ϕ .
7. The increase in temperature also improved shear strength of soil. Among the three samples tested, Landasan Ulin laterite soil had higher shear strength than Mandiangin and Cempaka ones.

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