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The influence of clay minerals on soil plasticity (Case study on weathering of claystone)

R. Husain[1]
[1]Department of Geological Engineering, Engineering Faculty, Hasanuddin University, Makassar, 90245, Indonesia.
*Corresponding authors: ratna7geologi@gmail.com

Abstract
Administratively the scope of research belongs to area of Banawa District, Palu City, Central Sulawesi Province. The research title is the influence of clay minerals on soil plasticity, (Case study on weathering of claystone). The purpose and intent of this research is to examine the clay mineral content that will affect the magnitude of the plasticity of the soil based on the type of clay minerals contained in the soil from weathered claystone. The method used in this research is taking soil samples in the field and processing the data using software or laboratory equipment. To determine the type of minerals contained in the research sample, the method used is the analysis of X-Ray Diffraction (XRD) and Atterberg method. From the analysis, it is concluded that the mineral characteristics greatly affect the plasticity index of the soil, especially the presence of clay minerals, especially the presence of illite minerals.

Keywords: clay mineral , X-Ray Diffraction, Atterberg, soil plasticity

1. Introduction

The decomposition of rocks and other materials at or near the earth's surface through chemical decomposition and physical disintegration, which can be caused by physical, chemical and/or biological processes, resulting in residual soils. The process of dissolving or destroying rock (source rock) from sedimentary rock, igneous rock, or metamorphic rock will produce unconsolidated sedimentary rock or residual soil (residual soil). Rocks will be dissolved or even completely destroyed by weathering, which will then turn them into soil or move them and deposit them as clastic sedimentary rocks. Some of the minerals might totally disintegrate and produce new minerals. Because of this, the composition of soil or clastic rock can be studied differently from that of the rock. The sort of soil formation process itself, as well as the nature, intensity, and length of weathering, all have an impact on soil composition in addition to the source rock [1].

The weathering of soil and minerals occurs in the same location, without movement or transportation, as a result of contact with the earth's atmosphere, biota, and water. Physical weathering (also known as mechanical weathering) and chemical weathering (also known as chemical weathering), both of which occasionally involve a biological component, are two significant classifications. Because they can coexist on a rock, chemical, physical, and biological weathering processes can be challenging to differentiate in the field.

Clay minerals are types of minerals that make up sedimentary rocks and are also the main component of soil (soil), the percentage is about

40%. According to Pettijohn [2], clay is a grain size on the Wentworth scale measuring about

1/256, whereas the term "clay" is used in the United States and by the International Society of Soil Science to refer to a rock or mineral particle contained in the soil with a grain size of less than 0.002 mm. 0.0039 mm. All sediments most frequently contain clay minerals, which are also present in soil from the polar regions to the equator. Clay minerals are created when the parent rock is changed through physical and chemical separation without the minerals' elements being changed, as well as through chemical weathering, which transforms the primary minerals and creates secondary clay minerals..

Secondary clay minerals combine to create a weathering complex that creates soil. Climate, vegetation, animals, human activity, lithography, geography, water interflow, and time all affect how soil and clay minerals develop. As a result, clay minerals can be used as a guide to identify the parent rock and the environmental factors that influenced its creation [3].

The research area is located in the Banawa District, Palu City, Central Sulawesi Province, and geographically it has coordinate between 119° 32' 00" - 119° 36' 00" South Latitude and 0°55'00" – 1°0'00" East Latitude, Maps of Bakosurtanal, Bogor [4]

The purpose and intent of this research is to examine the clay mineral content that will affect the magnitude of the plasticity of the soil based on the type of clay minerals contained in the soil from weathered claystone.

2. Methodology

Field study on soil samples and laboratory analysis using the XRD method and Atterberg test are the two steps of the approach used to analyze the mineral properties of weathered rocks on the impact of soil plasticity.

To obtain primary geological data, field data collection was carried out through direct field observations, which included field observations and soil sampling. The Bragg's Law equation is utilized in the X-Ray diffraction (XRD) method, which is now the oldest and most popular method for material characterization. By calculating the lattice structure parameters and obtaining the particle size, this method is utilized to detect the crystalline phase in the material. The average bulk composition of the studied sample was established after being finely powdered and homogenized. The Bragg equation serves as the basic guiding principle for the XRD method:

$$n \lambda = 2d \sin \theta$$

Where d is the distance between atomic layers, n is an integer (order of bias), X-ray wavelength, and angle between atomic layers.

The sample is placed on a glass slide and then inserted into the XRD device, then XRD operation is performed. A crystalline solid sample is illuminated by a moving light source, which then diffuses the light in all directions in accordance with Bragg's Law. For the purpose of detecting the X-ray beam diffracted by the sample, the detector rotates at a constant angular velocity. Powder or crystalline solid samples comprise crystalline particles as well as randomly distributed lattice planes with many potential orientations. Every group of lattice planes has a unique orientation angle.

The recording device will capture the brightness of the reflected light at any given angle. The analysis findings are in the form of a graph that compares the intensity of the reflection with the angle of the reflection.. XRD testing was done at Hasanuddin University's XRD and XRF Analysis

Laboratory, which is part of the faculty of engineering's department of geological engineering. Based on the water content of the soil, Atterberg [5] offers a way to describe the consistency limits of fine-grained soils. The liquid limit, plastic limit, and shrinkage limit are these positions, the soil's water content at the transition point between the liquid and plastic states, or the upper limit of the plastic area, is known as the liquid limit (LL). The Casagrande test method [6] is usually used to calculate the liquid limit content of soil.

A. Li**quid limit**

This test's objective is to establish the soil type's water content at the transition between its plastic and liquid states.

How it works based on ASTM D 4318 [7]:

- Sieve is used for soil samples that have been mashed sieve number 40.
- Increases the drop height of the Casagrande bowl by 10 mm.
- Using up to 150 grams of soil samples that pass through sieve no. 40, add water gradually while stirring to ensure an even distribution. Place the samples in a casagrande bowl and flatten the dough's surface so that it is parallel to the base..
- Divide the test object in the cassagrande bowl with the grooving tool and create a groove precisely in the middle.
- Counting the number of beats with the number of beats needing to be between 10 and 40 times, while rotating the lever till the two sides of the ground meet for 13 mm.
- The test object is placed in the center of the bowl to check the moisture content. This step was repeated several times for the test specimens in different doughs to produce four different tests, two of which had a knock below 25 and two of which had a beat above 25.

Calculation:

Determine the amount of water in each soil sample based on the number of taps, then calculate the moisture content of each soil sample. Draw a straight line connecting the four points.

Calculate the liquid limit value on the 25 stroke count.

B. P**lastic limit**

The objective is to ascertain a type of soil's water content at the transitional state between the plastic state and the semi-solid state.

How it works based on ASTM D 4318 [6]:

- Use sieve number 40 to sift the crushed soil sample
- A thumb-sized soil sample should be taken, and it should be rolled on a glass plate until it is 3 mm in diameter and cracked or broken.
- Put the test object into the container and weigh it afterwards.
- Testing how much water is in the test object.

Calculation :

The test object's moisture content with a cylinder diameter of less than 3 mm is known as the plastic limit value (PI).

C. **Plasticity Index**

The distinction between the liquid limit and the plastic limit is known as the plasticity index (PI). LL - PL = PI (table 1)

Tabel 1. Value of soil type and the plasticity index [8]

PI	Sifat	Macam Tanah	Kohesi
0	Non plastis	Sand	Non kohesif
< 7	Low plasticity	Shale	Partially cohesive
7 – 17	Medium plasticity	Shaly Clay	Kohesif
>17	High plasticity	Clay	Kohesif

3. Result and Discussion

The distribution of various types and ratios of minerals found in the residual claystone lithology is shown vertically in the form of a curve at each peak of the graph, according to the value, surface area, and thickness of each mineral.

The ratio of quartz which has the highest amount of other minerals indicates the properties of the remaining claystone soil. This was corroborated by the findings of the XRD test (Fig.1), which showed a quartz concentration of 41.3%. Clay minerals are also found in this residual soil, including ilite which contains 48.1%, kaolinite, vermiculite, and pyrophyllite, as well as 0.8% mica and 0.6% chlorite.

Quartz is a group of silica minerals that is often found in worn rocks to form fine-grained soils, and predominates in claystone bedrock waste soils, which consist mainly of the minerals illite and quartz. The soil has a cohesive quality related to the flexibility value of the soil due to the high concentration of fine grains.. Clay and quartz minerals have very stable qualities (low shrinkage-development), no crystals are attracted to each other, and little plasticity [9]. These minerals will form clay minerals due to chemical weathering of the hydrolysis process (kaolinite, illite, smectite and montmorillonite).

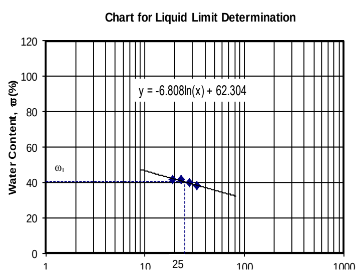
Due to the unique characteristics of illite minerals, the physical and chemical characteristics of the soil can be affected by its presence. One Al_2O_3 plate is sandwiched between two SiO_2 plates to form a lattice structure. Illite's structure allows it to change size along the c axis, and it also has the important characteristic of having a negative charge, which makes this mineral highly reactive to its environment. It has a high cation exchange capacity, so it expands when it's wet or shrinks, it's dry.

According to the correlation between the soil and clay mineral consistency values, the plasticity and quality values of the existing clay minerals can identify the capability characteristics and serve as valuable indicators of the residual soil development potential. based on the results of the atterberg limit test for the remaining clay bedrock.

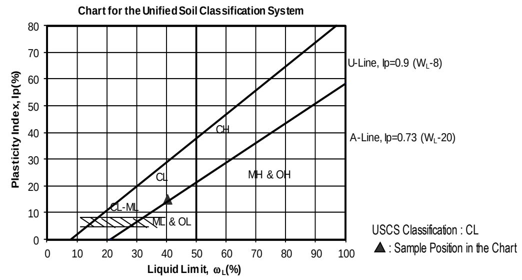
Based on the results of the Atterberg test (Table 2), the plasticity index is 15.01%, the liquid limit is 40.39%, the plastic limit is 25.38%, and the shrinkage limit is 12.40%. The type and amount of minerals, ease of ion transfer, also known as cation exchange capacity, electrolyte concentration, and mineral layer structure are just some of the factors that affect the quality of expansive (clay) soils. The presence of montmorillonite, illite, and kaolinite clay minerals will form expansive soils.

Table 2 Test results for residual soil atterberg limits from

Sample No.	:	LEMPUNG									
Depth of Sample	:										
	Unit	Plastic Limit		Liquid Limit							
Test Number	-	1	2	1		2		3		4	
Number of Blows	N	-	-	19		23		28		33	
Container No. or Can No.	-	A1	A2	B1	B2	C1	C2	D1	D2	E1	E2
Weigth of Wet Soil+Can, W1	gram	13.30	13.09	20.44	20.58	19.27	20.73	19.72	19.97	19.82	20.26
Weigth of Dry Soil+Can, W2	gram	12.86	12.68	19.02	19.08	18.17	19.14	18.55	18.73	18.59	18.97
Weigth of Water, Ww=W1-W2	gram	0.44	0.41	1.42	1.50	1.10	1.59	1.17	1.24	1.23	1.29
Weigth of Can, W3	gram	11.11	11.08	15.64	15.47	15.53	15.31	15.62	15.61	15.38	15.57
Weigth of Dry Soil, Ws=W2-W3	gram	1.75	1.60	3.38	3.61	2.64	3.83	2.93	3.12	3.21	3.40
Water Content, ω=Ww/Ws*100%	%	25.1	25.6	42.0	41.6	41.7	41.5	39.9	39.7	38.3	37.9
Average of Water Content, w	%	25.38		41.78		41.59		39.84		38.13	



Atterberg Limits	Value
Plastic Limit, ωp(%)	25.38
Liquid Limit, ω_L(%)	40.39
Plastic Index, Ip=ω_L-ωp	15.01
Shrinkage Limit, ω_L(%)	12.40



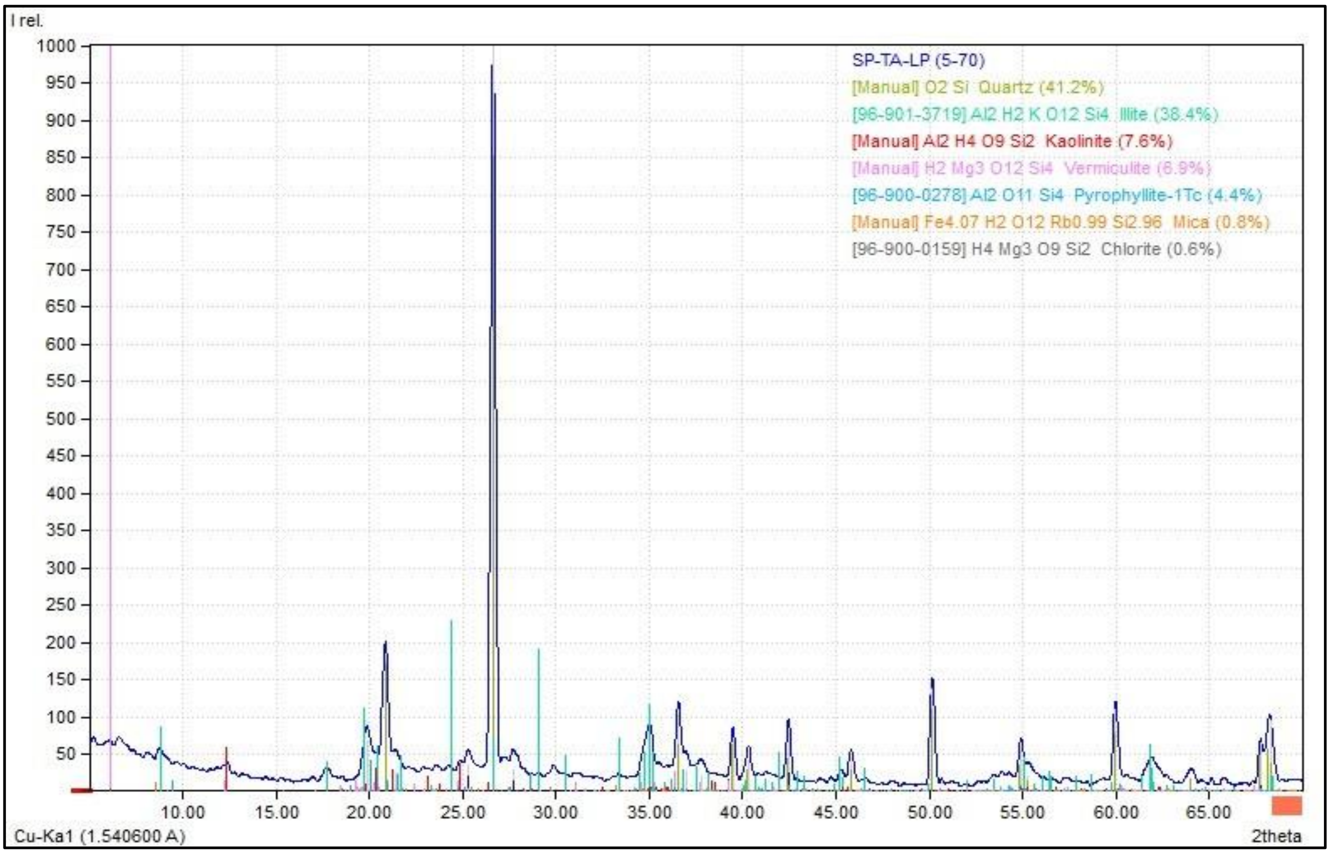


Figure 1. Difraktogram residual soil from claystone

Because montmorillonite has the greatest swelling and shrinkage of the three types of minerals [10]. Its presence is assumed to be the main contributory component that determines the expansive properties of clay soils. Knowing the mineralogy content of soil/rock can be used to estimate the expansive properties of clays [11].

Research by Billing [11] indicates that residual soil containing Kaolinite and Illit minerals will raise the soil's plastic limit value (high plasticity). The existence of kaolinite and illite in the residual soil from bedrock, or claystone in general, is demonstrated by (Table 2) and indicates that it is in the range of moderate to extremely high plasticity.

4. Conclusion

The results of the Atterberg limit test in this study, that weathered claystone on the soil has a high plasticity index of 15.01%. The presence of clay minerals such as Illite will have a major effect on the soil plasticity index, namely the presence of clay minerals such as illite in the soil resulting from weathering of claystone.

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References

[1] Boggs, Sam, J. R., 1995. Principles of Sedimentology and Stratigraphy, University of Oregon, Prentice Hall, Upper Saddle River, New Jersey.

[2] Pettijohn, F. J. 1987, Sedimentary Rocks. Harper and Row Limited. New York.

[3] Husain, R., 2015. Geokimia Mineral Lempung Dan Implikasinya Terhadap Gerakan Tanah, Program Studi Ilmu Teknik Sipil, Pasca Sarjana Repository, Universitas Hasanuddin, Makassar

[4] Bakosurtanal, 1991. Peta Rupa Bumi Lembar Palu 2015-32 dan Lembar Tavaili nomor 2015-34 Edisi 1. Bakosurtanal, Bogor.

[5] Atterberg, A., 1911. Uber die Physikalishe Bodenuntersuchung und uber die plastizitatder Tone. Int. Mitt. Boden, Vol.1

[6] Casagrande, A., 1948, Classifiaction and Identification of Soils. Transactions ASCE, Vol. 113. pp. 901

[7] ASTM, D4318, Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soil, Annual Book of ASTM Standards, section 4,Volume 04.08, Easten MD, USA.

[8] Braja M. 1993. Mekanika Tanah 1. Erlangga. Jakarta.

[9] Hardjowigeno, S. 1985. Klasifikasi Tanah. Survey Tanah Evaluasi Kemampuan Lahan. Perbaikan dari naskah aslinya. IPB. Bogor. 283 hal.

[10] Husain, R., Arifin, F., Asikin, B., Sirajuddin, H., Alimuddin, I., 2020. Characteristics of Clay Minerals from Weathering Various Origins Rock in West Palu City, EICSE 2020, EPI 034, Technical Faculty Conference, Hasanuddin University.

[11] Billings, M. P., 1946. Structural Geology, Prentice-Hall Inc, New York.