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Research Article

# Study of Physical and Mineral Properties of Soil Clay Landslide Location of IAIN Campus Ambon City

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**ABSTRACT**

This study aims to determine physical and clay mineral properties of soils and how they affect the occurrence of erosion in the IAIN Campus Ambon. The results indicated that the two soil profiles shows a variety in soil properties. the largest distribution of soil particle density is 2.63 at soil layer P2L3 and the smallest is 2.26 at P1L1, the largest soil pore distribution is 60.12% at P2L1 and the smallest is 29.36% at P1L3, while the largest soil pores ratio distribution is 1.51% at P2L1 and the smallest is 0.42% at soil layer P1L3. The soil porosity reflects the level of the soil ability to pass water flow (permeability) or the speed of water flow to pass through the soil mass (percolation). By the decreasing of soil porosity and pore ratio in layers 3 and 4, the permeability is also slower. The major clay mineral found in both soil profiles is kaolinite, an unwell consolidated secondary clay mineral type 1:1 mixed with quartz, the most weathering resistant primary minerals. These two minerals have lower friction resistance due to the increasing of clay content in the lower soil profiles. The physical and hydrological soil properties as well as the presence of kaolinite and quartz in the lower soil layers are considered to be the cause of the erosion occurrence in the study area (IAIN campus).

**Keywords**: *Clay Minerals, IAIN Campus location, Landslides, Physical Properties*

## Introduction

Maluku is one of the provinces in Indonesia that has the threat of earthquakes, tsunamis, floods, landslides, forest and land fires, droughts, extreme waves and high abrasion. This condition causes Maluku to have a Disaster Risk Index Value in 2020 of 160.35, which is a high category (BNPB, 2020). In addition, geographically Maluku is an archipelagic province which is located at the confluence of four tectonic plates, namely the Asian Continental Plate, the Australian Continent, the Indian Ocean Plate and the Pacific Ocean, causing Maluku to have highland islands that are both very

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potential and prone to geological disasters (Hosobuchi et al., 2021).

Ambon City in Maluku Province is an area that has a moderate threat of disaster with the value of the Disaster Risk Index in 2020 is 105.02 (BNPB, 2020), while based on the map of the land movement vulnerability zone on the island of Ambon, the Ambon city area is included in the moderate to high zone (Center for Volcanology and Geological Hazard Mitigation - Geological Agency, 2018).

Data from the Ambon City BPBD shows that the incidence of landslides in the Ambon city area continues to increase. In 2014 there were 21 landslides, and an increase of 42 landslides in 2015, and 38 in 2016 (Evelyn & Makarim, 2018). Furthermore, the Ambon City BPBD reported that in 2017 there were 94 landslides scattered in Sirimau sub-district, 61 points, Baguala District. 5 points, Nusaniwe District 3 points and South Leitimur District 1 point. In 2019 there were 32 landslides and landslides that spread across five sub-districts, while in 2020, 163 landslides were found in the Ambon City area (Ahmad, 2022);(Ahmed et al., 2021).

One of the causes of the high incidence of landslides in Ambon City is rainfall which tends to be high (>100 mm/day) which continues to occur from year to year. An example of high daily rainfall conditions (>100 mm) occurred on Ambon Island on July 11, 2021 (Zhan et al., 2019). Besides that, the topography of the Ambon City area which is dominated by steep to very steep slopes, and human activities such as building houses in sloping to steep locations also contribute to become the trigger and cause of the increasing incidence of landslides in the Ambon city area (Anda et al., 2021);(Noviyanto et al., 2020).

The landslide incident in the Ambon City area that attracted attention was the ground movement that occurred on the land around the IAIN Campus in June 2019 (Isra et al., 2019). In this incident several landslide locations were found that caused damage to buildings, such as the rectorate building, library building, MIPA building, auditorium building, and the PAI building (Sunbul et al., 2021).

Several landslide studies have been carried out in the Ambon City area, among others, landslide studies from the aspect of vulnerability to climate change (Osok et al., 2018), the use of multidisciplinary geoelectric, geotechnical and geochemical approaches to determine the potential for landslides in the area. Ambon City (Souisa, 2021), and the use of Geographic Information Systems (GIS) for mapping landslide vulnerability in Ambon City (Rakuasa & Rifai, 2020). Meanwhile , the ground motion inspection by the Ministry of Energy and Mineral Resources using a round - penetrating radar ( GPR sensor ) also reports on rock layers and subsurface (Nature, 2019);(Tutuarima et al., 2021). The above studies, both surveys and explorations as well as geotechnical investigation reports by the Ministry of Energy and Mineral Resources, do not examine landslide events from the soil aspect, even though soil is an important material to support the load on it. According to Agustina and Elfrida (2019), the shear strength of the soil or the ability of the soil to resist shear stresses that occur when loaded is strongly influenced by soil properties, namely grain size, porosity, and water content. Meanwhile, according to Soewandita (2018) in addition to geological factors, soil characteristics and vegetation factors that exist on the soil surface also affect the occurrence of landslides (Djaja Subardja et al., 2014);(Laimeheriwa, 2014).

This study aims to determine the physical characteristics and clay minerals of the landslides at the Ambon State Islamic Institute (IAIN) campus.

## Methods

### *Study Location and Soil Observation*

This research was conducted at the IAIN Ambon campus, Sirimau District, Ambon City - Maluku Province at the location of the 2019-2021 landslide (Liu et al., 2020). Soil observations and soil sampling were carried out on two soil profiles P1 and P2 (Figure 1) and 11 disturbed soil samples and 11 undisturbed samples (ring samples) were taken on each soil layer (horizon) including parent material (weathered material).

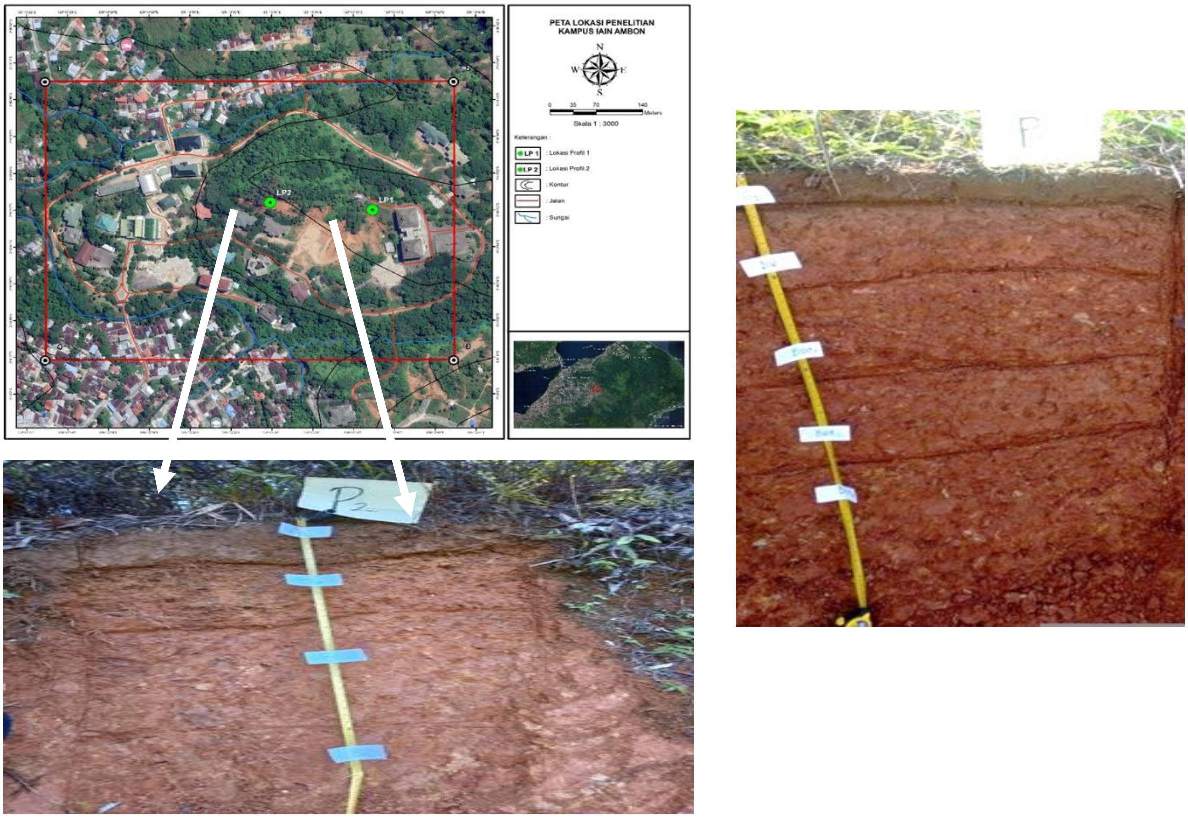


*Figure 1. Research site map and soil profil described (P1 and P2)*

In addition, observations of land conditions were carried out including rock types, slopes, land use (T. Wang et al., 2022). Soil physical properties including pore distribution, permeability, density of soil particles, soil density were analyzed in the soil and water conservation laboratory, Faculty of Agriculture, Pattimura University, Ambon. Meanwhile, analysis of particle distribution of 3 fractions (sand, dust and clay) and soil chemistry was carried out at the Laboratory of Soil, Plants, Fertilizer, Water, Agricultural Research and Development Agency – South Sulawesi AIAT in Maros (Priyanti & Suprianto, 2020);(Uyeturk et al., 2020). Clay mineral analysis was carried out at the XRD and XRF Laboratory of the Faculty of Mathematics and Natural Sciences, Hasanuddin University Makassar using the FTIR (Fourier Transform Infra Red) method (Gosal et al., 2018). Determination of soil type using the National Soil Classification Technical Guidelines (Balitbang Agriculture, 2014).

***Data analysis***

**a.** Pore distribution, calculated by the equation:

$$F = 1 - \frac{\rho b}{\rho p} \, x \, 100\%$$

Information :
F = Pore distribution (%)
$\rho$b = Grain Density (g/cm $^3$)
$\rho p$ = Filling weight (g/cm $^3$)

**b.** Permeability is measured based on Darcy's Law with the equation:

$$K\left(\frac{cm}{jam}\right) = \frac{Q \times L}{A \times h \times t}$$

Information :
K : Permeability (cm/hour)
Q : Volume of water flowing per measurement (ml)
t : Measuring Time
L : Width of Soil Sample (cm)
h : High water level from the surface of the soil sample (cm)
A : Surface Area (m)
A $=\pi r^2$

**c.** Soil Particle Density (Specific Gravity) is measured using the pycnometer method which can be calculated using the formula:

$$\rho s = \frac{\rho f M_3}{M_1 + M_2 + M_3}$$

Information :
$\rho s$= particle density
f = specific gravity of the liquid
M $_1$ = Weight of Pycnometer + liquid
M $_2$ = Solid mass of oven dry soil
M3 = Weight of $_{\text{pycnometer}}$ + soil sample + liquid
d. Dry Mass Density (Fit Weight) is calculated by the equation:

$$BI\left(\frac{g}{cm^3}\right) = \frac{Berat\ kering\ tanah}{Volume\ total\ tanah}$$

e. Field Moisture Content
Field water content is the water content that describes the condition of the water content in the soil in the field during direct measurements. Field moisture content was measured by the gravimetric method, namely:

$$KAL = \frac{berat\ basah - berat\ kering\ oven}{berat\ kering\ oven} \times 100\%$$

## Results and Discussion

### *General condition of the location*

Based on hydrological conditions, the research location is flanked by two large rivers that flow throughout the year, namely Wae Ruhu and Wae Batu Merah . The shape of the research location is low hill with a slope of 15-30% and an altitude of 125-127 meters above sea level. Based on the geological map of the island of Ambon scale 1: 100,000 by Dr. RDM Verbeek and W. van den Bos (1898), the research location is in a loss material formation (Kim et al., 2021).

The climate pattern in the study area is a local rainfall pattern that is different from most other regions in Indonesia which generally have moonson and equatorial rain patterns (Laimeheriwa, 2014). The rainy season in the study area lasts from May to August while the dry season lasts from November to February. March-April and September-October are transitional periods (transitional) between the two seasons; namely March-April is the transition period from the dry season to the rainy season and September-October is the transition period from the rainy season to the dry season (Noviyanto et al., 2020). The main characteristic of the climate in this region is the high rainfall with an average of 3,901 mm. The peak of rainfall occurs in May, June/July (average 545.3 – 839.5 mm), while November is the driest month in 10 years with an average rainfall of 73.6 mm.

Land use and land cover at the study site included scrub and secondary dryland forest with eucalyptus and cypress top cover, and ferns and alang-alang underland cover (Lalitha et al., 2021).

The results of soil observations in profiles 1 and 2 with the Kambik marker horizon also indicate that the leaching process has taken place in that area. This process can occur because the lateral movement of water is going well so that there is a seapage of groundwater from the ground water which causes no accumulation in the B horizon but a Kambik B horizon is formed which is a B horizon with less clay content compared to the layer above. or below. The soils found have differences in clay content that are not too significant in each layer. Another indication of the occurrence of this process is the washing of bases from the top layer down to form a Bw horizon (cambic horizon).

The soil unit found was Kambisol soil type determined based on the National Soil Classification System (Djaja Subardja et al., 2014);(L. Wang & Song, 2022).

### *Soil Physical Properties*

*Particle Distribution and Soil Texture*

The results of the texture analysis show that there are five soil texture classes based on the USDA, namely slightly coarse (sand loam), medium (clay and sandy clay loam) and moderately fine (clay loam, sandy loam). There is a diversity of texture classes at the landslide point, namely slightly smooth, medium and slightly rough (Rakuasa & Rifai, 2020);(Sunbul et al., 2021). The higher the clay content or the finer the texture of the soil, the more micro-pore spaces are formed so that it is easy to become saturated when it rains. Landslides will occur if there is an accumulation of water on the ground that is on a wavy to very steep slope, because it will increase the load on the slope and trigger landslides (Rahmaniah et al., 2020).

***Soil Particle Density***

Based on the results of the analysis of soil samples taken at the research location, the largest distribution of soil particle density was at P 2 L 3 at 2.63 and the smallest at P 1 L 1 at 2.26, presented in Figure 2. The increase in soil particle types due to increased clay content in the lower layer, so that the grain size of the soil is getting finer, and the soil surface area is wider. As a result, there is more water in the soil and the slope load is increasing and the potential for landslides is increasing (Osok et al., 2018);(Anda et al., 2021)

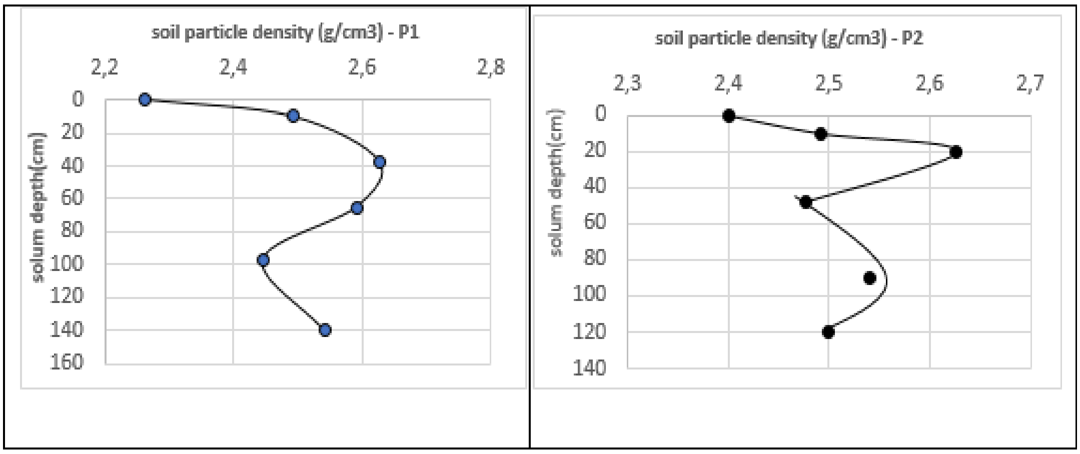


*Figure 2. Specific Gravity of Particles at location 1 (a) and location 2 (b)*

***Pore Distribution and Pore Ratio***

Based on the results of the analysis of soil samples taken at the research location, the largest distribution of soil pores was at P 2 L 1 at 60.12% and the smallest at P 1 L 3 at 29.36%. Presented in Table 1 and Figure 3. The presence of soil pore space is a medium for air to support root respiration. Micro activity, organisms and application of nutrients, soil porosity also greatly affects the infiltration rate. In addition, porosity is very influential on the movement of water in the soil.

*Table 1. Pore Distribution of Research Sites*

| No | Sample Code | Ground Oven Dry Weight | Volume Ring Sample | Soil Fill Weight (g/cm) | Particle Density Soil (g/cm$^3$) | Pore Distribution % |
|---|---|---|---|---|---|---|
| 1 | $P_1 L_1$ | 217 | 176.6 | 1.2 | 2.26 | 45.69 |
| 2 | $P_1 L_2$ | 256 | 190.4 | 1.3 | 2.49 | 46.07 |
| 3 | $P_1 L_3$ | 302 | 162.8 | 1.9 | 2.63 | 29.36 |
| 4 | $P_1 L_4$ | 281 | 185.5 | 1.5 | 2.59 | 41.54 |
| 5 | $P_1 L_5$ | 247 | 167.3 | 1.5 | 2.45 | 39.65 |
| 6 | $P_1$ BI | 271 | 176.6 | 1.5 | 2.54 | 39.62 |
| 7 | $P_2 L_1$ | 178 | 185.9 | 1.0 | 2.40 | 60.12 |
| 8 | $P_2 L_2$ | 262 | 176.6 | 1.5 | 2.49 | 40.49 |
| 9 | $P_2 L_3$ | 267 | 181.0 | 1.5 | 2.63 | 43.85 |
| 10 | $P_2 L_4$ | 281 | 180.5 | 1.6 | 2.48 | 37.16 |
| 11 | P2 BI _ | 261 | 181.0 | 1.4 | 2.54 | 43.27 |

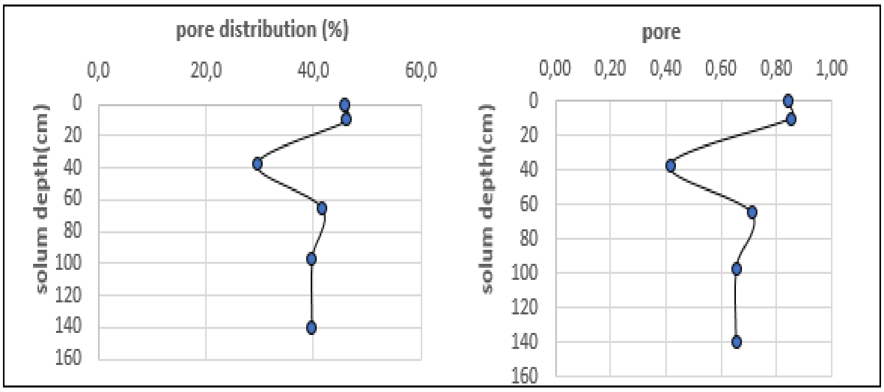


*Figure 3. Pore Distribution in Research Sites 1 (a) and 2 (b)*

Table 2 and Figure 4 show that the largest distribution of soil pore ratios is at P 2 L 1 at 1.51% and the smallest at P 1 L 3 at 0.42%. This is in line with the distribution in both soil profiles, the higher the soil pore, the larger the pore ratio and vice versa.

*Table 2. Pore Ratio of Research Sites*

| No | Sample Code | Soil Fill Weight (g/cm) | Soil Particle Density (gcm-3) | Vs (Soil Volume) | Vf (Pore Volume) | Pore Ratio % |
|---|---|---|---|---|---|---|
| 1 | $P_1 L_1$ | 1.2 | 2.26 | 95.93 | 80,70 | 0.84 |
| 2 | $P_1 L_2$ | 1.3 | 2.49 | 102.70 | 87.73 | 0.85 |
| 3 | $P_1 L_3$ | 1.9 | 2.63 | 114.98 | 47,80 | 0.42 |
| 4 | $P_1 L_4$ | 1.5 | 2.59 | 108.42 | 77.03 | 0.71 |
| 5 | $P_1 L_5$ | 1.5 | 2.45 | 100.98 | 66.35 | 0.66 |
| 6 | $P_1$ BI | 1.5 | 2.54 | 106.64 | 69.98 | 0.66 |
| 7 | $P_2 L_1$ | 1.0 | 2.40 | 74.14 | 111.76 | 1.51 |
| 8 | $P_2 L_2$ | 1.5 | 2.49 | 105.11 | 71.52 | 0.68 |
| 9 | $P_2 L_3$ | 1.5 | 2.63 | 101.66 | 79.38 | 0.78 |
| 10 | $P_2 L_4$ | 1.6 | 2.48 | 113.45 | 67.10 | 0.59 |
| 11 | P2 BI _ | 1.4 | 2.54 | 102.71 | 78.33 | 0.76 |

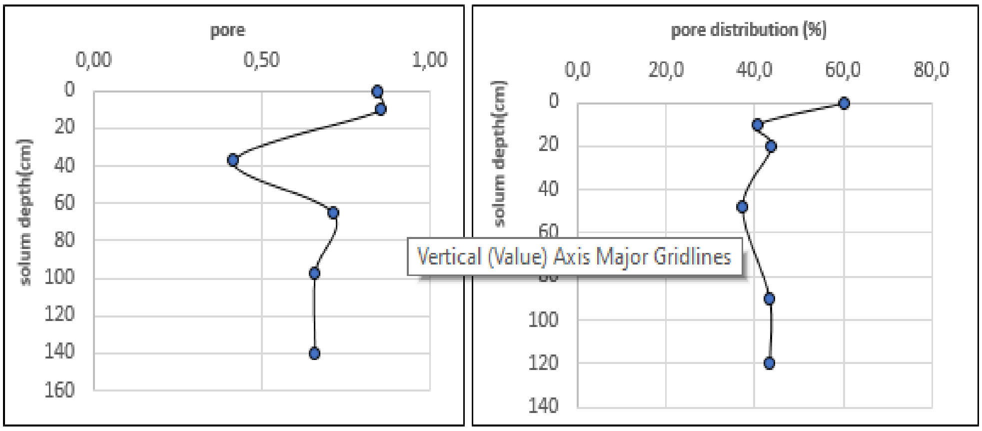


*Figure 4. Pore Ratio in Research Locations 1 (a) and 2 (b)*

The pore distribution and pore ratio in the study sites (P1 and P2) are high (average >40%) so that it can be said that the study location is a landslide-prone area because the soil has a large porosity value (Rustam et al., 2015).

Based on physical properties, namely soil particle distribution, water content, water content, pore distribution and pore ratio, supported by lithological conditions, geological structures, slopes and land use, the study sites, both location – 1 and location -2, are susceptible to landslide event.

The results of this study indicate that at both locations there was an increase in soil density due to increased content in layers 3 and 4 of the soil solum. As a result of the denser the soil, the higher the density, which means it is more difficult for the soil to carry water, because the density is an indication of the density of the soil. The denser the soil, the higher the weight of its contents, which means it is more difficult to pass water, resulting in water accumulation so that in layers 3 and 4 there is an increase in soil load due to the accumulation of water that fills the soil pores.

Total porosity is the easiest initial indicator to determine whether the soil structure is good or bad. Soil porosity will be high if the organic matter content in the soil is also high. Soils with crumb and granular structures have higher porosity than soils with dense structures. In addition, porosity reflects the level of ease of the soil to pass water flow (permeability) or the speed of water flow to pass through the soil mass (percolation). With decreasing porosity and pore ratio in layers 3 and 4, the permeability is also slower.

### *Permeability*

Results Measurements of soil samples at the research site showed that the level of soil permeability of the soil types found was categorized into 3 permeability classes, namely very slow (0.009-0.050 cm/hour), rather slow (0.157-0.211 cm/hour), and slow (0.157). - 0.342 cm/hour) (Table 3 and Figure 5). Many factors affect the level of soil permeability, especially texture, structure, aggregate stability, porosity, pore size distribution, pore continuity and organic matter content (Tutuarima et al., 2021). Soil permeability in both study sites (profile) was high in the top layer (0-20cm) due to the high organic matter and sandy soil texture, resulting in the formation of aggregation of soil grains into crumbs, and increased soil porosity (Talakua and Osok, 2019). In the lower layer there is an increase in clay so that clay permeability slows down. This is caused by the pore size in clay-textured soils that have small pore spaces. According to Isra (2019) particle distribution affects the pore size which will determine whether the soil has low or high permeability, and the permeability can approach zero if the soil pores are very small, such as in clay. Therefore, the slower the water seeps into the soil body, the more water is stored in the soil body so that the slope load is higher and the potential for landslides to occur. In the study area, both soil profiles showed slow to very slow soil permeability. Ningtyas, et al., (Setyanta & Setiadi, 2011) said that the slower the permeability of the soil, the more water retained in the soil so that the soil becomes saturated. Soil that is saturated with water has the potential to develop if the rain is heavier and longer. This saturation causes the soil grains to be compressed, causing the soil mass to move.

*Table 3. Classification of Soil Permeability*

| Class | Permeability (cm/hour) |
|---|---|
| Very slow | <0.0125 |
| Slow | 0.0125-0.5 |
| Slighty Slow | 0.5-2.0 |
| Currently | 2.0-6.25 |
| Kinda Fast | 6.25-12.5 |
| Fast | 12.5-25.5 |
| Very Fast | >25.5 |

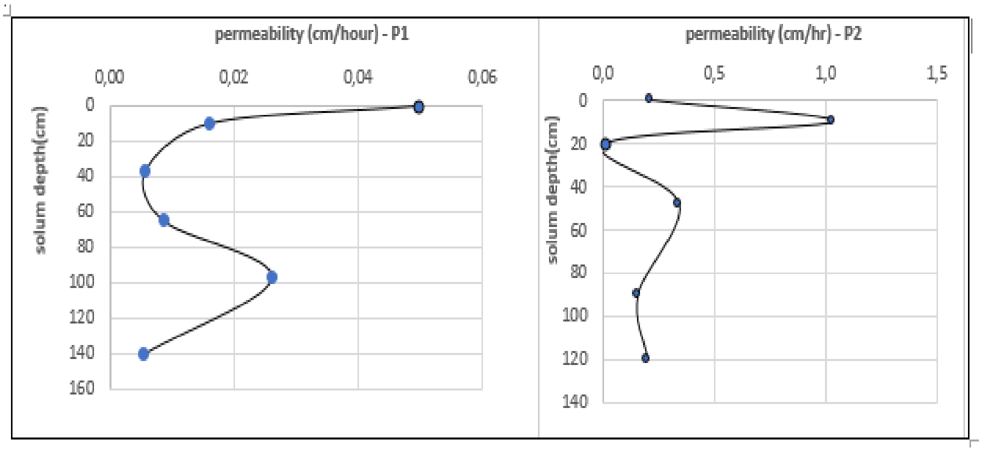


Figure 5. Permeability at location P1 and location P2

***Soil Chemical and Mineral Properties***

*Chemical Properties*

The chemical properties of the soil analyzed were texture, exchanged cations (Ca, Mg, K and NaMe/100 gr), CEC (%) and KB (%).

The concentration of bases in the soil such as calcium, magnesium, potassium and sodium cations is a soil cementing agent that helps the process of aggregation of soil constituents to form a better soil structure (not crumb). This means that the bases in the soil help the aggregation process in the soil. However, calcium and Mg which are divalent cations have higher aggregation strength than monovalent K and Na cations. This means that the more Ca and Mg in the soil, the more binds and neutralizes the negative charge of the clay so that a primary aggregation process occurs, while the monovalent K serves as a soil cementing agent. On the other hand, Na is dispersing soil aggregates.

*Clay Minerals*

Based on the results of mineral analysis on the two profiles taken as representatives, it shows that the dominant mineral found is clay mineral type 1: 1, namely kaolonit.

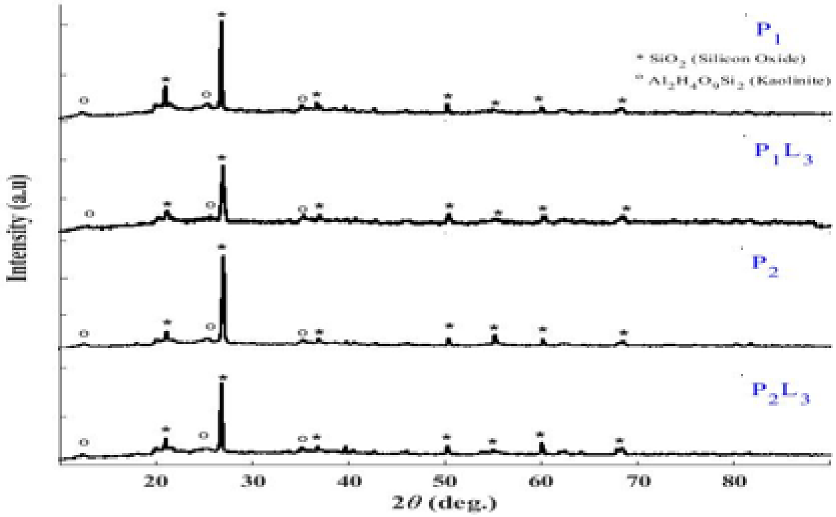


*Figure 6. Distribution of kaolinite minerals at Locations 1 and 2*

Table 4. Percentage of Quartz and Kaolinite in the landslide material sample

| No | Sample | Low Quartz (%) | Kaolinite (%) |
|---|---|---|---|
| 1 | P1 | ~54.82 | ~43.21 |
| 2 | P1L3 | ~27.41 | ~70.61 |
| 3 | P2 | ~27.31 | ~70.71 |
| 4 | P2L3 | ~30.22 | ~66.82 |

The results showed that there was an increase in clay content in layers 2, 3 and 4 at both observation locations. Clay has fine grains that have the properties of cohesion, plasticity, does not show dilatation properties because it has a grain weight of finer soil than 0.002 mm. The clay minerals found at the research site (P1 and P2) are of the 1:1 clay type, namely kaolinite clay minerals (Figure 6). Kaolinite which has a low swelling and shrinking capacity has low water absorption so that there is no accumulation of water in the soil, therefore, the stability of slopes with smooth soil texture is strongly influenced by the amount of water that seeps into the soil which can increase soil weight (D Subardja et al., 2016). The results of laboratory analysis show that the kaolinite mineral at the study site is a deposit that has not been well consolidated (mixed with weathering-resistant quartz - Table 4), so the presence of these two minerals causes the study area to become an area prone to landslides. According to Evelyn and Makarim (2018) kaolinite can be an indication of a high plasticity index content, but it cannot be used as a reference to determine the expansive potential, because the expansive potential is usually associated with the presence of montmorillonite (or other smectite minerals) which are the main triggers for expansive properties. Kaolinite minerals and also several other minerals such as illite, smectite also affect the quality of the soil which causes a decrease in the quality of the slopes, this is because these minerals have high plasticity properties (Rahmaniah et al., 2020).

## Conclusion

The occurrence of landslides at the IAIN Campus location is influenced by the physical properties of the soil, namely the distribution of clay particles (fine) which tends to increase in the lower layers followed by an increase in the distribution of fine soil pores which results in decreased soil permeability or slower movement of water in the soil resulting in accumulation of content in the soil. bottom layer (horizon 3 and 4). Meanwhile, the presence of kaolinite is the driving force behind the entry of water into the lower layer of the larger soil profile because it is not well consolidated and mixed with weathering-resistant quartz. This condition reduces slope stability because kaolinite also has high plasticity properties

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