ANALYSIS OF LANDSLIDE CAUSES IN NANGGERANG VILLAGE, SUKASARI SUB DISTRICT, SUMEDANG REGENCY THROUGH IDENTIFICATION LANDSLIDE SLOPE MATERIAL CHARACTERISTICS

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ABSTRACT

On February 3, 2024, a landslide occurred in Nanggerang Village, Sukasari District, Sumedang Regency, West Java Province. The landslide took place on the slopes of local farmland. This event was investigated through an analysis of the characteristics of the landslide material collected immediately after the landslide to determine its cause and mechanism. The landslide slope was divided into three units based on the type and degree of weathering: topsoil (OH), silt soil (MH), and weathered tuff rock. Three undisturbed samples were used in laboratory experiment to determine the materials' physical characteristics. The physical characteristics of the two soil units, which included silt-sized grains, a specific gravity of roughly 2.6, a unit weight ranging from 21 to 45 kN/m^3, and a plasticity index of 16 to 20, were not substantially different, according to the results of the laboratory tests. For the tuff rock, the unit weight was 17.31, water content 48.8, and specific gravity 22.7. The laboratory test results, and studio analysis found that the high water content in the soil due to rainfall caused the two soil units to exceed their liquid limit, resulting in a translational (arc) landslide. The presence of clay minerals due to weathering acted as a catalyst for the landslide. The addition of water from heavy rainfall made the material more fluid, changing the type of landslide to an earth flow.

Keyword: Back Analysis, Physical Properties, Landslide, Nanggerang Village, Clay Minerals

INTRODUCTION

The landslide that occurred in Nanggerang Village, Sukasari District, Sumedang Regency, West Jawa on February 3, 2024, caused economic losses for the local community. This event resulted in the destruction of local farmland and the connecting road between two villages. Finding the reason for landslides through a retrospective analysis of the physical properties of the slope-forming material is the aim of this research.

The dominance of volcanic soil, which tends to be loose, and intense climate change are among the causes of landslides, with around 24.37% of all disasters in Indonesia over the past decade being landslides (Anonim, 2024b). Landslides frequently occur in the mountainous regions of Java, which are tectonically active, and often result in fatalities and significant economic losses every year (Lahai et al., 2021). Many landslides in mountainous areas are caused by high rainfall on slopes, which worsens soil resistance, increases soil moisture, and raises pore pressure, among other factors(D'Ippolito et al., 2023). Therefore, analysing the causes of landslides in such areas is crucial for proper management, mitigation, and measures to reduce risk.

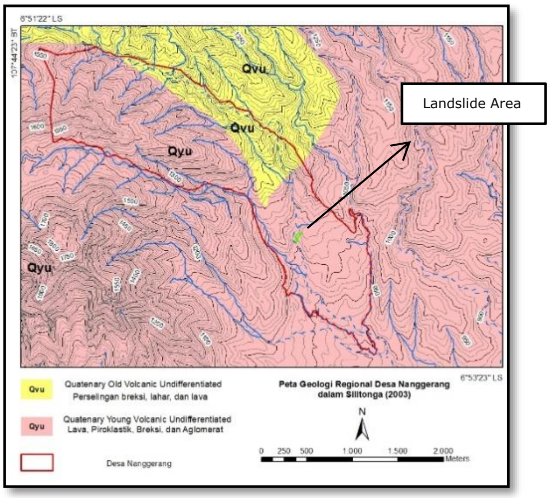

Figure 1. The Regional Geological Map of Nanggerang Village according to Sunardi & Kimura (1998)

The study area is included in the Regional Geological Map of Bandung Sheet in . These materials are partly derived from the eruptions of Mount Tangkubanparahu and partly from Mount Tampomas. This unit forms ridges and low valleys covered by reddish-gray soil.

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Sukasari is also part of the foothills of Mount Manglayang, which broadly features the continuity of the Lembang Fault trending NNW-EES (North-Northeast to East-Southeast). According to Sunardi & Kimura (1998), the eruptions of Mount Sunda and Mount Tangkubanparahu caused this fault to emerge. This Suggests that the study region is situated in a fault zone that is active, which may make slope instability worse.

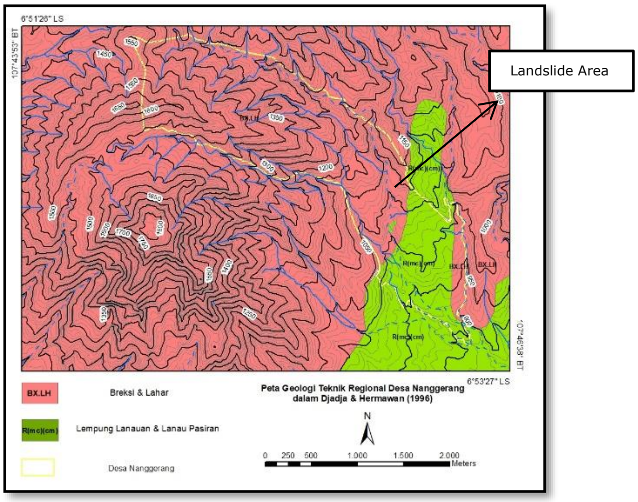

Figure 2. The Regional Engineering Geology Map of Nanggerang Village according to Djadja & Hermawan (1996)

Based on the Engineering Geological Map by Djadja & Hermawan (1996) (Figure 2), the study area is situated in the BX, LH, and R(mc)(cm) units. The BX and LH units consist of agglomerate, lapilli, and lava, which are volcanic deposits from Mount Tangkubanparahu and Mount Tampomas. The R(mc)(cm) unit is residual soil resulting from the weathering of tuff sandstone, tuff, conglomerate, agglomerate, lapilli, and breccia, with a thickness ranging from 2 to 20 meters.

RESEARCH METHOD

The research began with an observation of the landslide body to determine representative sampling points. This was followed by geological and engineering geological mapping around the study slope to support the argument for dividing the units within the landslide body. Three undisturbed samples representing the divided horizons were then collected. General identification of soil and rock in the field was also carried out by observing material descriptions, the degree of weathering zones, and slope geometry measurements.

Following the collection of the material samples, tests in the lab were carried out to evaluate the material's physical characteristics, including:

1. **Unit Weight** The mass of substance, including the pore spaces inside it, per unit volume is known as its unit weight. As per Brady & Weil (2008), a material's unit weight is contingent upon its texture, structure, and level of compaction.
2. **Moisture Content** Hillel (1998) indicates that soil moisture content influences numerous physical and chemical properties of the material. Moisture content is the quantity of water contained in the substance, expressed as percentage of the weight of the soil.
3. **Atterberg Limits** The liquid, plastic, and shrinkage Atterberg limits are the water content thresholds at which soil undergoes a consistency state transition. Terzaghi et al. (1996) state that soils are categorized using consistency limitations.
4. **Specific Gravity** The mass of a material divided by the mass of an equivalent volume of water is knows as specific gravity. According to Holtz & Kovacs (1981), specific gravity plays a significant role in identifying a variety of a material's physical characteristics.
5. **Grain Size** Grain size or particle size distribution describes the proportion of various particle sizes within the soil. According to Bowles (1992), grain size analysis is used to identify soil texture and determine soil drainage characteristics.
6. **Swelling Potential** Swelling potential is the ability of soil to expand when it absorbs water (Chen, 1975).

After obtaining the laboratory test results on the physical properties of the samples, an analysis was conducted to reconstruct the causes of the landslide.

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RESULT AND DISCUSSION

Based on field observations and laboratory tests, the research area is divided into three units: topsoil OH, MH soil, and weathered tuff rock. The slope is highly saturated. The slope location is also situated on volcanic products in the form of tuff. Yalcin & Bulut (2007)explain that the type of lithology that makes up the slope is a major factor controlling slope stability due to the differences in physical and mechanical properties. Each lithology has varying compositions and structures that affect the strength of the slope. The stronger the slope-forming material, the more resistant it is to driving forces (Mersha & Meten, 2020).

Topsoil OH is dark brown in color and tends to be cohesive with a soft strength. It has silt-sized particles, is highly plastic, has a relatively moist water content, and is relatively homogeneous. This unit has a thickness of 0.8 meters and contains remnants of vegetation, as observed in the landslide body. The weathering level of this soil type, according to Anonim (1981), is residual soil (decomposed rock = 100%).

MH soil itself has a thickness of ~5 meters and has a red color resulting from the oxidation and weathering of tuff rock. This soil tends to be cohesive, soft, plastic, moist, homogeneous, and has silt-sized particles. The weathering level of this soil type, according to Anonim (1981), is completely weathered (decomposed rock > 90%).

Both types of soil, namely topsoil OH and MH soil, are consistent with previous research by Iqbal et al. (2020)and Zakaria et al. (2018), where the soil that dominates the research area is MH/OH soil with silt-sized particles.

Figure 3. Spheroidal weathering in tuff units

Meanwhile, the weathered tuff rock unit has a thickness of >5 meters. The unit exhibits an onion-skin weathering structure (Figure 3). Based on Schmidt Hammer tests, with 30 trials, this unit has an average UCS value of 12.7 MPa, and it is cohesive, brittle, moist, and homogeneous. The weathering level of this unit, according to Anonim (1981), is highly to moderately weathered.

Table 1. The values of physical properties of the three units from laboratory test

Units	Unit Weight	Water Content	Specific Gravity	Grain Size	Hydrometer Analysis		Atterberg Limit			Activity Number	Swelling Potential
					%Silt	%Clay	Liquid Limit	Plastic Limit	PI		
Top Soil OH	21,418	63,891	2,620	Silt	65,917	34,082	60	41	20	0,586	7,14
Tanah MH	21.153	45,712	2,623	Silt	60,2	39,799	53	38	16	21.153	7,14

Units	Unit Weight	Water Content	Specific Gravity	Degree of Saturation	Porosity	Voit Ratio
Weathered Tuff	17,318	41,81	2,704	98,13	78,89	0,8

Based on the Table 1, the physical properties of the two soil materials are not significantly different, with the bulk density of both units ranging around ~20 Kg/m3; specific gravity around ~2.6; the ratio of %silt to %clay is 1:2; plasticity index ranges from 12-20 (topsoil contains organic material that can increase the plasticity index (Hugar & Soraganvi, 2014); water content ranges from 50% to 64%.

The rock unit has a natural bulk density of 17.3 kN/m3 and an original water content of 41.81%. Although this rock is classified as young (Quaternary age) according to Silitonga (2003), it has undergone quite intense weathering. This is because weathering in tropical regions is relatively more intense or faster compared to other regions (Nelson,

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2015). The weathering can also be observed through thin sections of tuff rock samples in Figure 4.

Clay minerals were categorized by Das & Sobhan (2018) according to activity number, plastic limit, and percentage of liquid limit (Table 2). Specific values for the liquid limit, plastic limit, and activity number are typically found in clay minerals.

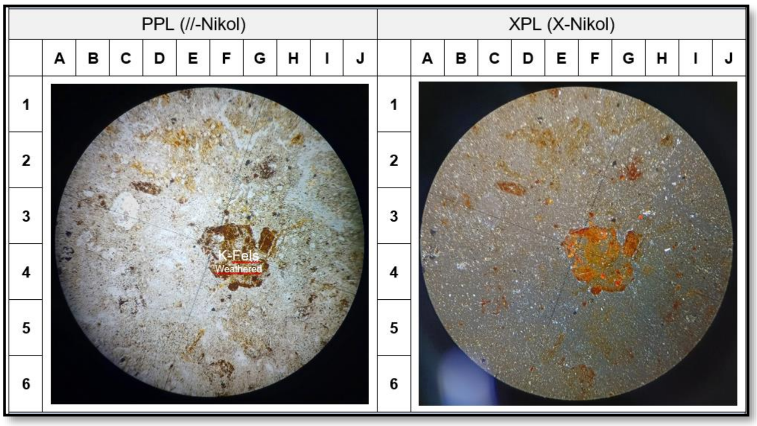

Figure 4 . Microscopic appearance of the tuff unit section (40x magnification)

Table 2. Values for the activity number, plastic limit, and liquid limit of different clay minerals

Mineral	Liquid Limit	Plastic Limit	Activity Number
Kaolinite	35 – 100	20 – 40	0,3 – 0,5
Illite	60 – 120	35 – 60	0,5 – 1,2
Montmorillonite	100 – 900	50 – 100	1,5 – 7
Halloysite (hydrated)	50 – 70	40 – 60	0,1 – 0,2
Halloysite (dehydrated)	40 – 55	30 – 45	0,4 – 0,6
Attapulgite	150 – 250	100 – 125	0,4 – 1,3
Allophane	200 - 250	120 - 150	0,4 – 1,3

Through the above table, the clay minerals in the three soil units can be determined. Table 1 shows that the topsoil OH unit is made up of illite clay minerals since it has liquid limit of 60, plastic limit of 41, and activity number of 0.58. According to the same table, the MH soil unit has a liquid limit of 53, plastic limit of 38-40, and activity number of 0.301-0.402, indicating that this unit contains kaolinite clay minerals. The reworked MH unit has liquid limit of 53, plastic limit of 40, and activity number of 0.292, indicating that this unit consists of dehydrated halloysite clay minerals.

Bhandary & Yatabe (2007) explain that clay minerals can act as both a cause and a catalyst in the occurrence of landslides. The impact of clay minerals on slope stability is controlled by the type of clay mineral, each having specific characteristics. According to Akisanmi (2022), which explains the properties of clay minerals, dehydrated halloysite has a lower shear strength compared to the two clay minerals mentioned above, followed by kaolinite and illite.

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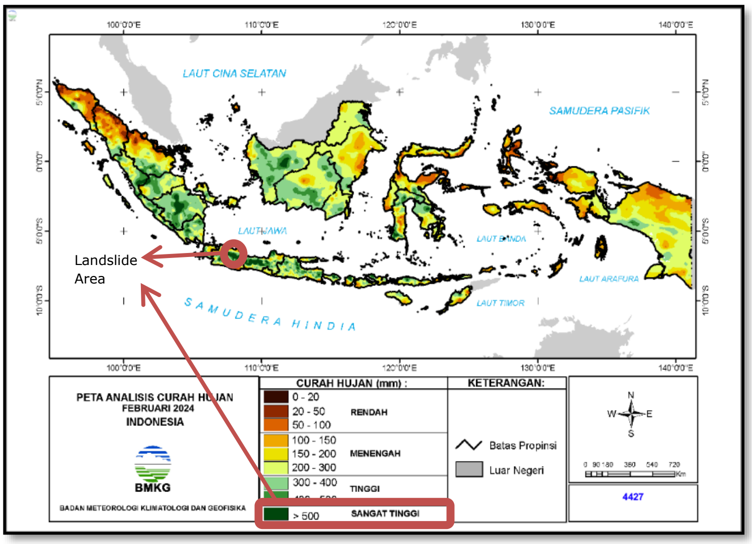

Figure 5. Rainfall in Indonesia in February 2024 (Anonim, 2024a)

According to data from Anonim (2024a), rainfall in Sumedang Regency, West Java Province, during the month of occurrence, fell into the very high category (>500mm). The high rainfall underlies the high water content in each sample unit of material. High rainfall intensity and sufficiently hot daytime temperatures accelerate weathering. This, coupled with chemical weathering, also underlies the occurrence of 'onion-skin' weathering (Thomas et al., 2005) in the rock unit, causing differences in physical properties values in each rock sample.

The moisture content also affects the potential for slope materials to expand. The soil expansion potential test results (Table 4.3), using Anonim (1978), show a potential swelling index (FSI) of 7.14% for topsoil OH and MH soil. According to Chen (1975) classification, the expansion potential of these two units falls into the medium class (3%-10%). These expansion potential test results validate the previous liquid limit results. All three soil units will liquefy when the water content is between 53% and 60%, so the soil will not expand excessively.

According to the description given above, the landslide that is happening on the study slope is translational and earth flow landslide, meaning that failure results from the topsoil OH and MH soil units' water content exceeding their liquid limit. The presence of clay minerals and the strength differences between MH soil and tuff rock act as catalysts for the occurrence of arcuate-type landslides. High rainfall further saturates the landslide material, and the type of landslide changes to a flow characterized by Earth Flow composed of a high proportion of fine material.

CONCLUSION

Laboratory test results show that the water content in each unit is very high (36% - 64%), indicating a high level of saturation in the slope-forming material. This is corroborated by the fact that the research area saw extremely heavy rainfall during the time of the landslide occurrence – more than 500mm in February. The increase in water content in the slope material reduces the index properties of each slope material, leading to failure. Laboratory test results also show that the soil expansion level (topsoil OH and soil MH) is moderate, which is one of the causes of the landslide. The presence of clay minerals from weathering acts as a catalyst in the occurrence of the landslide.

The landslide mechanism can be summarized as follows. Intensive weathering processes, the presence of clay minerals, and high rainfall levels cause the soil to expand beyond its liquid limit, resulting in a translational (arc) type landslide. The high water content makes the landslide material more saturated and creates an earth flow type of movement, dragging the swept material to a lower elevation.

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