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Research article

Landslide potential in Cihanjuang, Cimanggung, Sumedang, West Java Province

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ABSTRACT

Landslides had occurred in the Cihanjuang area, Cimanggung, Sumedang Regency, West Java on January, 9th 2021 with 40 fatalities and several buildings severely damaged. This area is in the form of hills with a fairly steep slope and housing is built on it. Geologically, the research area is composed of Undecomposed Young Volcanoes (Qyu) in the form of tuffaceous sand, lapilli, breccias, lava, and agglomerates. The research aims to determine the potential and volume of landslides. The research methods used were geotechnical testing and topographical mapping. Geotechnical tests carried out were water content, specific gravity, sieve analysis, hydrometer, and direct shear strength. The geotechnical test results showed that water content: 16.37% – 31.26%, cohesion: 59.2 kPa – 112.7 kPa, and internal friction angle: 6.30° – 30.50°, percentage of gravel and sand 11.10 % – 34.90 %, percentage of silt and clay 65.10 % – 88.90 %. According to USCS, this soil sample includes the MH-CH-OH classification. Topographical mapping was carried out, covering an area of 7.006 hectares. The internal friction angle is relatively steep, and the percentage of gravel and sand is quite high, so water infiltration becomes easy, so the Cimanggung area has a high potential for landslides. From the topographic mapping, the volume of the landslide was around 161.981 m³. To maintain slope stability and avoid landslides, apart from planting strong-rooted plants in areas with high elevations, they also manage the drainage by making waterways on the northwest and southeast sides of the steep slopes to the main road.

INTRODUCTION

The research area is in Cihanjuang village, Cimanggung sub-district, Sumedang Regency, West Java at coordinates 6°51'33.0" L - 6°59'38.6" L and 107°42'26.2" E - 107°58 '44.5 E. In general, this location is a hilly area with slopes of 4° - 8°, rather steep: 8° - 16°, and steep: 16° - 35° located at an altitude between 700 – 750 m above sea level (Sumaryono, 2021). On January 9th, 2021, there was a landslide in the area. Natural and non-natural factors triggered the occurrence of landslides. This disaster caused fatalities and several houses were badly damaged, the provisional data was that the number of victims who died was 40 (Maulana, 2021a).

Previously this area was a former stone quarry and landfill, then it was leveled and made into housing. Geologically, the soil and rock structures in the Satria Bumintara Gumilang (SBG) Residential area of Cihanjuang village are included in the Qyu volcanic rock. In the Geological Map issued by the Geological Agency of the Ministry of Energy and Mineral Resources, 2021, Qyu volcanic rock is a product of young volcanic rock that cannot be separated, so it is still mixed between hard and soft layers. Because it is a young volcanic rock, this layer of soil and rock is quite vulnerable. The vulnerability has been spotted before at some point. The southeastern boundary of the housing is facing a cliff that is bounded by a water channel. It is suspected that during prolonged heavy rains, the flow of water seeps into the ground and forms slip planes that allow landslides to occur. Some of the houses bordering the cliffs also look cracked. This indicates that the area has the potential for land shifts, which trigger landslides, as well as the presence of new settlement projects built on the cliffs to the north and southeast of the SBG housing complex. Heavy equipment traffic activity on top of a cliff also increases the potential for landslides. Geotechnically, this activity weakens the bonds of existing soil grains, so there is the potential for landslides to occur. Previously, the landslide area was a swale area planted with trees, then it was cut down, and housing was made at the bottom (Maulana, 2021b).

In this research activity, testing of soil characteristics was carried out which included geotechnical testing and topographical mapping. With the parameters of the soil test results, the behavior of the soil samples can be identified. One of the factors that influence changes in soil behavior is the increase in soil water content due to the high intensity of water coming from rainfall. Most of the landslides occur during the rainy season due to increased pore water pressure on the slopes (Leroueil et al., 2009).

Infiltration of water into the soil affects the strength of the soil. To obtain the value of soil strength, a direct shear strength test can be carried out in the laboratory. The parameters obtained from this test are the cohesion value (C), and the internal friction angle (Ø) (Priyono, 2015).

The scope of the research is: conducting field investigations, taking soil samples, testing soil samples in the laboratory, and analyzing test results. Geotechnical testing of soil samples in the laboratory is as follows: testing for water content, specific gravity, particle size analysis, hydrometer, and direct shear strength. Topographical mapping was also carried out in the landslide area.

The research aims to determine the potential and volume of landslides. The benefit to be achieved in this activity is that it can provide an optimal contribution to the area regarding the importance of slope failure research. This is expected to be a general reference source regarding the correlation of the parameters of the geotechnical test results of soil samples in the laboratory on rainfall intensity. It can also estimate the volume of landslides and the direction of the slide to anticipate landslide hazards.

METHODOLOGY

Research locations

The research area is located in the village of Cihanjuang, Sumedang Regency (Figure 1), about 34 kilometers from Bandung. It can be reached by two-wheeled or four-wheeled vehicles via the Nanggeleng – Cirahayu road or the Padalarang – Cileunyi toll road.

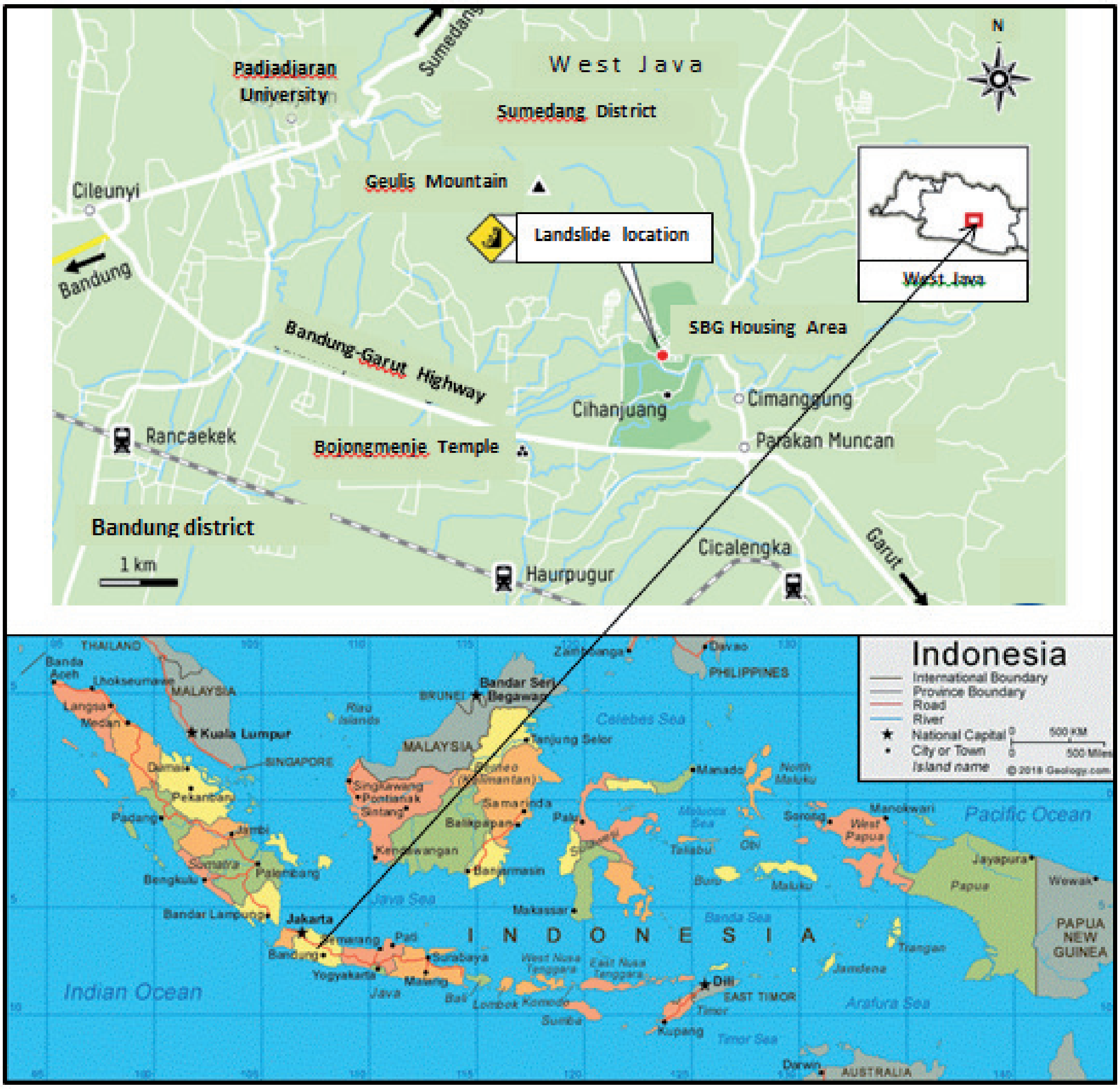

Figure 1 Location of the research area in the Sumedang Regency of West Java Province, Indonesia (Google Maps, 2023)

Topographical mapping

Topographical mapping can be defined: as a scientific discipline that includes all methods of measuring and gathering information about the earth and the physical environment, processing information, and disseminating various products produced for various needs (Syaripudin, 2023). The map is a miniature conventional representation of the natural and man-made physical appearance of part or all of the earth's surface on a flat plane with a certain scale (Rahman et al., 2019).

Topographic mapping was carried out using a GPS device with the GARMIN brand type GPSMAP 64s to map an area of around 7.006 hectares. Elevation differences are marked with contour lines at 1-meter intervals. A map of the research location is made with a scale of 1:1000 so that it can be more detailed in predicting the shape of the land when there is ground movement. Topographic mapping not only depicts 2D information from coordinate points (X and Y values) but also informs the 3-dimensional shape of the earth projected in 2D marked with contour lines Z values as shown in Figure 2.

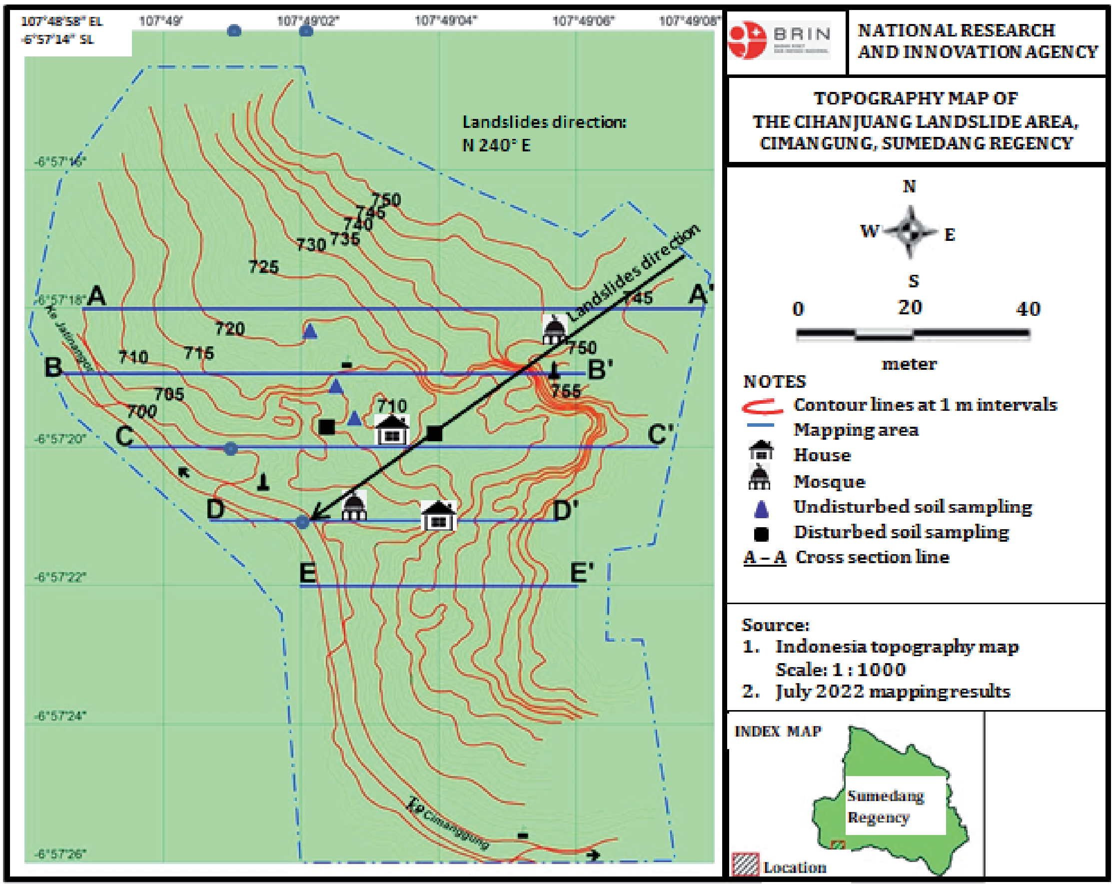

Figure 2 Topographic Map (mapping data taken on July 2022)

All section lines (A-A’, B-B’, C-C’, D-D’, and E-E’) are used to calculate the volume of landslides in each section line. From the topographic map, the average slope is 23°. The direction of the slide is N 240° E, this was obtained based on direct measurements at the landslide location using GPS. Which leaves a critical slope with a slope of 80° (see Figure 2, sections A-A’, B-B’, C-C’, D-D’, and E-E’). The critical slope extends and borders residential land within a radius of ± 10-15 meters. The material expansion factor is the ratio of the percentage volume of in-situ material to the volume of loose rock (Herlita et al., 2018). Swell percentages and material load factors for various materials are shown in full in Table 1 as follows: (Rochmanhadi, 2018).

Table 1 Percentage swell and load factor material

Kinds of materials	lb/BCY	% Swell	lb/LCY	Load factor (%)
Bauxite	3200	33	2400	75
Caliche	3800	82	2100	55
Cinders	1450	52	950	66
Karnotit, uranium ore	3700	35	2750	74
Clay	3400	22	2800	82
Dry clay for digging	3100	23	2500	81
Wet clay for digging	3500	25	2800	80
Dry clay and gravel	2800	41	2000	71
Wet clay and gravel	3100	11	2800	80
Young anthracite coal	2700	35	2000	74
Washed young anthracite coal	2500	35	1850	74
Young bituminous coal	2150	35	1600	74
Washed young bituminous coal	1900	35	1400	74

Source: (Rochmanhadi, 2018)

Regional Geological Map

The soil that makes up this slide is contact weathering between volcanic products that have not been degraded, consisting of tuff sand, lapilli, breccias, and agglomerates with cavities between grains that are quite porous and allow water to pass in the northeastern part at a higher elevation compared to weathering of lake sedimentary soil. In the form of tuffaceous clay, tuffaceous sandstone, and tuffaceous gravel with lower porosity and gradation occupy areas with lower elevations. Regional geological mapping is not carried out in the field but only examines the existing regional geological map, as presented in Figure 3.

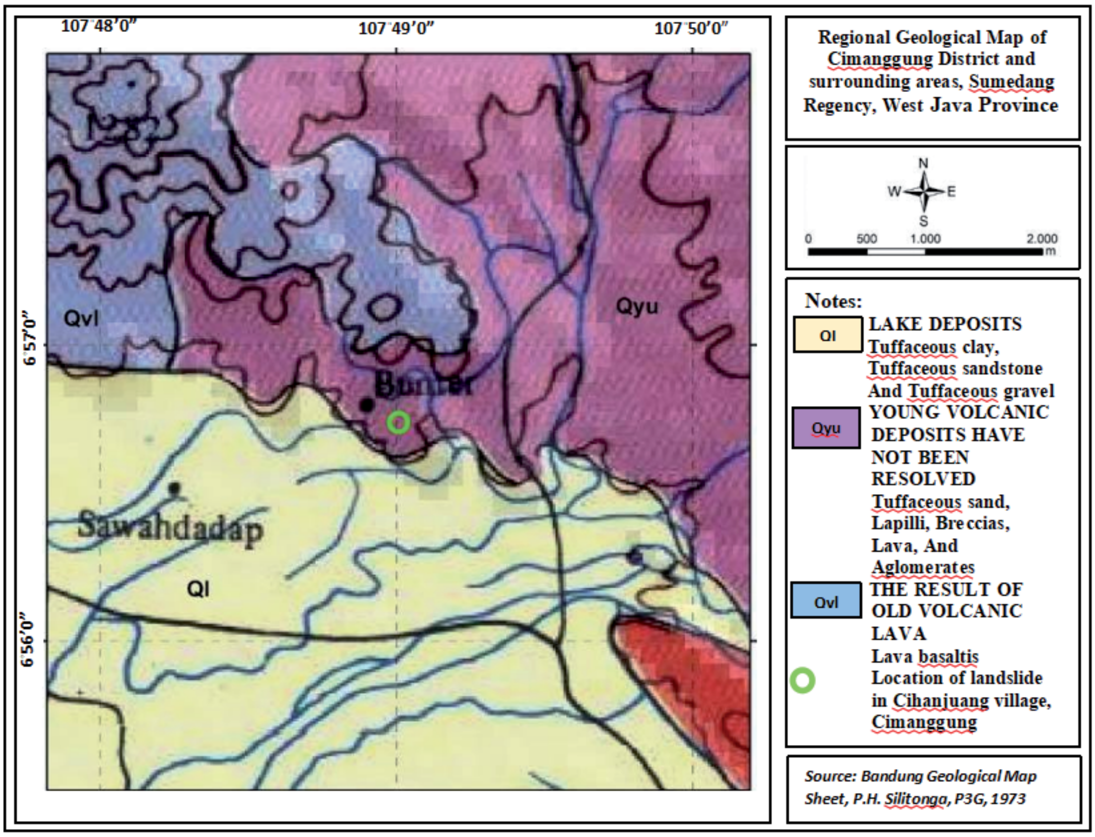

Figure 3. Regional geological map of the landslide area in Cimanggung, Sumedang

For research, soil sampling and topographical mapping were carried out in this area. Soil sampling includes disturbed and undisturbed soil samples with depth 0.50 m – 1.50 m as shown in Figure 4 and Figure 5.

Figure 4. Disturbed soil sampling

Figure 5. Undisturbed soil sampling

Laboratory tests

Geotechnical tests were carried out for the soil samples, namely testing water content, specific gravity, sieving analysis, hydrometer, and direct shear strength. Testing of soil samples was carried out at the Geomechanics Laboratory of the tekMIRA Mineral and Coal Testing Center - Bandung.

Laboratory tests use the following standards: the water content of soil samples to obtain parameters for water content using a reference (ASTM D-2216, 2019). A Specific gravity test to obtain specific gravity parameters using reference (ASTM D 854 – 02, 2006). Sieve analysis test and hydrometer using reference (ASTM D 422-63 (Reapproved 2002), 2007) to obtain the percentage of gravel, sand, silt, and clay (Das, 1995). Direct shear strength test to obtain cohesion parameter (C), and internal friction angle, (Ø) using reference. The results of geotechnical testing of soil samples are presented in Table 2 below.

Table 2 Results of geotechnics soil testing

No.	Parameter	Unit	Sample Code				
			Disturbed and Undisturbed				
			TL-01 DS	TL-02 DS	TA-01 UDS	TA-02 UDS	TA-03 UDS
Physical characteristic							
1.	Water Content	%	16.37	16.87	19.17	31.26	22.91
2.	Specific Gravity	-	2.57	2.57	2.56	2.56	2.57
3.	Hydrometer and Sieve Analysis:						
	Coarse Gravel	%	0.40	0.20	2.30	0.00	1.00
	Fine Gravel	%	10.50	10.70	1.40	0.00	5.10
	Coarse Sand	%	4.90	4.60	2.50	0.00	3.30
	Medium Sand	%	8.60	8.90	2.70	2.00	5.40
	Fine Sand	%	10.30	10.50	5.30	9.10	10.00
	Silt	%	39.50	39.20	32.70	31.50	49.10
	Clay	%	25.80	25.90	53.10	57.40	26.10
Mechanical characteristic							
4.	Direct shear :						
	Cohesion (C)	kPa	112.70	102.20	73.60	59.20	76.80
	Internal friction angle (Ø)	(º)	6.30	6.50	30.50	28.50	23.50

Explanation of the results of soil sample testing Table 2:

The water content of disturbed soil samples TL-01 DS: 16.37 % and TL-02 DS: 16.87 %, while the water content of undisturbed soil samples TA-01 UDS: 19.17 %, TA-02 UDS: 31.26 %, and TA-03 UDS: 22.91 %. The disturbed soil water content is less than the undisturbed soil water content.

Hydrometer and sieve analyses for disturbed soil samples TL-01 DS: gravel 10.90 %, sand 23.80 %, or gravel and sand 34.70 %, silt 39.50 %, clay 25.80 %, or silt and clay 65, 30%. Disturbed soil sample TL-02 DS: gravel 10.90 %, sand 24.00 %, gravel and sand 34.90 %, silt 39.20 %, clay 25.90 %, or silt and clay 65.10 %. Disturbed soil samples TA-01 UDS: gravel 3.70 %, sand 10.50 %, gravel and sand 14.20 %, silt 32.70 %, clay 53.10 %, or silt and clay 85.80 %. Disturbed soil samples TA-02 UDS: gravel 0.00 %, sand 11.10 %, gravel and sand 11.10 %, silt 31.50 %, clay 57.40 %, or silt and clay 88.90 %. Disturbed soil samples TA-03 UDS: gravel 6.10 %, sand 18.70 %, gravel and sand 24.80 %, silt 49.10%, clay 26.10 %, or silt and clay 75.20 %.

For all hydrometer tests and sieve analyses of disturbed and undisturbed soil samples, the range of gravel and sand is 11.10 % - 34.90 %, while silt and clay are 65.10 % - 88.90 %. The test results show that the composition of silt and clay is more than 50%. According to USCS, soil samples with more than 50% silt and clay have the MH-CH-OH classification (Das, 1995).

The cohesion of disturbed soil samples TL-01 DS and TL-02 DS was greater than undisturbed TA-01 UDS, TA-02 UDS, and TA-03 UDS. Meanwhile, the internal friction angle is smaller.

Rainfall analysis

The rainy season with the highest intensity in Sumedang occurs in January, with an average rainfall of 266.8 millimeters/hour. Rainfall intensity is defined as the addition of water content to the soil. The least rainy month in Sumedang occurs in August, with an average rainfall of 37 millimeters/hour. One millimeter of rain means rainwater that falls on an area of one square meter and will have a height of one millimeter if the rainwater does not seep, flow, or evaporate. The threshold values used to determine the intensity of rainfall are as follows: 0 mm/day: overcast; 0.5 – 20 mm/day: light rain; 20 – 50 mm/day: moderate rain; 50 – 100 mm/day: heavy rain; 100 – 150 mm/day: heavy rain; >150 mm/day: extreme rain, (BMKG, 2022).

If short-term rainfall data is not available and only daily rainfall data is available, the intensity can be calculated using the Mononobe formula (Astarini et al., 2022).

$$I = \frac{R_{24}}{24}\left(\frac{24}{t}\right)^{2/3}$$

I = rain intensity (mm/hour)
t = rain duration (hour)
R24= daily maximum rainfall (mm).

RESULTS AND DISCUSSION

Potential and Volume Landslide

The volume of post-slide soil, which is estimated to be prone to landslides based on the calculation results with a radius of 20 m from the edge of the collapse, is 114.880 m^3 (in situ). Observations in the field showed the type of avalanche material in the form of dry clay and gravel. This material has a swelling percentage of 41% as shown in Table 1. Thus, the released volume is estimated at 161.981 m^3.

Correlation between NWC and direct shear strength test results

The relationship between laboratory test results, landslide water content (sample code TL), natural soil (sample code TA), and cohesion are shown in Table 3 and graphed a in Figure 6.

Table 3 Relationship between natural water content (NWC) and cohesion, C

No.	Parameter	Unit	Sample Code				
			Disturbed and Undisturbed				
			TL-01 DS	TL-02 DS	TA-01 UDS	TA-02 UDS	TA-03 UDS
	Physical characteristic						
1.	Water Content	%	16.37	16.87	19.17	31.26	22.91
	Mechanical characteristic						
2.	Direct shear :						
	Cohesion (C)	kPa	112.70	102.20	73.60	59.20	76.80
	Internal friction angle (Ø)	(º)	6.30	6.50	30.50	28.50	23.50

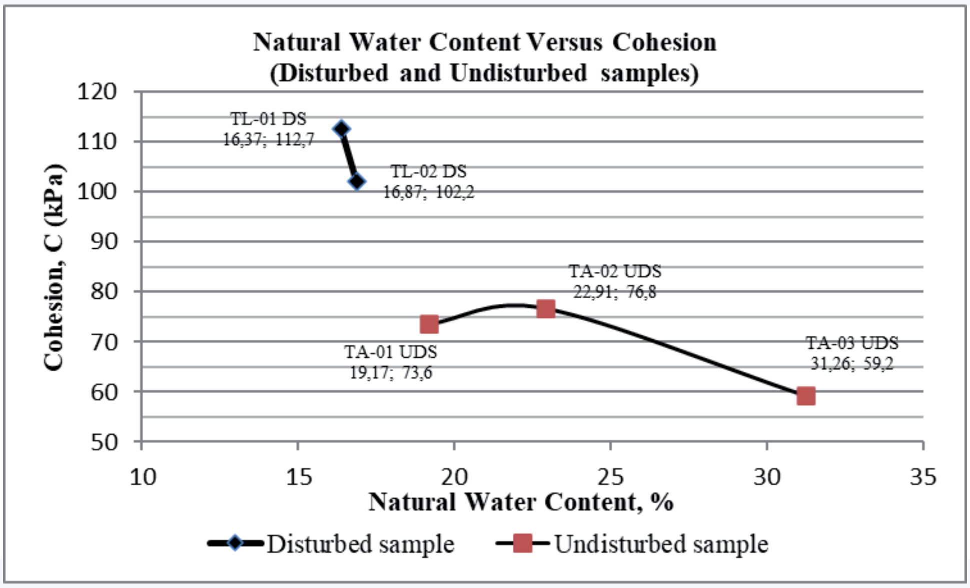

Figure 6 Comparison of natural water content (NWC) and cohesion (C) (disturbed and undisturbed samples)

Figure 6 shows a graph of the relationship between water content and cohesion in disturbed and undisturbed soil samples. The two soil samples show that if the water content is low, the cohesion is high.

CONCLUSIONS AND RECOMMENDATIONS

The area of the landslide that was mapped was 7.006 hectares. The overall average slope obtained from the topographic mapping is 23° in the direction of the slide direction, and the landslide direction is N 240° E. The post-slide volume, which is estimated to be prone to landslides based on the calculation results with a radius of 20 m from the edge of the failure, is 114.880 m^3 (in situ). The types of soil in the research area are dry clay and gravel with a swelling percentage of 41% so that the loose volume becomes 161.981 m^3. The NWC value for samples TL-01 DS, TL-02 DS, TA-01 UDS, TA-02 UDS, and TA-03 UDS was inversely proportional to the cohesion value, or the higher the water content, the cohesion value (C) decreased. This means that the attractive forces or bonds between sample particles decrease with increasing water content. To maintain the stability of the slopes and avoid landslides, apart from planting strong-rooted plants in areas with high elevations, they also manage drainage by making waterways on the northwestern and southeastern sides of the steep slopes up to the main road.

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