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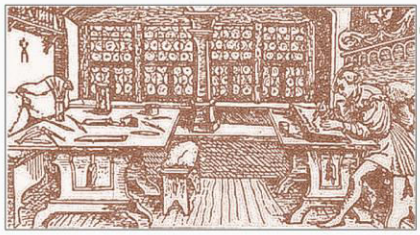

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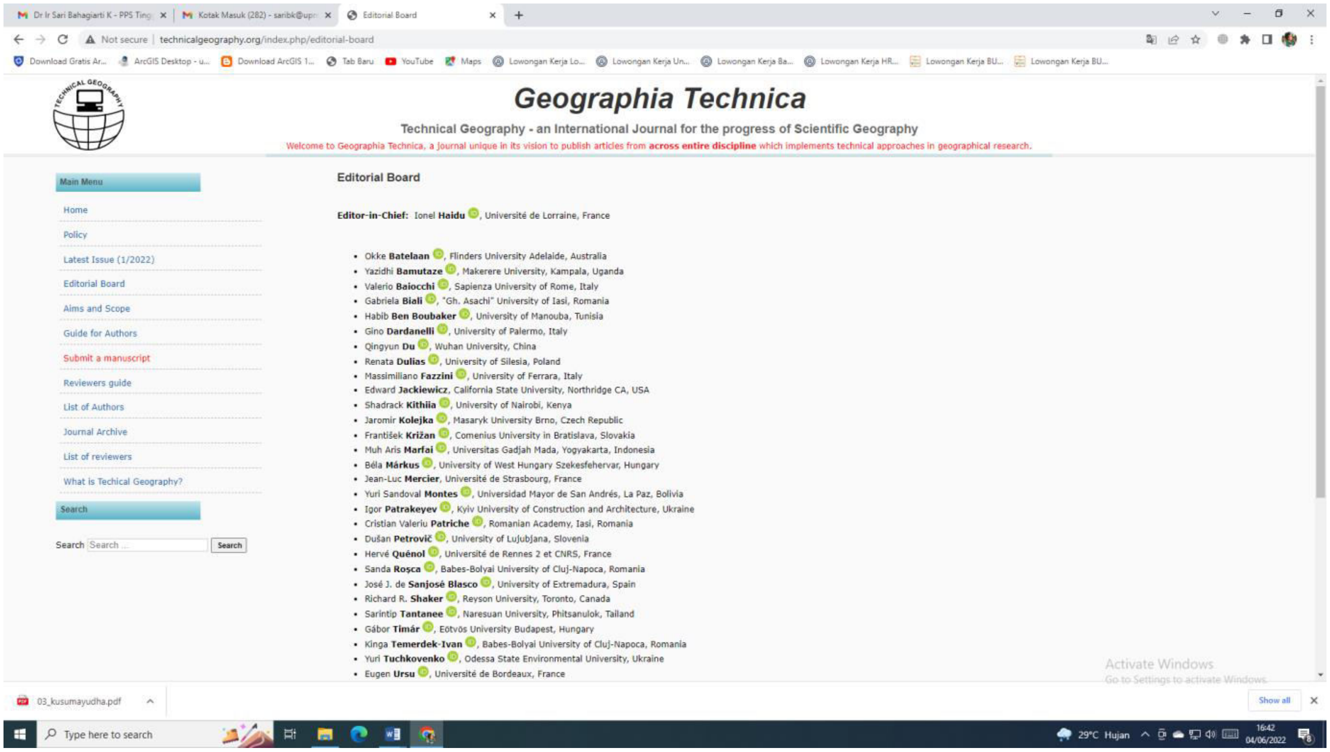

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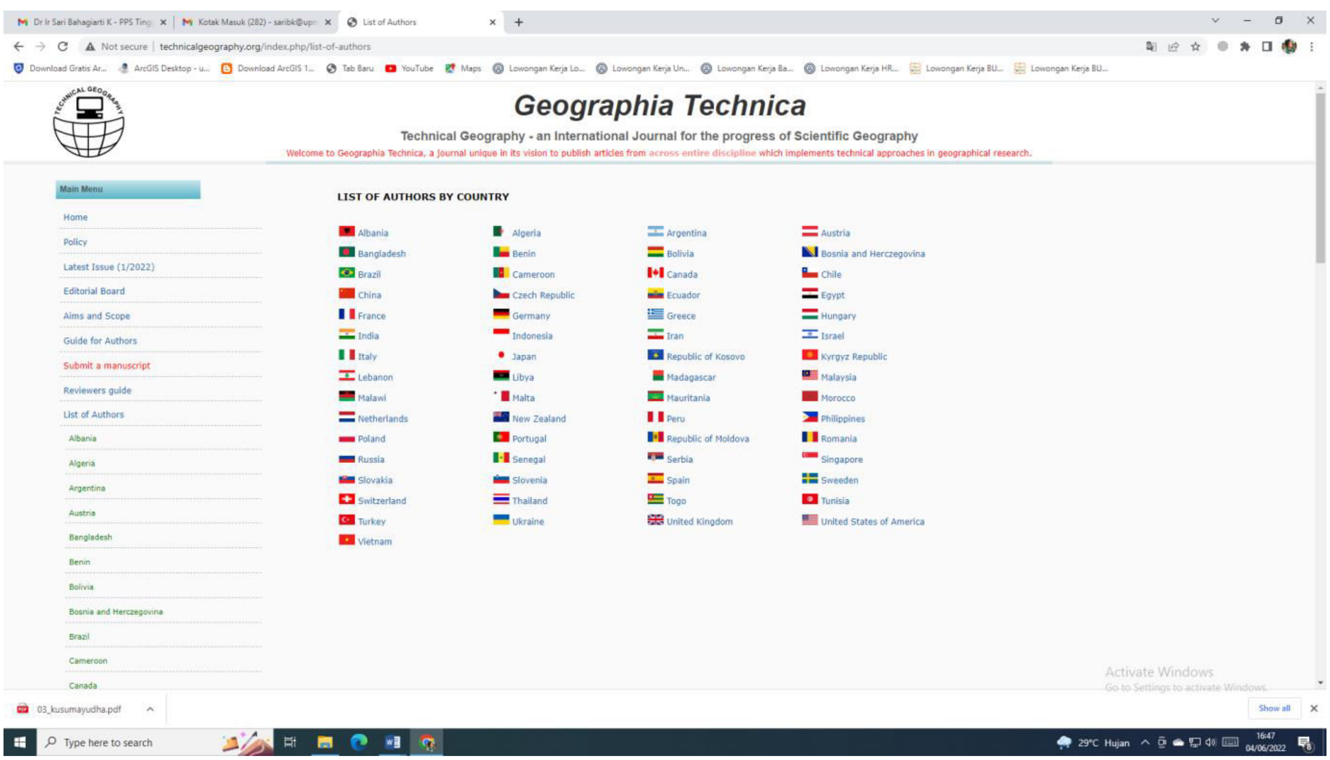

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FACTORS INFLUENCING SOIL BEHAVIOR AND PROPERTIES OF MASS MOVEMENTS IN THE BLIMBING AREA, BRUNO DISTRICT, PURWOREJO REGENCY, CENTRAL JAVA, INDONESIA

Sari Bahagiarti KUSUMAYUDHA[1 *], Riskhy JUMADIL AKHIR[1] and PURWANTO[1]

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ABSTRACT:
The Blimbing area, Bruno district of Purwrejo Regency, Central Java, belongs to a susceptible area for mass movement. Its geomorphology expresses homoclinic hills, undulating plains, and denudated volcanic hills. The lithology is composed of sandstone of the Halang Formation and andesite breccia of the Peniron Formation. A study was conducted that aimed to examine the factors influencing soil behavior and mass movements in this area by applying an analytical descriptive method along with a field survey and surface mapping. There were eight slopes, namely Slope 1 to Slope 8, being examined and analysed. Slope 1 and Slope 5 are composed of high-plastic clay with very expansive properties. Slope 2 is occupied by high-plastic silt with slightly expansive properties. Slope 3, Slope 4, Slope 6, and Slope 7 comprise high-plastic silt with slightly expansive to very expansive properties, while Slope 8 is built of highly fractured rock, with a joint density of 0.36 m. Using the simplified Bishop method, it can be determined that Slope 1 to Slope 7 have safety factor values of 1.095, 1.369, 1.262, 1.128, 1.605, 1.095, and 0.961, respectively. Slope 8 has a rock mass rating (RMR) value of 38, which belongs to class IV (poor rock). It has the potential for wedge and toppling failures. Results of this study indicate that the existence of water in the slopes increases the load on the slopes by 15%, decreasing the cohesion force and reducing the friction angle values, especially when the water content is more than 70%. The type of soil is in the form of high-plastic clay and high-plastic silt that is slightly expansive to very expansive, with low permeability. Thus, water content and the very expansive soil are the main influencing factors for mass movements in the study area.

Key-words: Soil behaviour, Expansive clay, Poor rock, Water content, Mass movement.

1. INTRODUCTION

Soil/rock mass movements often occur in the Blimbing area and its surroundings in Bruno District, Purworejo Regency, Central Java, especially during the rainy season. The last landslide, which occurred in Tegalsari Village, resulted in 2 houses collapsing, 1 mosque, and 11 other houses threatened to move, with a total loss of more than 100 million rupiahs (BPS, 2021, Imam, 2021). The second rank of the landslide-prone areas in the Central Java province is the Purworejo Regency. It has an Indonesia Disaster Risk Index (IRBI) of 18th out of 496 regencies and cities in Indonesia that are classified into a high-risk category (Wicaksono, 2020, BPS, 2021).

The study area belongs to an area with an average heavy rainfall of more than 2000 mm/year (BMKG, 2021). Therefore, in order to identify and understand the factors influencing mass movement in the research area, it is necessary to study its soil behavior and characteristics so that the occurrence of mass movement can be anticipated, a countermeasure can be planned, and a mitigation model can be designed.

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The research location is administratively situated in the Bruno district, Purworejo regency, Central Java province. Astronomically, it is positioned at the coordinates of X = 382000 mE – 388000 mE and Y = 91600000 mN – 9168000 mN (Universal Transverse Mercator, World Geodetic System 1984 in zone 49S), (**Fig. 1**). This research aims to examine the factors that influence soil behavior of mass movements in the study area.

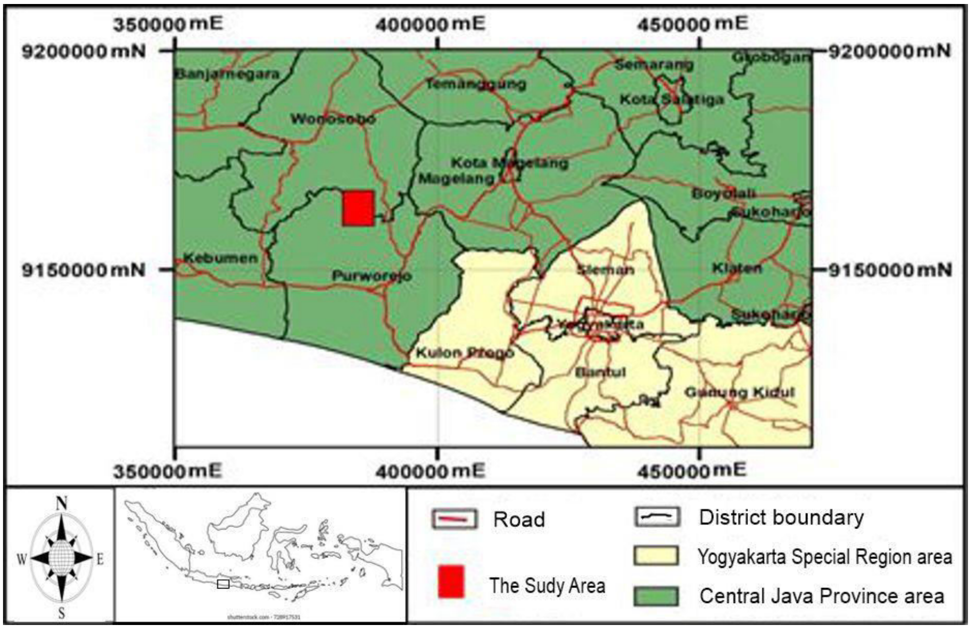

Fig. 1. Location map of the study area (www.mapsofworld.com/indonesia/provinces/jawa-tengah.html).

2. METHOD OF STUDY AND DATA

This research applied an analytical-descriptive method with a field survey and surface mapping. Some undisturbed soil samples and rock samples were taken for laboratory testing and analysis. Sample testing and assessment in the laboratory included petrographic description; compressive strength tests for undisturbed soil samples, disturbed soil samples, rock samples, and unconfined compressive strength tests using the American Society for Testing and Material (ASTM D-2938-95) for rock mass rating (RMR). Determination of soil physical properties includes unit weight (ASTM D-2937), soil density (ASTM D-654-9), water content (ASTM D-2216-982), Atterberg limit (ASTM D-4318-89), permeability measurement (ASTM D-2434), soil shear strength analysis (ASTM D-3080-72), and sieve analysis (ASTM C-136-06) for classifying the soil types.

The Simplified Bishop method was used in determining the safety factor of the slope formed by soil, with the assumption that the sliding plane is circular in form and the movement is rotational (Kusumayudha & Ciptahening, 2016, Kusumayudha, et. al., 2020). In order to determine the type of soil mass movement, Varnes classification is used (Varnes, 1978). The RMR (rock mass rating) method is used to analyse slopes composed of rocks (Bieniawski, 1989), as well as the Markland Method (Citrabhuwana et al., 2016). The Simplified Bishop Method uses Limit Equilibrium and utilizes a sectional approach where the forces acting on each slice are shown as in **Fig. 2** (Rajagukguk et al., 2014). In the RMR assessment, **Table 1** and **Table 2** were used (Bieniawki, 1989).

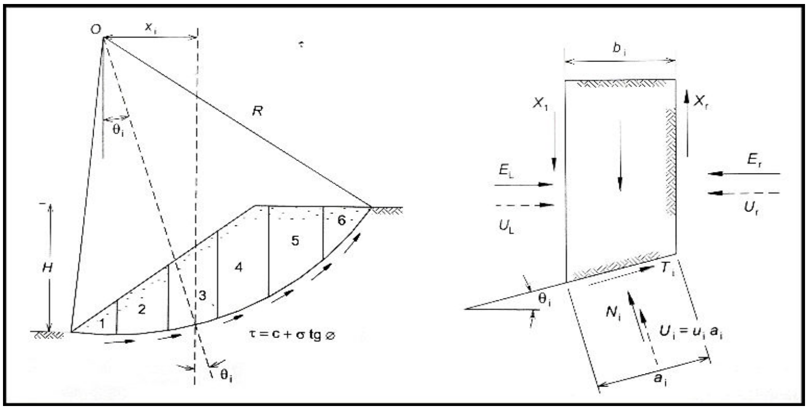

Fig. 2. Stress distribution in sliced soil slope (Rajagukguk, et.al., 2014).

Table 1.

Parameters and range of values of Rock Mass Rating (RMR), (Bieniawski, 1989).

Parameter		Range of Values						
Compressive strength (Mpa)	Values	>250	100-250	50-100	25-50	10-25	3-10	<3
	Rating	15	12	7	4	2	1	0
RQD (%)	Values	90 – 100	75 – 90	50 – 75	25 – 50	<25		
	Rating	20	17	13	8	3		
Joint Dencity	Values	>2	0.6 – 2	0.2 – 0.6	0.06 – 0.2	<0.006		
	Rating	20	15	10	8	5		
Joint Condition	Values	Very rough surfaces Not continuous No separation Unweathered wall rock	Slightly rough surfaces Separation <1 mm Slightly weathered walls	Slightly rough surfaces Separation <1 mm Highly weathered walls	Slickensided surfaces or Gouge <5 mm thick, or Separation 1 – 5 mm Continuous	Soft gough >5 mm thick, or Separation > 5 mm Continuous		
	Rating	30	25	20	10	0		
Ground-water Condition	Values	Completely dry	Damp	Wet	Dripping	Flowing		
	Rating	15	10	7	4	0		

In determining the plasticity index (PI) of soil, the interpretation of the plastic and liquid limits is carried out using the Casagrande diagram (**Fig. 3**). To classify the soil type, it uses the American Association of State Highway and Transportation Officials (AASHTO) naming system (Hardiyatmo, 2014). Expansive properties, expansive soils, and swelling potentials are used to indicate soils that are prone to shrinkage and contain a lot of clay, especially the mineral of montmorillonite (Hardiyatmo, 2014). Based on their expansive properties, there are three groups of clay minerals (Nelson & Miller, 1991), namely kaolinite, non-expansive, mica-like, for example, illite and vermiculite, which can be expansive, and mildly developed illite, the smactite group, including montmotillonite, which is highly expandable or expansive (Duncan & Fasce, 1995).

Table 2.

Geomechanical classification of rock masses (Bieniawski, 1989).

Class	Description of Rock Mass	RMR (Sum of Rating Increments)
I	Very Good Rock	81 – 100
II	Good Rock	61 – 80
III	Fair Rock	41 – 60
IV	Poor Rock	21 - 40
V	Very Poor Rock	>20

The relationship between the degree of soil expansion and the plasticity index according to ASTM D-1883 is shown in **Table 3**. This table describes the association between the value of plasticity index, the degree of swelling of the soil when it contains water, and the percentage of its expansion. For example, if the plasticity index value of the soil is 0 to 10, the soil will be categorized as unexpansive, because the percentage of expansion is less than 2%. On the other hand, when the plasticity index value is greater than 20, then the soil is said to be very expansive or highly swelled, with a percentage expansion of more than 4%. Meanwhile, the relationship between the potency of clay expansion and the plasticity index (PI) is laid out in **Table 4** (Chen (1975).

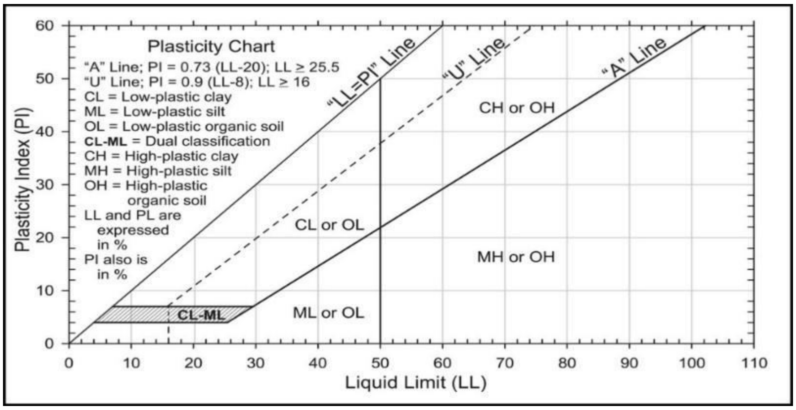

Fig. 3. Casagrande Diagram (ASTM D-2487).

Table 3.
Degree and % of the expansive due to the plasticity index (PI) (ASTM D-1883, vide Hardiyatmo, 2014).

Plasticity Index (ASTM D-424)	Degree of Expansive	Percent of expansive (ASTM D-1883)
0 – 10	Unexpansive	2% or less
10 - 20	Rather Expansive	2% - 4%
> 20	Very Expansive	>4%

Table 4.
Relationship of the expansive potency and plasticity index (PI) (Chen, 1975).

Plasticity Index (PI)	Expansive Potency
> 35	Very High
20 – 55	High
10 – 35	Moderate
0 – 15	Low

3. RESULTS AND DISCUSSIONS

3.1. Geomorphology and Geology

The Blimbing and surrounding area are included in the South Serayu Mountains (Van Bemmelen, 1949), a geoanticlinic ridge stretching from the west to the east for 100 km (**Fig. 4**). Using Van Zuidam's classification (1984), the geomorphology of the study area can be divided into homoclinic hills, undulating plains, and denuded volcanic hills. The homoclinic hills are in the middle part, occupying 12.80% of the study area, with slopes of 7%–140% (4°–55°) very steep. The lowest elevation is 200 m asl and the highest is 500 m asl. The undulating plain occupies 63.05% of the study area, with slopes of 2%–140% (2°–55°), very sloping–very steep. The lowest elevation is 187 m asl, and the highest is 597 m asl. The denudated volcanic hills are located in the southeast, occupying 21.8% of the study area, with slopes of 15%–140% (8°–55°), moderate to very steep.

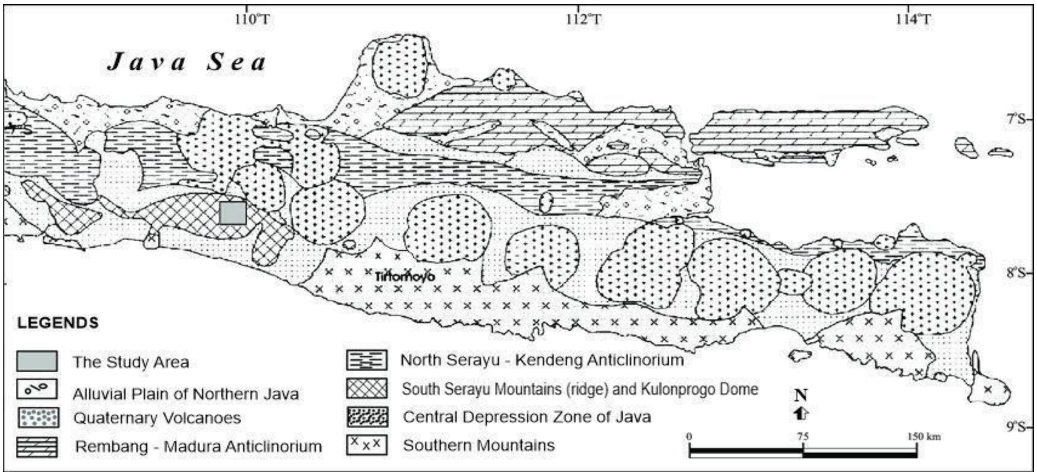

Fig. 4. The physiographic map of the Central - Eastern Java, and the study area belongs to the South Serayu Mountains (Van Bemmelen, 1949).

In the study area, there are two main rivers, namely Kali Jali and Kali Gowong, with relatively lateral erosion processes, so that the cross section of the rivers shows a "U" shape. Stratigraphically, the study area consists of alternating sandstones with claystones of the Halang Formation and volcanic andesite breccias of the Peniron Formation, in a conformable stratigraphical relationship (**Fig. 5**).

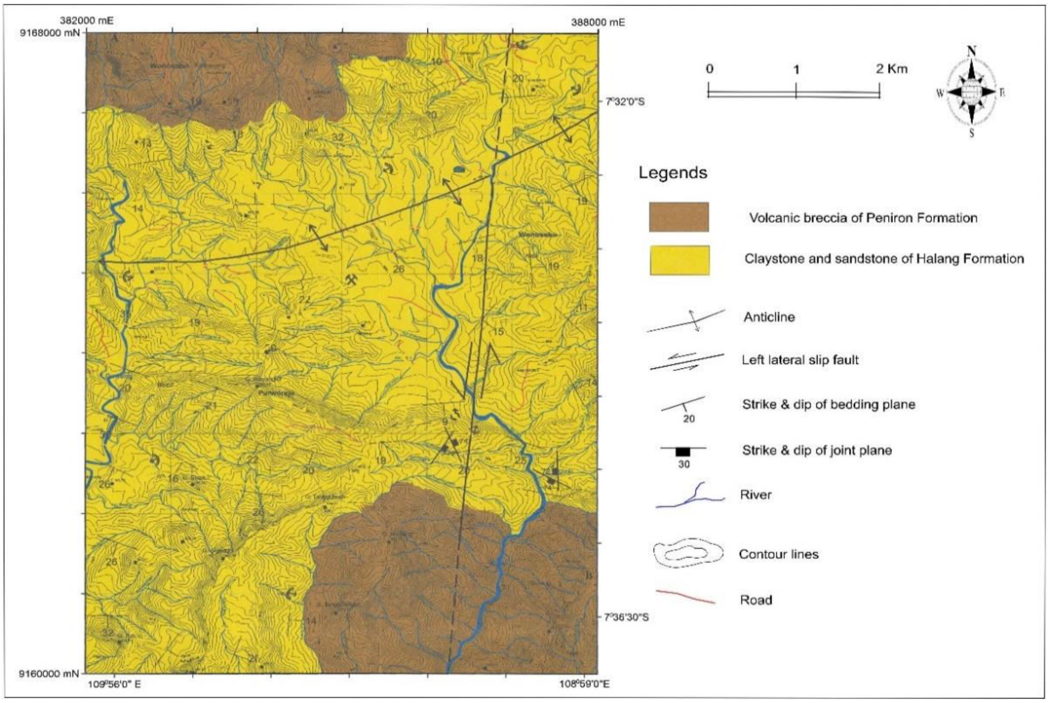

Fig. 5. Geological map of the study area.

The Halang Formation occupies 75.84% of the total study area, consisting of sandstone, claystone, carbonate sandstone, carbonate claystone, and polymixed breccia. The formation is late Miocene to early Pliocene epoch. The Peniron Formation consists of breccias with andesite fragments from the Pliocene epoch, which occupies the northwest and southeast areas of the study area.

There is a normal left-slip fault in the study area called the Blimbing Fault (**Fig. 5**). The fault plane is striking N6°E and dipping 70°, with a plunge of 5°, a bearing of 11°, and a rake of 32°. The general pattern of the shear joint is N118°E/72° and N173°E/74, while the distribution of principal stress is 1 = 0°, N318°E, 2 = 70°, N228°E, and 3 = 19°, N48°E.

3.2. Mass Movements

Mass movements in the study area can mostly be classified as landslides. Although most of the mass movements in the study area involve weathered soil, in some locations the slopes are composed of rock, and they also often have the potential to fail. In this study, seven representative slopes comprising soil, coded as LR1, LR2, LR3, LR4, LR5, LR6, LR7 (**Fig. 6** to **Fig. 9**), and one slope consisting of rock (LR8), were analysed. The selection of the studied slopes is based on their potential threat to settlements and/or public roads if they move.

Fig. 6. Slope 1 (LR 1), left, and Slope 2 (LR 2), right.

Fig. 7. Slope 3 (LR 3), left, and Slope 4 (LR 4), right.

Fig. 8. Slope 5 (LR 5), left, and Slope 6 (LR 6), right.

Fig. 9. Slope 7 (LR 7), and the direction of movement (blue arrow).

Soil and rock samples for laboratory testing were also taken from those slopes. The results of soil physical properties testing are listed in **Table 5.**

Table 5.

Physical properties of the soil composing Slope 1 (LR1) to Slope 7 (LR7), and the rock of Slope 8 (LR8).

LR	Unit Weight (kg/m3)	Dry unit Weight (kg/m3)	Specific Gravity (gr/cm3)	Water Content (%)	Permeability (cm/s)	Atterberg Limit			Shear Strength	
						LL	Pl	PI	C (kN/m2)	Φ (°)
1	1655.8	1113.1	2.43	46.35	5.5x10-5	59	30	29	25	20
2	1301.5	663.45	2.21	822.04	7.63x10-4	57	48	9	21	25
3	1552.54	1016.199	2.38	56.68	33.34x10-4	51	34	18	36	21
4	2906.25	1666.14	2.34	80.47	5.85x10-4	67	44	23	8	49
5	1637.5	1066.36	2.42	511.64	11.5x10-4	59	31	28	25	34
6	1531.84	867.27	2.2	72.555	8.75x10-4	79	43	35	11	43
7	1530.8	856.34	2.49	77.17	3.4x10-4	57	37	20	14	30
8	UCS of Rock = 7.23 MPa									

The results of the soil consistency test in the form of plasticity index (PI) and liquid limit (LL) values were then plotted into the Casagrande diagram for determining the soil type (**Fig. 10**).

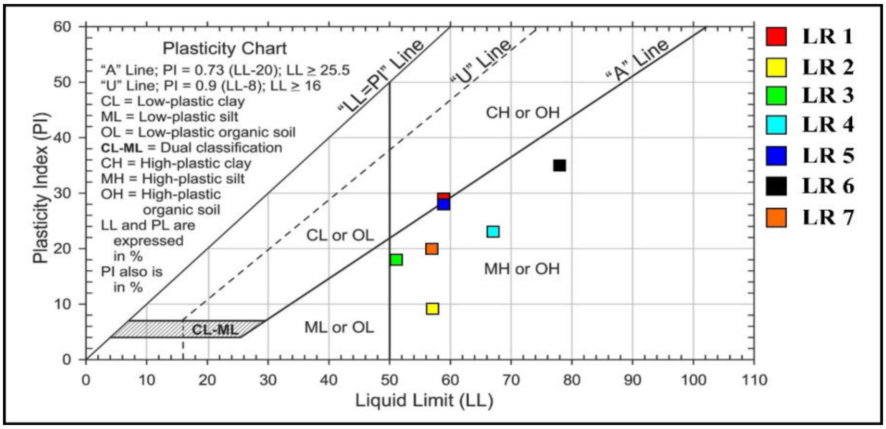

Fig. 10. The plots of liquid limit and plasticity index from LR1 to LR7 are used to determine the soil type. It shows that most of the soils are included in MH (high-plastic silt) or OH (high-plastic organic soil), except for LR1 and LR5, which belong to CH (high-plastic clay).

After being analysed, the soil samples taken from the representative slopes in the study area were classified using USCS and AASTHO classification as listed in **Table 6**.

Table 6.

Soil type (USCS and AASHTO classification) of mass movements in the study area.

Slope (LR)	USCS		AASTHO	PI	Expansive Degree	Expansive Potential	Clay Minerals
	Symbol	Name					
1	CH	High-plastic clay	A-7-5 (32)	29	Very Expansive	High	Smactite
2	MH	High-plastic silt	A-5 (13)	9	Not Expansive	Low	Kaolinite
3	MH	High-plastic silt	A-7-5 (19)	18	Rather Expansive	Medium	Mica-like
4	MH	High-plastic silt	A-7-5 (30)	23	Very Expansive	High	Smactite
5	CH	High-plastic clay	A-7-5 (32)	28	Very Expansive	High	Smactite
6	MH	High-plastic silt	A-7-5 (44)	35	Very Expansive	Very high	Smactite
7	MH	High-plastic silt	A-7-5 (22)	20	Rather Expansive	High	Mica-like

The expansive nature of soil depends on the type of clay content in it. By approaching ASTM (Chen, 1975; Nelson & Miller, 1991) from the value of the plasticity index (PI), the expansive properties of soil can be known (**Table 6**). Table 6 shows that in all of the representative slopes being studied, the types of soil constituents are very expansive, having the potential to expand, and some of them contain smactite clay. This is reinforced by the results of petrographic analysis of the Halang tuffaceous sandstone unit, which shows the large content of volcanic material, especially plagioclase. It is known that when plagiolase undergoes weathering, clay minerals will be formed. On the 7 representative slopes, the determination of the safety factor was carried out using the simplified bishop method (**Fig 11**). The overall results are described in detail in **Table 7**.

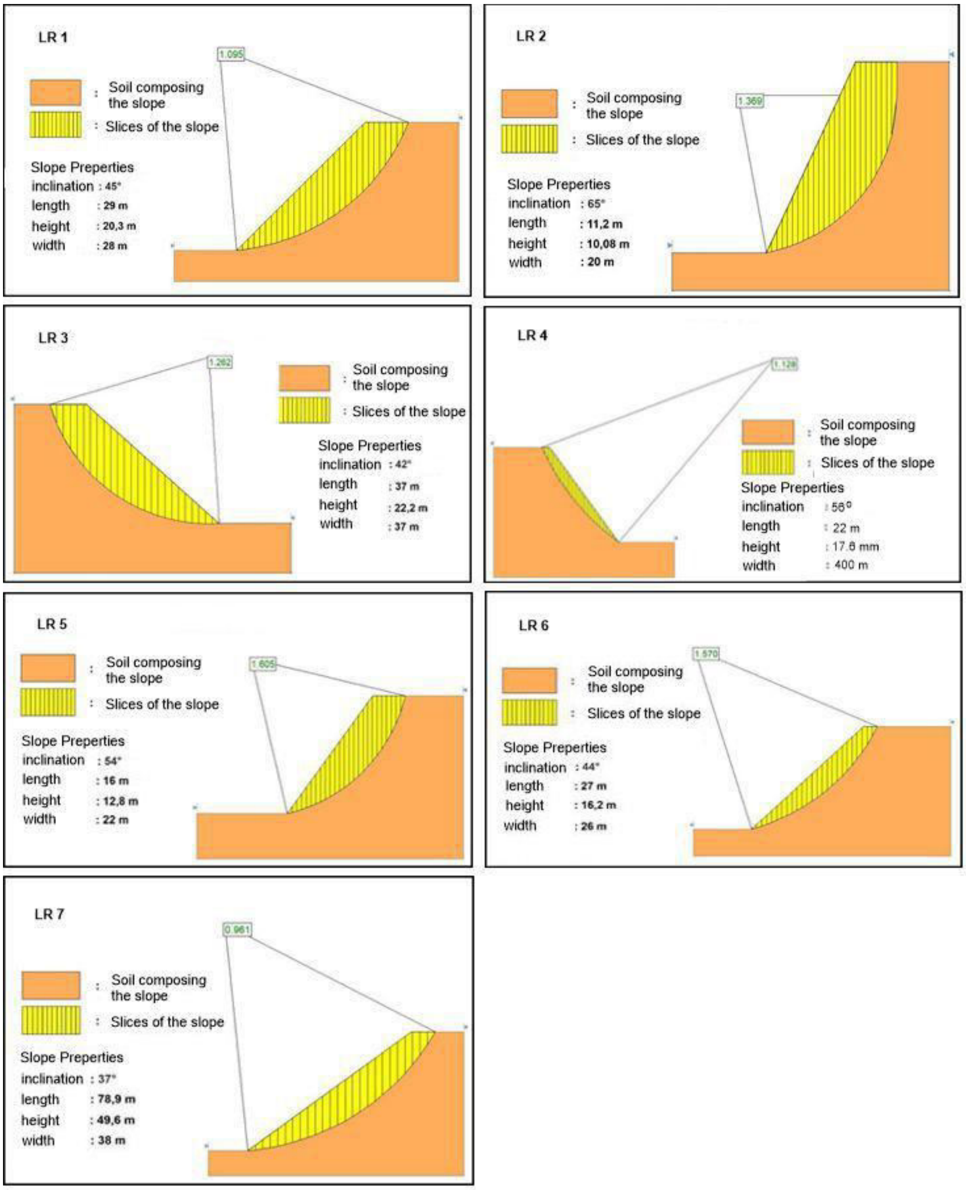

Fig. 11. Model of mass movements and factor of safety determination in the study area.

Table 7.

Description of soil movements potential in the study area.

Slope (LR)	Location	Environment and Slope condition	Material	Soil properties		Safety Factor, Movement Type
1	Jangkrikan village, 387754 mE 9167300 mN	Farming area, sloping 45°, slope length 29 m,	Tuffaceous sandstone of Halang Fm, intensively weathered, wet condition	CH, high plasticity, clay, A-7-5 (32), γ = 1301,5 kN/m3 Expansive clay, smactite	C = 25 kN/m2; ϕ = 20o W= 46,35% K = 35x 10-4 cm/s	Fs = 1.095 Slump (Landslide) Slide direction N335oE
2	Jangkrikan village, main road side Kutoarjo – Bruno 387049 mE 9167841 mN	Settlement area, sloping 45°, slope length 29 m,	Tuffaceous sandstone of Halang Formation, intensively weathered, wet condition	MH, high plasticity, silt, A-5 (13), γ = 1665,8 kN/m3 Expansive clay, smactite	C = 21 kN/m2; ϕ = 25o W= 82,04% K = 7.63 x 10-4 cm/s	Fs = 1.369 Slump (Landslide) Slide direction N15oE
3	Kaliwungu village, road side of Ngemplak – Krawan, 382508 mE 9165122 mN	Farming area, fruit trees, sloping 42°, slope length 37 m,	Tuffaceous sandstone of Halang Fm, intensively weathered, wet condition	MH, high plasticity, silt, A-7-5 (13), γ = 1552,54 kN/m3 Expansive clay, smactite	C = 35 kN/m2; ϕ = 21o W= 56,68% K = 3.34 x 10-4 cm/s	Fs = 1.262 Slump (Landslide) Slide direction N 110oE
4	Suati – Sruwudadi Tengah, road side 384576 mE 9161165 mN	Farming area, sloping 56°, slope length 22 m,	Tuffaceous sandstone of Halang Fm, intensively weathered, wet condition	MH, high plasticity, silt, A-7-5 (30), γ = 2906,25 kN/m3 Expansive clay, smactite	C = 8 kN/m2; ϕ = 49o W= 46,35% K = 35x 10-4 cm/s	Fs = 1.128 Slump (Landslide) Slide direction N115oE
5	Brunosari village, main road side 382813 mE 9162569 mN	Farming area, sengon trees, sloping 54°, slope length 16 m,	Tuffaceous sandstone, Halang Fm, weathered but there is rock debris, moistured condition	CH, high plasticity, clay, A-7-5 (32), γ = 1637,5 kN/m3 Expansive clay, smactite	C = 25 kN/m2; ϕ = 34o W= 51,64% K = 11.5 x 10-4 cm/s	Fs = 1.605 Slump (Landslide) Slide direction
6	Kaliwungu village, road side 382813 mE 9162569 mN	Farming area, sloping 45°, slope length 29 m,	Tuffaceous sandstone of Halang Fm, intensively weathered, wet condition	MH, high plasticity. silt, A-7-5 (32), γ = 1665,8 kN/m3 Expansive clay, smactite	C = 25 kN/m2; ϕ = 20o W= 51,64% K = 11,5 x 10-4 cm/s	Fs = 1.570 Slump (Landslide) Slide direction
7	Tegalsari village, main road side Kutoarjo – Bruno 385599 mE 9163143 mN	Threatening 12 houses, sloping 37°, slope length 78.3 m,	Tuffaceous sandstone of Halang Fm, intensively weathered, wet condition,	MH, high plasticity, silt, A-7-5 (22), γ = 1530,8 kN/m3 Expansive clay, illite	C = 14 kN/m2; ϕ = 30o W= 77.1% K = 3.4 x 10-4 cm/s	Fs = 0.961 Slump (Landslide) Slide direction

The next example of the slope to be investigated is LR8. It is located beside the road connecting Blimbing village and Somoleter village and next to the Blimbing fault geological structure. On this slope, mass movement potential is in the direction of N20°E and threatens the road body. Administratively, the slope belongs to Somoleterkrajan hamlet, Somoleter village. The UTM coordinates are 386564 mE and 9163143 mN. The morphology at this location has a slope of 63°. In the unit composed of the Halang tuffaceous sandstone unit, the position of the groundwater table is not clearly found, but in the joint set of the rock, there are water drops. It indicates that the rock is saturated with water. The land use at this location is shrubs. This type of potential mass movement can be categorized as a rockslide. A rock mass rating has been carried out on this slope, and the results show that the rocks that make up the slope have a total score equal to 38. It means that the material composing the slope can be classified as poor rock. (**Table 8**).

Table 8.

Rock mass rating of slope 8 (LR 8).

Parameter	Assessment	Rating
Rock Strength	7.231 MPa	2
RQD	33.50%	8
Joint Spacing	0.36 m	10
Joint Condition	Opening of 1 – 5 mm	10
Groundwater Condition	Wet and saturated	7
	Total Score / Class	38 / Poor Rock

There are discontinuity planes at this location with the strike and dip of joint set 1 (JS1) N203 °E/82°, joint set 2 (JS2) N226°E/72°, joint set 3 (JS) N80°E/21°, the slope face is N280°E/63°, and the friction angle is 25°. The plot of this data for Markland analysis is shown in **Fig. 12**.

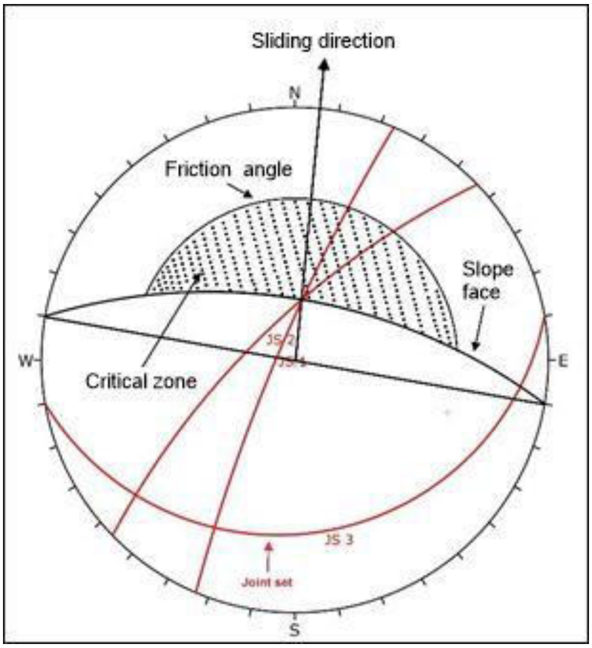

Fig. 12. The stereonet plot of LR 8, showing failure potencies of wedge type through the interception of JS2 and JS4, and toppling through JS 3.

The result of the stereonet plot and markland analysis demonstrate that the slope is not safe and the type of landslide potential is wedge and toppling failures. As well as the strike of the discontinuity plane, which is represented by the joint set of 3 forming an angle of 20° toward the strike of the slope, so that it will form a toppling landslide.

3.3. Soil Behavior and Characteristics

In this study, the formation that has the highest potential to be eroded is the Halang Formation, which consists of mainly clayey sandstone and claystone. Based on the results of laboratory analysis that showed the permeability values are very low, it can be inferred that the speed of water movement in the lithology composing the slopes being studied is very slow. This will trigger the existence of hydrostatic pressure in terms of pore pressure to weaken the shear strength of the slope (Kusumayudha, et al, 2020).

The soil cohesion (c) values of the investigated slopes range from 8 KN/m2 to 25 KN/m2, and the internal friction angle (∟) values extent from 20° to 49°. The types of soil are high plastic clay and high plastic silt with slightly expansive potential to very expansive, so that it will cause swelling when the water content is high and be able to form cracks if it loses its water content. The permeability ranges from 3.410^{-4} to 5.510^{-5} and the water content ranges from 46.35% to 80.47%. This shows that the speed of water movement in the body of the slopes is very low. With this very slow motion, the presence of water in the soil will cause hydrostatic pressure in the pores of the material. In turn, this condition will increase the weight force, reduce the cohesion force (c) value, and reduce the friction angle (∟) (**Fig. 13, Fig. 14, Fig. 15**), thereby increasing the potential for mass movements in the area.

On slopes made up of rocks, such as LR8, the uniaxial compressive strength value of the rock is 7,231 Mpa, indicating that this rock is very weak (Hoek & Bray 1997). The result of the rock mass rating (RMR) on this slope is 38, which is classified as poor rock in class IV. Of course, poor rock has a higher potential to fail. Based on the Markland method, the potential failure types are wedge and toppling.

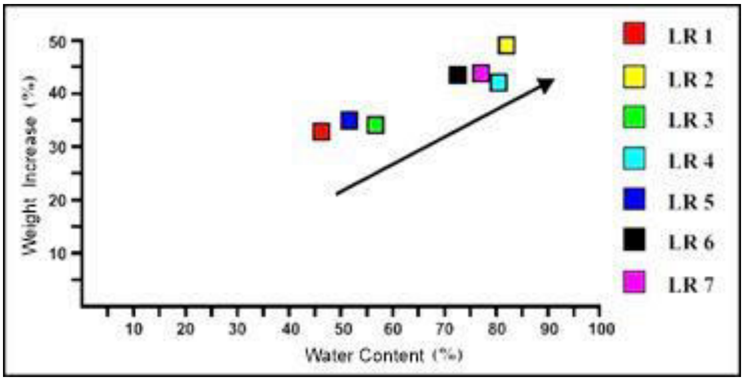

Fig. 13. The plots of water content and percent weight increase of the soil sample, showing the correlation of water content and weight increase. The higher the water content, the greater the percentage of the soil weight increase.

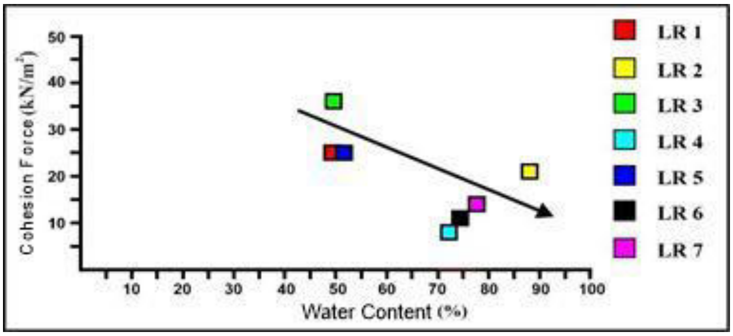

Fig. 14. The plots of water content and cohesion force value of the soil sample, showing the correlation of water content and cohesion force (c). The higher the water content, the lower the cohesion force.

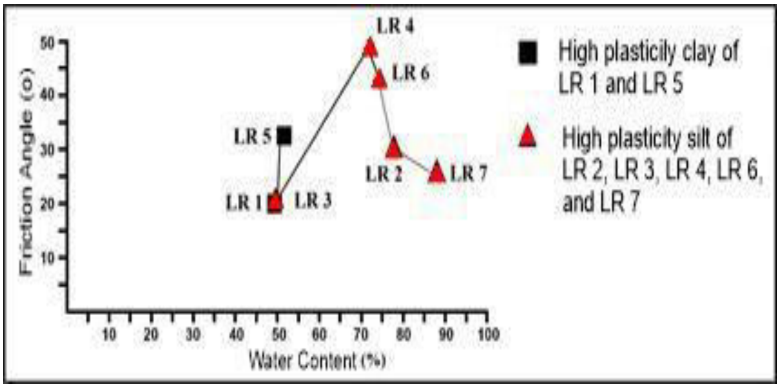

Fig. 15. The plots of water content and friction angle ( ) value of the soil sample, showing that when the water content is higher than 70%, the friction angle will decrease.

The results of this study demonstrate that the factors influencing soil behavior in the occurrence of mass movement are the type of clay mineral (smactite group) and the amount of water content in the soil. Thus, the information on soil properties is very important to be understood by stakeholders in managing landslide-prone areas. Soil which is very expansive with high water content, low cohesion force, and low friction angle value will decrease its shear strength and therefore is susceptible to landslides. By knowing the soil behavior and characteristics in the area, the potential for mass movements in the area can be detected early, anticipation can be made, and countermeasures can be planned in the framework of designing a landslide disaster mitigation model.

5. CONCLUSIONS

Based on the results of the study, the following conclusions can be drawn:

The geomorphology of the research area consists of homoclinic hills, undulating wavy plains, and denudated volcanic hills. The lithology of the study area comprises sandstone units of the Halang Formation, from the late Miocene, and andesite breccia of the Peniron Formation, from the Pliocene epoch, with conformable stratigraphic relationships. There is a normal left slip fault, called the Blimbing Fault, striking N6°E and dipping 70°.

Slope 1 (LR1) and Slope 5 (LR5) are composed of high-plastic clay with very expansive properties. Slope 2 (LR2) is a high-plastic silt with non-extensive properties. Slope 3 (LR3), Slope 4 (LR4), Slope 6 (LR6), and Slope 7 (LR7) are high-plastic silt with slightly expansive to very expansive properties. Using the simplified Bishop method, the safety factor of slopes composed of soil (LR1 to LR7) is 1.095, 1.369, 1.262, 1.128, 1.605, 1.570, and 0.961, respectively, with slump or landslide type of movement. Slope 8 (LR8) has many discontinuities with a joint density of 0.36 m. The RMR value is 38, which belongs to rock mass class IV, or poor rock. The potential for movement is in the form of wedges and toppling types.

The effect of soil water content is to increase the load of the slopes by 15%, decreasing the cohesion value (c), and reducing the friction angle (∟). The friction angle decreases when the water content is more than 70%. The types of soil are high-plastic clay and high-plastic silt with smactite mineral, slightly expansive to very expansive. The velocity of water movement on the slope is very low, making the slope more conducive for ground or mass movements to occur.

Factors influencing soil behavior in the occurrence of mass movement are the type of clay mineral (smactite group) and the amount of water content in the soil. This study indicates that information on soil behavior and characteristics is important to stakeholders for landslide-prone area management, especially for anticipating and countermeasure planning in the framework of landslide disaster mitigation.

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