

The Impact of Physical and Chemical Properties to Form a Slip Surface in Pyroclastic Breccia in Pawinihan Landslide, Banjarnegara

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Abstract. Pawinihan Landslide in 2006 is a landslide that occurred in breccia material that has weathered. So this study will discuss the influence of weathering to form sliding surface. Weathering is as a result of a natural process because of the atmosphere and hydrosphere condition. These changes will affect the decrease of the rock strength. This study will focus on the influence of physical and chemical weathering to landslide. The method used is the British Standard BS EN ISO 14689-1 to differentiate levels of weathering, and then perform a sampling of the physical, mechanical, and chemical weathering on different levels. Furthermore there will be a study of slope stability by differentiating layers of weathering level. The results obtained are sliding surface at a weathering rate of 3 in accordance with conditions on the ground, but it rather shift up to conditions on the ground.

1. Introduction

Sliding surface is a plane at the ground level as the lower limit of the material moving before the landslide [1]. Then the sliding surface weak, the masses of soil and rock occurred a shift in intensive process that is accompanied by grinding, drag, erosion, and destruction of grain (grain crushing). The shape of sliding surface divided into two types, rotational and translational [1]. Here's a picture of both the sliding surface (Figure 1).

Previous research has identified several zones of weathering that became sliding surface [2] which states sliding surface being formed on the degree of weathering and strong at the granite landslides in the mountains of Khao Luang southern Thailand. In addition, research conducted by the author shows the sliding surface contained on the degree of moderately and highly weathering in breccias, volcanic, koluvial weathered, and volcanic altered on the location of landslide Kedungrong in Yogyakarta, Langkap landslide in Purbalingga, and Somagede landslide in Banyumas [3-5]. It also has a identified other forms of landslide associated with weathering zones, namely the formation of a rotational sliding surface on the ground residue and translational sliding surface at the level of medium and strong weathering on granite and metamorphic rocks [6].

Above research has not explained genetically altered levels of weathering that occurs with indicators of changes in physical, mechanical, and chemical cause's weak zones in the weathering profile. The



research location is the area of Mount Pawinihan, Banjarnegara. According to Condon et al. (1996) rocks in the study area is composed of pyroclastic breccias and has a slope of 30° - 45° [7] (Figure 2).

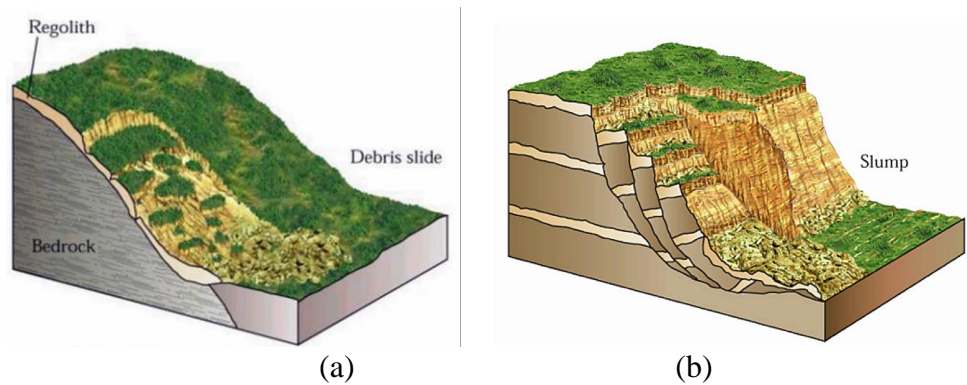


Figure 1. Sliding surface of translational (a) and rotational (b) [1].



Figure 2. Geological map of research area [7].

2. Methods

This research use a weathering zone classification method by British Standard BS EN ISO 14689-1 for non-uniform material [9] (Table 1). After that, researcher enter the value of properties of soil and rock weathering on different levels to simulate the method GLE (General Liquid Equilibrium). After that the researchers do the simulation and compared with the results of the mapping, wells test, and geo-electric field testing. Beside that, there is observation of rocks in a field on a sliding surface and take megascopic data of petrology and microscopic observation (petrographic, SEM, XRD and XRF) in the laboratory. The latest results obtained are able to do a back analysis by entering the weathering zone for the physical and mechanical data.

Table 1. Classification of degree of weathering base on British Standard BS EN ISO 14689-1 for heterogen material [9].

Zone	Description	Typical Characteristic
1	100% grades I-III	Behave as rock, apply rock mechanics principles to mass assessment and design
2	>90% grades I-III <10% grades IV-VI	Weak materials along discontinuities, shear strength stiffness and permeability affected
3	50% to 90% grades I-III 10% to 50% grades IV-VI	Rock framework still locked and control strength, and stiffness, matrix control permeability
4	30% to 50% grades I-III 50% to 70% grades IV-VI	Rock framework contribute to strength, matrix or weathering product control stiffness and permeability
5	<30% grades I-III 70% to 100% grades IV-VI	Weak grades will control behavior, core stones may be significant for investigation and construction
6	100% grades IV-VI	May behave as soil although relict fabric may still be significant

3. Results and Discussion

In area of Pawinihan landslide, sliding surface found in weathered layer based on field observations and petrographic. Based on field observations, characteristics of megascopic is a brown color and the composition of rocks with soil (F = 50% M = 30%) + soil = 20% fragments are still visible with the gray-brown color, condition matrix mostly rotted, texture breccia still seen clearly indicate a breccia lithology, fragments measuring 5 cm - 10 cm and the condition rather soft, can be scratched with a hammer. Visible oxidation, hydrolysis, and an intense hydration has been running with the increasingly brown discoloration and development of land as a result of the weathering process, the microstructure can still be observed from grains fragments, probably due process of disintegration (Figure 3).

**Figure 3.** Position of sliding surface in zone 3.

Based on the laboratory analysis of physical and mechanical, density values of sliding surface is 1.70, 19.88% of moisture content, bulk density of 1.45 g/cm³, LL 44.07%, PL 39.94%, PI 4.13%, clay 34.00%, the cohesion of 0.05 kg/cm², and the friction angle in 34.640. So it can be explained that if the condition is very possible in this zone as a sliding surface for low cohesion values, material fragments still show solid conditions making it possible to give effect to the imposition of the slopes. Furthermore, 19.88% water content allows the water flooded the zone. Then the clay percentage of 34.00% serves as a matrix breccia material and it become weak because of water saturation. It can be seen from the percentage LL, PL and PI showed moderate plasticity.

Based on petrographic analysis of the fragments and the matrix contained in the zone of sliding surface, rock fragments in sliding surface zone is andesite oxidized (7%) altered by phenocrysts form plagioclase (20%), k-feldspar (5%) and pyroxene (10%) which is embedded in a mass basis in the form microlit plagioclase (10%) and the mass of glass (25%), cuts the rock is transformed into mineral opaque (8%) and clay minerals (7%), chlorite (5%) encountered cavity of (3%) (Figure 4.a).

Then the composition of the rocks matrix in the zone sliding plane is breccias volcanic brown rock, compiled by the granular fragments of rock (25%), plagioclase (10%), pyroxene (5%), k-feldspar (3%), carbon (2%), iron oxide (10%) are embedded in a matrix form of glass volcanics (10%) and material pyroclastic (15%) sized tuff rough, incision rock is transformed into clay minerals (7%), mineral opaque (5%) and chlorite (3%), common cavity of (5%) (Figure 4.b). Then based on XRF analysis consists of oxide mayor SiO₂ 52.3% Al₂O₃ 31.6%, Fe₂O₃ 12.1%, TiO₂ 1.61%, MgO 0.903%, K₂O 0.702%, CaO 0.278%, MnO 0.248%, P₂O₅ 0.169 %, BaO 0.0329%, ZnO 0.0164%.

Then from the XRD analysis results obtained mineral kaolinite, maghemite, halosit, cristobalite and montmorillonite (Figure 5). SEM analysis with 2500x magnification shows the texture of clay minerals smectite and illite group. Smectite seemed a form pieces in between the grains, whereas illite looks like fine fibers form between granules. There are grains of quartz covered by clay minerals in the center of the photo with dimensions of approximately 30 x 30 μ m. Porosity is a bad primer on samples with a variation of pore size between 1-10 μ m with a fairly evenly spread. Secondary porosity may be a cracks in between the grains and the relationship between pore too bad (Figure 6).

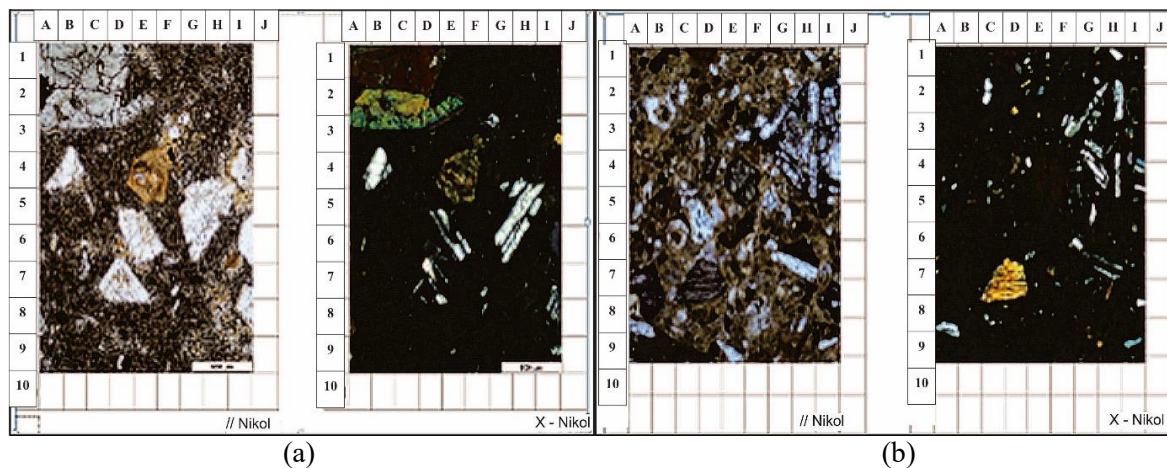


Figure 4. Petrographic of fragment and matrix of sliding surface.

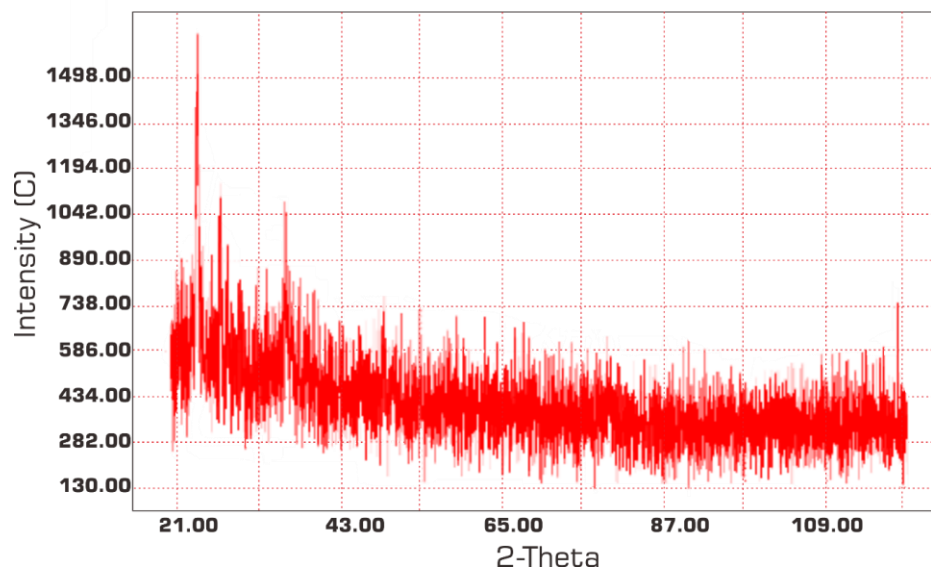


Figure 5. XRD analysis in sliding surface.

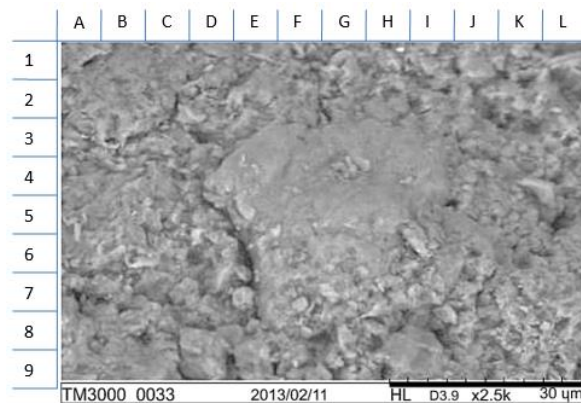


Figure 6. SEM photo in the sliding surface of Pawinihan landslide.

3.1. Physical and mechanical analysis of sliding surface

Based on the analysis of physical and mechanical properties in sliding surface obtained a value of 2.10 for density, then the value of water content of 4.88%, the value of the unit weight of 2.19 g/cm³, cohesion value is 55.52 kg/cm², and the friction angle at 53,64°. So it can be explained that the conditions in this zone is possible as a sliding surface for high cohesion values, material fragments are still showing solid conditions making it possible to give effect to the imposition of the slopes. The slopes at the site of the Pawinihan landslide has a slope angle of $\pm 45^\circ$ correspond to topographic maps before the landslide. Topographic maps is used to determine the surface before the landslide (initial ground surface) and to reconstruct the reverse occurrence of landslides. Recent topography and constituent materials can be seen in the geo-electric landslides testing area.

Correlation geo-electric with field mapping and test pit can be seen in Figure 7. The results of geo-electric measurements and elevation measurements with GPS obtained the lowest point sliding surface as high as 949 m above sea level and the highest point of landslides is 999 m above sea level, measured slope angle is 35°. Based on geo-electrical data at point B1 obtained soil layers at depths of 0-375 m with resistivity from 297.27 to 52.20 Ohm M, meanwhile on the point B2 obtained soil layer at a depth of 0 to 1.98 with resistivity 867.54 to 3775, 76 Ohm M. Point B3 has a soil layer at a depth of 0 to 3.9 m with resistivity from 0.60 to 59.32 Ohm M. When correlated with a layer of soil based on trials in the top of the landslide, obtained a depth of strong weathered layers as deep as 0-4 m. So it is interpreted that the soil layers included in the weathered zone with a high residual soil that is visually dominated by land than a rock. So, beneath the layer of soil is breccia, sand, breccia, and sand again.

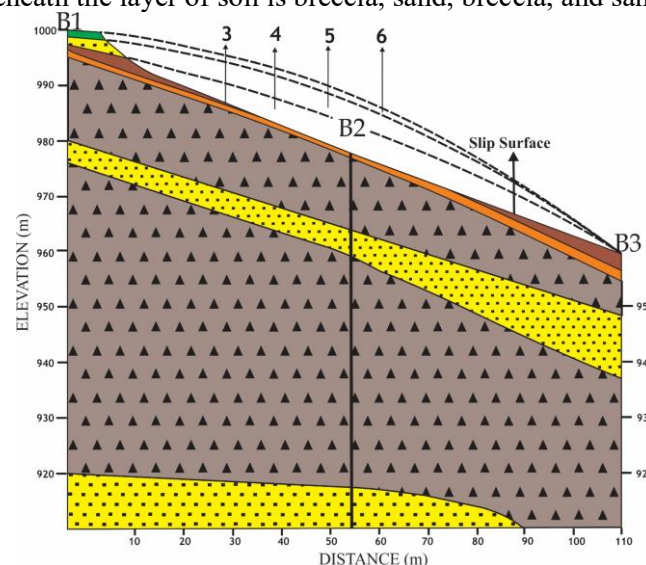


Figure 7. Correlation in the point B1-B2-B3 with test pit in track of landslide.

3.2. *Material forming the slopes*

Slope forming material is a material obtained from different degrees of weathering that have been classified in the previous chapters. Material defined slope changes in the degree of weathering, and its closer to real conditions, also it can be linked genetically. Studies about slope stability materials are usually unorganized one another and the layers not related, but linked by strata layers of the soil. But with a degree of rock weathering, slope stability can be precisely analysed the genesis and also a physical changes, mechanical and chemical. With the change in the physical, mechanical, and chemical is identified, it is easier to find the cause of the instability slope.

The layer thickness with varying weathering levels can be observed from wells test at point B. Point B is the point of wells test in the middle of the top avalanches and consists of three levels correlated with the testing data. Test pit, geo-electric data and geologic mapping techniques produce a corresponding correlation subsoil weathering rate. Sectional profile is then assumed to be a cross-section prior to the occurrence of avalanches. Then researcher make the analysis behind the occurrence of landslides by using a layer of soil based on the level of rock weathering. By inserting the material properties into the soil layer in appropriate level of weathering whether to generate conditions like the present.

Modeling is used as an evaluation for the determination of landslide potential in previously landslide-prone areas especially in the breccia area. So it will be precisely known chemical weathering index prone areas as a sliding plane on breccia areas. The following data is based on the degree of weathering layer of soil from the wells test at point B. Soil residue, from 0 to 1.2 m depth, has a specific gravity of 2.18, 74.9% moisture content, bulk density of 1.27 g / cm³, liquid limit of 52.56%, 40.5% plastic limit, plasticity index 15.2%, the percentage clay 35.3%, the shear angle in 34.4°, cohesion 0.13 g / cm². Perfect weathering grade, has a depth of 1.2 m - 2.8 m with a specific gravity of 2.32, 53.4% moisture content, bulk density of 1.3 g / cm³, liquid limit of 50.08%, 35.8% plastic limit plasticity index of 14.2%, 38.9% the percentage of clay, shear angle in 29.3°, cohesion 0.25 g / cm².

High degree of weathering of the upper depth of 2.8m - 4.0m has a specific gravity of 2.32, 38.62% moisture content, bulk density of 1.4 g / cm³, liquid limit of 42.97%, 37.05 plastic limit %, 5.92% plasticity index, the percentage of 27.44% clay, 30.4 ° angle of friction, cohesion 0.22 g / cm². The degree of weathering has a specific gravity of 2.07 4.88% moisture content, bulk density of 2.16 g / cm³, the limits of Atterberg not identified, cohesion 55.51 kg / cm², the friction angle in 53.64°.

Zone of weathering rate change can be created based on the interpretation of resistivity value. Based on the test results at point B is divided into four layers, namely a layer of weathered high bottom, a layer of weathered high-top, weathered perfect, and soil residue layer in the well test correlated with a resistivity value (Figure 8). The data used in the analysis method is the weight limit equilibrium content (γ), the angle of friction (ϕ) and cohesion (C).

Modeling began with creating slope geometry based on topographical maps before the avalanche, then make a range of materials including the limits in accordance with the degree of weathering, wells test data and geological mapping techniques. The next step is reconstructing slope conditions before the landslides by means plotting the boundaries of weathering, well test data and geological mapping techniques into geo-electric cross-section. The final result is a simulated heterogeneous slope by entering a range of materials based on the degree of weathering with different material properties for each degree of weathering. From the simulation results, obtained a safety factor and a vulnerable zones.

Here are the results of simulations that have been carried out with a slide program version 6 for a conditions before the landslide (Figure 8) and then the data based on the simulation results by taking FK = 1.5 (Figure 8) obtained deployment sliding plane cut zones 6, 5, 4 and stopping in the zone 3 in accordance with the real conditions (Figure 9) but position of top avalanches shifted down.

This study was limited on explore aspects of weathering, so the inundated condition and crops are not taken into the calculation, then the top landslide shifting is expected because of crop and hydrological not taken into the calculation. But from the simulation results, it can be concluded that with the calculations of other factors such as horticultural and changes in pore water, the the top of avalanche passed through zones 6,5, and 4 then stopped in zone 3.

Safety factor value used to predicts an unstable condition. Slope Stability Analysis is using Equilibrium Limit Method.

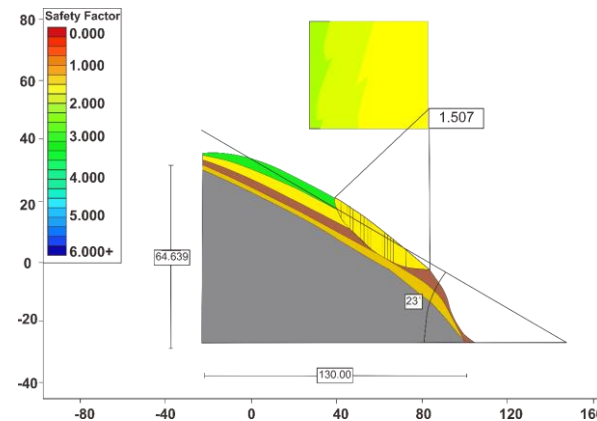


Figure 8. Section of Pawinihan landslide with simulation before landslide.

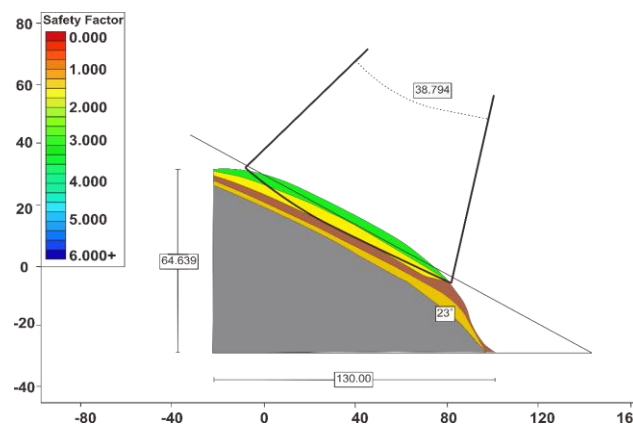


Figure 9. Result of simulation with General Limits Equilibrium after landslide.

4. Conclusion

Based on the method of British Standard BS EN ISO 14689-1, a sliding surface found in weathered layer 3, Based on observations obtained lithological conditions have a composition ratio of rock to the ground ($F = 50\%$ $M = 30\%$) + soil = 20%. Based on the testing of physical and mechanical properties obtained the value of physical and mechanical properties for a specific gravity of 2.10, then the value of water content of 4.88%, the value of the land unit weight of 2.19 g / cm³, cohesion value of 55.52 kg / cm², and the angle of shear in 53,64°. With the composition of cohesion which is quite high and the percentage of stone material is higher than the soil material that causes these zones as avalanches sliding plane. Then from XRF analysis has oxide composition major SiO₂ 52.3%, Al₂O₃ 31.6%, Fe₂O₃ 12.1%, TiO₂ 1.61%, MgO 0.903%, K₂O 0.702%, CaO 0.278%, MnO 0.248%, P₂O₅ 0.169%, BaO 0.0329%, ZnO 0.0164 %. Then from the XRD analysis results obtained mineral kaolinite, maghemite, halosite, cristobalite and montmorillonite. Based on SEM photograph with a magnification of 2500 x shows the texture of clay minerals smectite and illite group. Therefore we can conclude the clay mineral composition is very conducive to a weak zone, namely the development of mineral montmorillonite / smectite in these zones as a result of weathering of rocks essentially are breccias. The categorized mineral clay are quite vulnerable as sliding surface deployment related to a high altitude field. Based on simulations using Limits General Equilibrium obtained sliding plane contained in zone 3 although conditions sliding surface slightly shifted downwards, it is possible because there are cracks in the topas a result of factors that are not identified such as trees. But the same thing can be proved from the simulation results and observations in the field earned sliding plane contained in the weathered zone 3.

References

- [1] Varnes D J 1978 *Slope Movement Type and Processes in Landslide Analysis and Control*, Transportation Research Board, National Academy of Science
- [2] Jworchan I 2006 Mineralogy and Chemical Properties of Residual Soils, Engineering Geology, IAEG, *The Geological Society of London*, Paper Number 21: 1-7
- [3] Permanajati I 2004 *Pengaruh Stratigrafi Lereng dan Sifat Mekanika Tanah terhadap Longsoran di Daerah Kedungrong, Kecamatan Samigaluh, Kabupaten Kulon Progo, Yogyakarta*, Thesis, Universitas Gadjah Mada, tidak dipublikasikan
- [4] Permanajati I, Waluyo G, Suwardi, and Setijadi R 2006 Longsoran Gunung Pawinihan, Desa Sijeruk, Kecamatan Banjarmangu, Banjarnegara, *Prosiding Lokakarya DAS Serayu Hulu, Unsoed*, pp. 1-4
- [5] Permanajati I 2009 Aplikasi Agrogeologi dan Geologi Teknik di Bencana Alam Longsoran Langkap Kabupaten Purbalingga, *Proceeding Seminar National on Applied Technology, Science dan Art, ITS*, pp. 1-6
- [6] Calcaterra D dan Parise M 2010 Weathering as a Predisposing Factor to Slope Movements: an Introduction, Engineering Geology Special Publications, *Geological Society London*, **23**: 1-4
- [7] Condon W H, Pardyanto L, Ketner K B, Amin, Gafoer S, dan Samodra H 1996 *Peta Geologi Lembar Banjarnegara dan Pekalongan, Jawa, Pusat Penelitian dan Pengembangan Geologi*, Edisi ke-2
- [8] Priyono K D dan Priyono 2008 Analisis Morfometri dan Morfostruktur Lereng kejadian Longsoran di Kecamatan Banjarmangu, Kabupaten Banjarnegara, *Forum Geografi, Universitas Muhammadiyah Surakarta*, **22**: 72-84
- [9] Price J R, Velbel M A 2003 *Chemical Weathering Indices Applied to Weathering Profil Developed on Heterogeneous Felsic Metamorphic Parent Rock*, Elsevier, Chemical Geology, **202**: 397-416