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ENGINEERING GEOLOGICAL STUDY OF MALINO-MANIPI LANDSLIDE SUSCEPTIBILITY SOUTH SULAWESI INDONESIA

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ABSTRACT

Mountainous area of southern South Sulawesi Province, Indonesia is prone to landslides. During 2009 to 2013 more than 50 landslides have occurred causing road connecting Malino-Gowa Regency to Manipi-Sinjai Regency heavily damaged. The aim of this research is to find out the influence of engineering geological aspect against landslide susceptibility in the study area. The research uses field survey method consisting of: characteristic study of tuff weathering profile: determining water content, infiltration rate and shear strength of weathered rock and residual soil, as well as laboratory analysis covering petrographic analysis of fresh rock composition. Field survey result indicates that tuff profile consists of six stages including unweathered tuff (fresh), slightly weathered tuff, moderately weathered tuff, , highly weathered tuff, completely weathered tuff, and residual soil. Most tuff mineral compositions are volcanic glass. The more the weathering stage increases, the higher the water content and infiltration rate. Conversely, the shear strength becomes low. Under this condition, landslide becomes susceptible.

Keywords: landslide susceptibility, engineering geology, tuff characteristic, Malino-Manipi road, South Sulawesi.

INTRODUCTION

Landslide is one natural disaster which often takes place in Indonesia because many parts of Indonesia are susceptible to landslides due to its geological conditions. Landslide susceptibility is a phenomenon where condition of slope becomes potential or susceptible to move even though at the time when the slope is still stable but if there is a trigger (for example heavy rains, vibration, and human factors) it will soon move or occur as a landslide [1]. Indonesia in general due to its topographic condition is very prone to landslides occurrences. Java Island is the highest rate of landslide incidence. The latest landslide incidence occurred in the earlier 2014 was in Jombang and Bogor causing more than 10 victims.

Most of the southern part of South Sulawesi province are occupied by hills and mountains and composed by lithology that are generally and relatively young volcanic rocks cause large parts of the region are susceptible to landslides [2]. Malino-Manipi road is one of the roads in the southern South Sulawesi often hit by the landslide every year and according to [2] is one of the roads susceptible to landslides.

The recent data indicate that during January-July 2013 period there have been landslides in 34 locations. The slope experiencing landslide generally occurred in tuff volcanic rocks. The landslide has caused broken and buried main road thus transportation flow and community economic activity became disturbed. Moreover, road damaged due to landslide incidence may also destroy gardens and community crops with a vast amount of material loss.

Methods used to study landslide susceptibility are heuristic approach which is used in landslide susceptibility mapping in Tawangmangu Region Central Java [3], reference [3] used 6 parameters which are slope, lithology, soil depth, texture, permeability, and land use. While [4] use environmental factor, fuzzy membership function and GIS.

In addition, a study on the landslide susceptibility by [5] using the Analytical Hierarchy Process approach uses data of elevation, slope aspect, slope angle, distance from drainage, lithology, distance from lineament, soil texture, precipitation, land use / land cover and NDVD (Normalized Difference Vegetation Index) and [6] uses the Geographical Information System (GIS) and Analytical Hierarchy Process (AHP) using the data of elevation, slope aspect, slope steepness, proximity to road, proximity to river, lithology, lineament, soil texture, rainfall, land use or land cover . Other experts such as [7] use statistical and geotechnical approach in landslide susceptibility analysis. Landslide susceptibility analysis was also performed by [8], through bivariate approach and GIS approach. Thus the experts conduct research on landslide susceptibility using various methods and parameters.

This research is conducted according to tuff rock engineering geological characteristics which are: weathering stage, fresh water content of weathered tuff and residual soil, infiltration rate and shear strength. According to those parameters a formula can be made as follow:

Landslide Susceptibility (LS) = f (X1 + X2 + X3 + X4)

Where
X_1 = Fresh tuff mineral composition
X_2 = Water content
X_3 = Infiltration Rate
X_4 = Shear Strength

The objective of this research is to find out the influence of engineering geological aspect against

landslide susceptibility of tuff slope along the Malino-Manipi road. The expected advantages from this research are the data and information yielded from this research can be used by the authority for an effective and efficient landslide mitigation plan and as reference to researchers interested in landslide incidence disaster.

RESEARCH METHODOLOGY

Study area

The location of study area is in Malino-Manipi road which connects Malino Tourism Region, Gowa Regency and Manipi WestSinjai, Sinjai Regency (Figure-1). The study area is at the east slope of Lompobattang Mountain. The distance of study area from Makassar is about 100 kms. The location altitude lies in 700 meter to 1600 meter above sea level surface (mean sea level) (Figure-1).

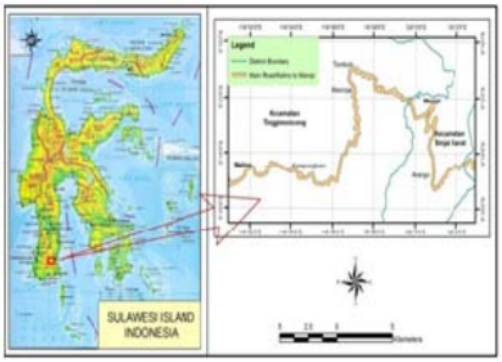

Figure-1. Research location map.

Method of Research

This research is performed in landslide incidence locations and in steep slopes estimated would be hit by landslide composed by tuff lithology. The research method applied is field survey and laboratory analysis. The field survey consists of point and extremely dangerous landslide identification, geological characteristic observation, fresh and weathered tuff sampling, water content estimation uses moisturemeter soil device type PMS-714, infiltration rate estimation by single ring method and weathering tuff shear strength estimation by vane shear test in 4 landslide locations. Laboratory analysis is tuff rock petrography analysis for 4 samples conducted in Petrographic Laboratory of Geological Department of Engineering Faculty of Hasanuddin University.

RESULTS AND DISCUSSIONS

Weathered Tuff characteristic

Field investigation result of tuff characteristic indicates that tuff profile consists of 6 stages that are fresh tuff, slightly weathered tuff, moderately weathered tuff, highly weathered tuff, completely weathered tuff, and residual soil. Fresh tuff characteristics are weathering indication which not visible or no colour change occurs yet that is from bright grey to dark grey tuff; slightly weathered tuff characteristics are colour change has been occurred in its rock bodies and existing small open crack; moderately weathered tuff characteristics identified by colour change in half part of rock bodies and already has little disintegration into soil, can already be cut off by cutter or slightly by nail, has reddish grey tuff colour and clear rock texture; highly weathered tuff characteristics can be known by its reddish grey tuff and crack, commonly tuff can already be cut off by nail or finger and its rock texture is hard to recognize; completely weathered tuff characteristics are almost all of the rock body colour has changed into red to brownish red, the rock texture is very hard to recognize, and can be easily taken by hand and; residual soil from tuff characteristics are all tuff has already modified into soil, has brownish red into brown colour, its texture and structure are not visible anymore but yet experiences transportation process.

Tuff mineral composition

Petrographic observation result taken from fresh tuff reveals that mineral composition consists of volcanic glass, bytownite mineral, pyroxene, quartz, and opaque mineral. Tuff on thin section appearance can be seen in photographs in Figure-2 and for its each sample of mineral composition in Table-1.

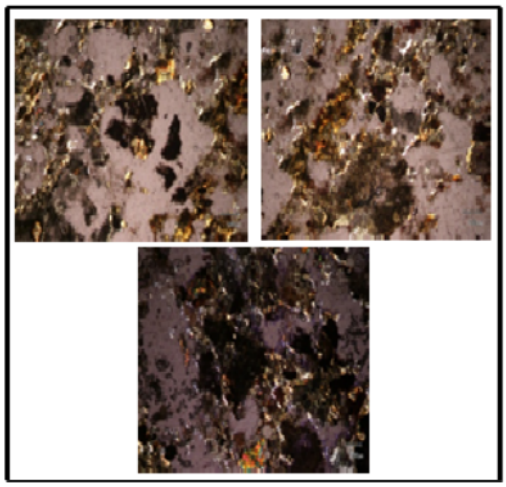

Figure-2. Tuff thin section photo consists of volcanic glass, plagioclace mineral, pyroxene, quartz, and opaque mineral.

Mineral compositions from 4 observed samples are as follows:

Table-1. Petrographic of Tuff mineral composition.

Mineral name	Mineral composition (%)			
	Sample 1	Sample 2	Sample 3	Sample 4
Plagioclase	19	10	18	15
Pyroxene	15	19	15	14
Quartz	13	9	12	10
Volcanic Glass	50	60	50	55
Opaque mineral	2	2	5	6
	100	100	100	100

Water content, infiltration rate, and shear strength of weathered tuff and residual soil

The result of water content, infiltration rate, and shear strength of weathered tuff and residual soil is presented in Table-2.

Engineering properties of rock is influenced by its weathering stage [9] The tuff composition of research location slope has experienced weathering process starting from moderately weathered until becoming soil and generally is high to completely weathered. One cause of highly weathering is its dominant rock composition which is volcanic glass, bytownite type of plagioclase, pyroxene, quartz, and opaque mineral. That kind of composition is thus strongly support a rapid weathering process. [10] Suggested that rock which contains much volcanic glass is easily to weather. In addition, tuff condition is not compact because the lithology belongs to the young volcanic rock from Lompobattang's Pleistocene Volcanic Rock [11 and 12]. This cause weathering process easily occurs.

The water content examination (Figure-3) reveals that tuff water content is higher due to higher weathering and shrinks back after turning into residual soil, this occurred because the weathered tuff experiences disintegration of bound release among its grain composition rock thus the rock become porous and its water content becomes high.

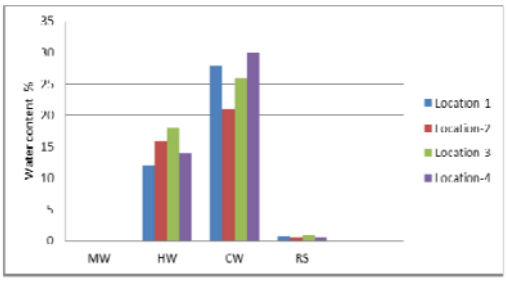

Figure-3. Correlation graph of water content and tuff weathering stage.

This phenomenon is in compliance to a research result by [14], [15], and [16] that the higher the rock weathering rate, the higher the water content. Likewise tuff infiltration rate will increase in accordance to the increasing of weathering stage but after it turns into residual soil the infiltration rate becomes low (Figure-4). This occurs because the permeability of weathering rock becomes high thus the infiltration rate gets high as well. The phenomenon is accordance to [17] research result which indicates that infiltration rate will be higher if the weathering stage is also higher because the rock experiences crushing and consequently its permeability and porosity becomes high.

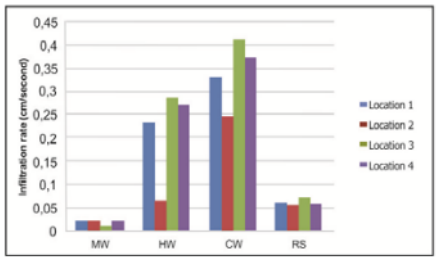

Figure-4. Correlation graph of infiltration rate and tuff weathering stage.

Furthermore based on the shear strength result, it is obtained a correlation graph of rock weathering stage and weathering tuff shear strength (Figure-5).

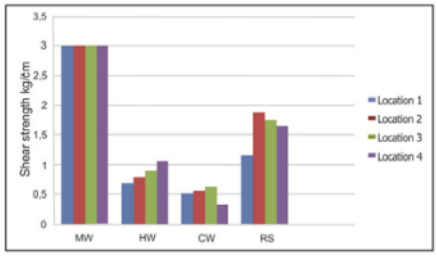

Figure-5. Correlation graph of shear strength and tuff weathering stage.

In Figure-5 we can see that if tuff experiences weathering begin from moderately weathered to completely weathered, its shear strength will be lower because the cohesion properties of rock will decrease along with it's highly weathering and increase again after being modified into residual soil. One cause of the high shear strength of soil is soil cohesion properties. Therefore it can be revealed that cohesion of weathering tuff will decrease and the inside shear angle will be lower thus its shear strength will also be lower. Reference [18] suggested that the weathering condition in a rock will decrease its shear strength while [19] clarified that the factors which come from the inside

Table-2. Result of water content, infiltration rate, and shear strength of weathered tuff and residual soil

Weathering Stages	Location-1			Location-2			Location-3			Location-4		
	A (%)	B (cm/second)	C (Kg/cm²)	A (%)	B (cm/second)	C (Kg/cm²)	A (%)	B (cm/second)	C (Kg/cm²)	A (%)	B (cm/second)	C (Kg/cm²)
Moderately Weathering (MW)	-	0,002	> 3	-	0,002	> 3	-	0,003	> 3	-	0,021	> 3
Highly Weathering (HW)	12	0,235	0,69	16	0,246	0,80	18	0,289	0,91	14	0,271	1,09
Completely Weathering (CW)	28	0,331	0,52	21	0,469	0,58	26	0,412	0,65	30	0,374	0,34
Residual Soil (RS)	0,7	0,059	1,18	0,51	0,068	1,90	1,0	0,072	1,77	0,6	0,059	1,67

Explanation: A = Water Content, B = Infiltration Rate, C = Shear Strength

slope such as weathering will weaken the rock condition and can trigger landslide. Thus when the rock has been in a high to completely weathered condition then the slope in which the rock exists will be susceptible to become landslide.

CONCLUSIONS

From this research we conclude that descriptively tuff characteristic can be classified into 6 weathering stages that are fresh tuff, slightly weathered tuff, moderately weathered tuff, highly weathered tuff, completely weathered tuff, and residual soil. The tuff in research location is easily weathered tuff because its dominating mineral composition is volcanic glass. Along with the higher weathering its water content and infiltration rate become higher (highly and completely weathered tuff) but its shear strength becomes low (the lowest in completely weathered tuff). Every weathering stage will have certain water content, infiltration rate, and shear strength values. The three conditions causing the slope built by highly to completely weathering tuff in the research location to become susceptible to landslide.

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