GEOLOGICAL CONTROL AND MITIGATION OF MALINO- MANIPI LANDSLIDE, SOUTH SULAWESI INDONESIA

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ABSTRACT

Road access of Malino – Manipi is a main road from Gowa Regency to Sinjai Regency, South Sulawesi. In 4 years latter the road experiences landslide, which has an impact such as the road itself, furthermore economic activities of community in that area.

Method that has been applied in this research is landsat image interpretation, detail geological mapping, and geoelectric resistivity measurement at 2 locations. The result of study shows that the area has a steep slope ranging from $35^O - 85^O$, many lineaments and opened crack of topography. The research area consists of young volcanic rocks which intercalate between phyroclastics such tuff and breccia and lava. The rocks experienced deformation indicated by faults, fracturea and high alteration of the rocks.

The geological condition triggeres the area a high risk of landslide. Based on the condition, to mitigate tha area it is needed two methods that can be applied. They are structural method (stabilization of slope geometry, drainage construction for surface water flow control and slope strengthening by applying anchoe system), and non-structural method (vegetative mitigation and educating community for potential landside).

KEY WORDS: landslide, mitigation, geological control, Malino-Manipi road acces

1. INTRODUCTION

The occurrence of landslide is increasing nowadays in Indonesia resulting loss of human life and property. South Sulawesi which is involving in this case has a high risk of landslide due to steep slope topography and young volcanics lithology

Since 2001 – 2008 there were 36 the occurrence of landslide in Indonesia with 1228 people death/missing and 4044 houses destroying (Karnawati & Fathani, 2008). The largest landslide in 2010 occured in Ciwedey, West Java Indonesia in which 44 people were died (Nugroho, 2010), and around 104 people died in 2011(BNPB, 2012). In 2012 it is recorded that there 21 peopole as a victim of landslide in Ambonyang and destroyed 118 houses. It is though that this phenomena will increase each year in the feature due to the increasing of land conservation to other lans use (Karnawati & Fathani, 2008).

Topographically and lithologically 11 regencies in South Sulawesi are high potential of landslide (BNPB, 2012) namely Tana Toraja, Luwu, Pinrang, Sidenreng Rappang, Wajo, Soppeng, Bone, Sinjai, Bantaeng, dan Gowa (Harian Fajar, 2010). Topography of the regencies is dominantly mountaneous and lithology is mostly consist of young volcanics rocks. Based on the geological survey there are several landslides that have been occured along Malino-Manipi main road during 2009 – 2012 (Pachri

(2009 and Busthan, 2011). The effect of the landslide has obstructed the transportation along the road as well as economic activity at the region. The fact indicates that the region will be frequently experienced landslide in the future. Therefore it should be mitigated to reduce the impact of the landslide itself.

Landslide mitigation has been broadly applied through the wold including Indonesia. Some methods of mitigation such as structural, vegetative, as well as socialized one were aplied in Purworejo and Kulongprogo, Central Java (Sukresno and Adi, 2003). Winarno & Sunarto, (2007) suggested that to apply a combination of terracering, dam and green belt in mitigating landslide in Kulonproga Yogyakarta. White and Stearns (1990) propose retaining walls, drainage on building pads, drainage on hill cut slope, revegtating slope, including public education for landslide mitigation. Yin and Wang (2005) applied enchor for strengtening lope and drainage for mitigating landslide in China.The purpose of the research is to analyze the geological control of landslide occurrence along the Malino – Manipi road and to determine mitigation method on the slope which haspotentially prone landslide.

The study area is located in the eastern part of G Bawakaraeng or at the uppermost of S. Tangka. It lies on the road of Malino – Manipi line, or at 119 $^{\circ}$55'0" E - 120°6'0" E and 5°10'0" S – 5°15'0". Most of the location lies in West Sinjai District and in small part locates in Malino (Gowa Regency). Topography is relatively steep slope with elevation ranging from 200 m (in the east) – 1600 m (in the west).

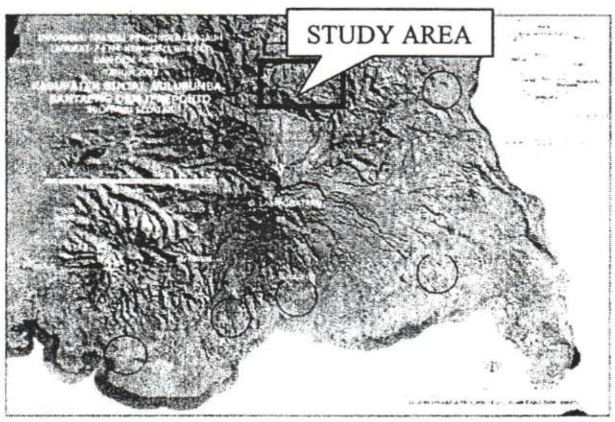

Figure 1. Study Area On the Northeast of G. Bawakaraeng, South Sulawesi.

2. METHODOLOGY

Instability factors than influence severe landslides in tropical area area include surface and badrock, lithology, structure, seismicity, slope steepness, morphology, stream, groundwater, climate, vegetation cover, land use and human activity. In this study only geological factors were considered such as morphology (include sloope angle), lithology and structural geology.

The geological factors were obtained by doing a detail surface geological mapping, interpreting satelite image, and geoelectric resistivity measurement in two locations. Satelite image was used to identify the surface lineament and topography. Surface geological mapping include type of lithology, geological structures (fault, fold and fractures) in small scale, weatering degree and stratigraphy. Resistivity interpretation was applied to determine the subsurface condition including sliding plane and discontinuity boundary. Due to the mountaneous topography and steep slope it was used multi-channel geoelectricresistivity measurement.The interpretation results are described intwodimensions.

3. RESULT AND DISCUSSION

3.1 Geological Framework

Citra satelite interpretation and surface measurement show that study area has moderately to steep slopes (35 – 85°). Some lineaments and strike topography were found as an indication of fault and/or cracks. Fig. 2 shows topography of G Bawakaraeng with the peak until 2833 m above sea level.

Regionally the study area consists mainly of Camba Volcanics (volcanic breccia, lava, conglomerate and tuffs), Baturappe – Cindako Volcanics (lava, volcanic breccia, tuff and aglomerate), Lompo battang volcanics (aglomerat, lava, volcanics breccia, laharic deposit and tuff) (Sukamto & Supriatna, 1982).

Study sitesarepart of the complex Lompo battang mountainin the northeastern partand consists of the youngest volcano in the South Sulawesi with conetypesor strato volcano(Yuwono,1989). The stratigraphy is intercalation of phyroclastic rocks (tuff and volcanic breccia, laharic breccia)andlava (Figure 3).In addition to the rocks that are not properly compacted.

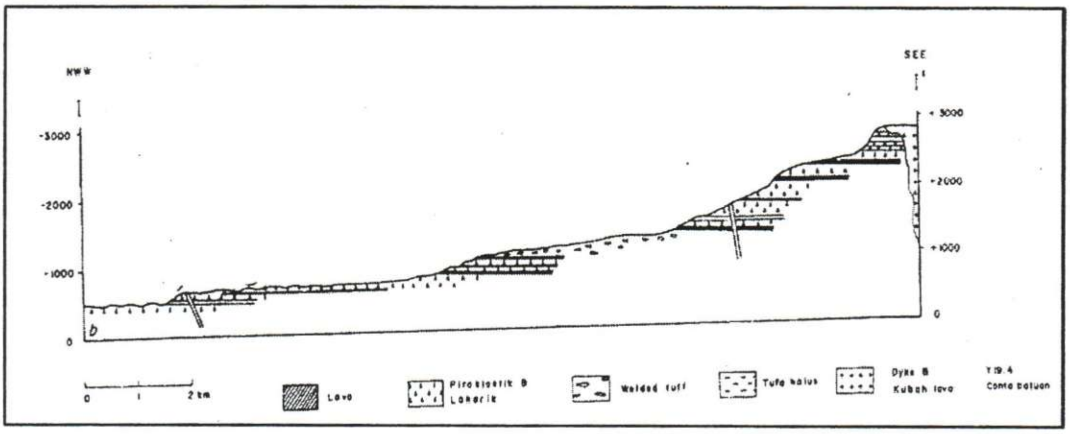

Figure 3. StratigraphyLompobattangMountain (Yuwono, 1989)

Researchand surrounding area shave experienced deformation, whichis characterized by the presence of several faults, fructure and rocks slide.Faults are generally trending nearly north-south and northwest-southeast. The frcture itself is mostly opened (shear joint) with wide openings 1-2 cm and spacing ranging from 20 cm to 45 cm . Furthermore the rockshave experienced weatheringranging from theslightlyweatheredtoheavy weathered (Soil).

3.2 Resistivity Interpretation

Resistivity measurements performed at the former land slide material and location of potentially to occur landslide. The aim is mainly intended todetermineslipplane of landslide. Study of landslide by applying resistivity interpretation has been broadly conducted such as in Magelang by Permana et al (2010).

The result of the measurement are interpreted that: a) the location consists of volcanic rocksnamely coarsetuff, fine tuff and the intrusion of basaltic rocks, b) there are two locations of potential landslides (at the upper side of the roadand shallow land slides at down side of the road) (Figure 4),c) at the location 2 the result shows that there is asingle potential landslide toward of the upper side of the road (Figure 4).

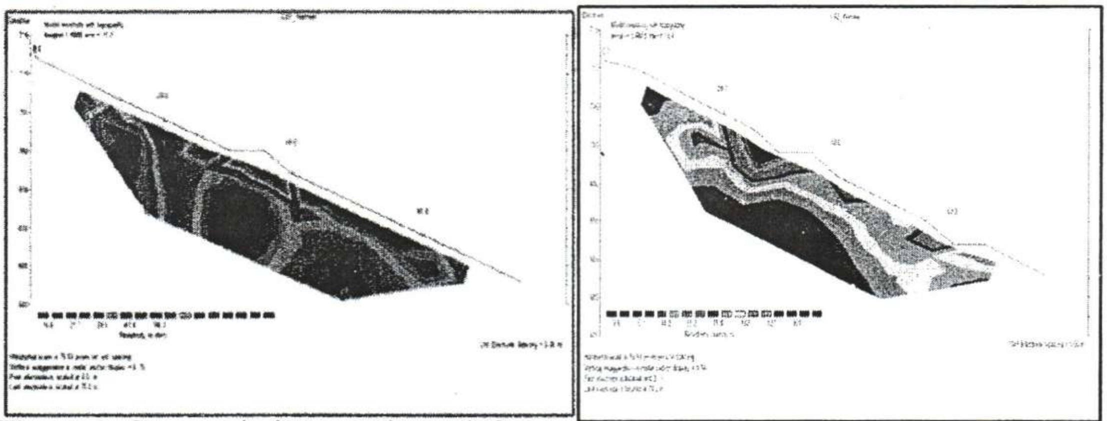

Figure 4. Cross-sectioninterpretationresultsfrom resistivity measurementonlocation1 (left) and 2 (right).

3.3 Landslide Potential of Regional Research

Based on geological conditions,the study area consists of high wethering tuff, an intercalating of permeable (tuff) and impermeable rock layers (lava/laharic rocks) and many discontinuity boundary by fracturing and faulting. In addition to slope that hasa steep slopes ranging from 35° - 85°causes the slope becomes unstable and prone to landslides. The control of geological structure of landslide occurence also has been studied in the region of Cikarang by Sunarno and Hussein (2010). Based on the resistivity value and stratigraphy it is interpreted that the boundary of weathered tuff (soil) and tuff itself becomes a sliding plane.

Based on the resistivity interpretation and geological condition mention above it can be explaned that the landslides type potentially occured in the study area is debris slump (Varnes, 1978) or rotational landslide (USGS, 2003). Based on the explanation above it can be said that the type of potential lanslide inthe study area is debris slump or rotational landslide.

The sliding plane of Potential landslideslies between weathered tuff with resistivity valuesranging from 15 to 29.5ohm.mand host rock or intrusive rocksof basalt(resistivity400-1000ohm.m),at thediscontinuity (faults and fractures). This sliding plane is interprted at the depth ofover 25m, 7,5 m and 10m.

3.4 Engineering and Mitigation Efforts on area of Landslide Potency

There are some efforts can be applied both structurally and non-structurally to mitigate land slides that may occuring the study area. However they can not properly work without law enforcement ofregulations (Anonymous, 2002). Type of engineering and mitigation that suitable for the study area as follow:

3.5 Structural Mitigation

Types of land slides are debrisavalanches and rotational slump(landslide), therefore it should be applied structuralengineeringby:

- modifying slope geometry such as reducingsteep slope
- constructinggooddrainageto controll surface waterflow
- strengtening the slope with engineering methode such as anchor system

3.6 Non-Structural Mitigation

Non-structural efforts that can bedoneare:

- vegetative mitigationis by planting trees orplantsin orderto preventerosion, reducing infiltration of surface water.
- Socializedto the communitying order to educate people concerning landslide potential and its impacts.

4. CONCLUSION

Based onthe above explanationof geologicalandresistivity interpretationapproach, it can be concluded that:

1. The geological control (steepslope,lithology, highweathering,

discontinuity) of landslide potency onMalino-Manipimain roadisplays an important role.

2. There are three types of sliding plane namely boundary between weatheredrocks (soil)weathered and host rocks (tuff and volcanic breecia), fracture and the existing of lava or laharic rock as impermeable layer.
3. Mitigation that can be done according to the type of land slidesis bothnon-structurally and structurally.

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'GALODO' PADANG 2012: CAUSES AND PREVENTION

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ABSTRACT

The Galodo Padang 2012 that has taken the lives is caused landslide in catchment area of Batang Kuranji river. The land slide it self is triggered by the heavy rain in few hours before. The slope of Batang Kuranji river catchment area is located in hilly terrain. The physical changes of the soil caused the loss of slope stability. To determine the cause of the Padang landslide 2012, the field investigation was conducted. The physical and mechanical properties of the soil in the area are examined. The research of physical properties is especially useful for understanding the behaviour of soil in the change of water content. The type of soil that dominates the catchments area is fine grained soil. This type of soil will change the mechanical behaviour with the change of the water content. Protection should be taken to avoid the similar phenomenon in the same place and in the same area.

KEY WORDS: Landslide, Mitigation, Remedial action

1. BACKGROUND

In the Minangkabau land, mud flows, landslides and similar disasters are named as Galodo. There is proclaimed that galodo is an abbreviation of words means the wave of sins. So with natural disasters, Minang people take lessons for themselves on what they have done in the past that cause sin to the God, sin on humanity and sin against the natural surroundings. So the sin or mistake should be a lesson that the same mistake should not be repeated again in the future.

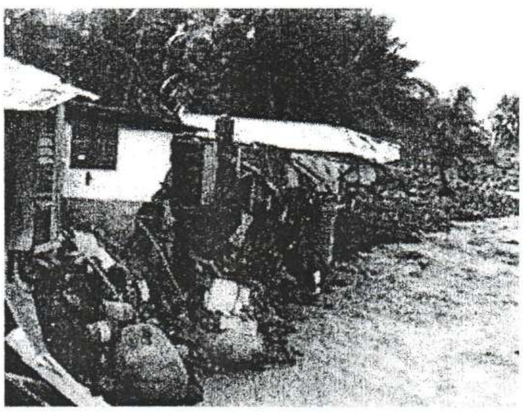


Figure 1. Scouring on the the river bang of Batang Kuranji due galodo I

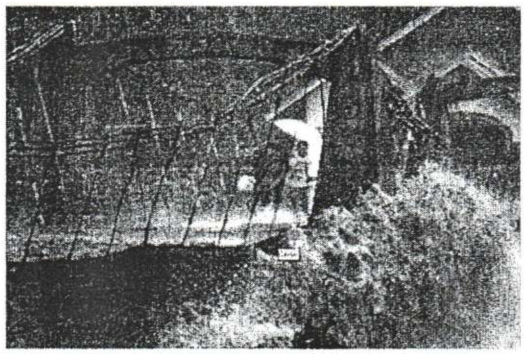


Figure 2. People crossing the unsafe bridge in Galodo II [1]

On Thursday afternoon 13 September 2012, the city of Padang hit by flood again which is named as Galodo by the local people. This is the second time the Galodo happened in Batang Kuranji river which divides the Padang city into two from east to west. This deadly flood is almost the same as a big flood on 24 July 2012. The first flood occurred in the same watershed that is in Limau Manis watershed. But the second Galodo was followed by landslide in the area around of the Batu Busuk river. Both Limau Manis river and Batu Busuk river come together the form of a big river named Batang Kuranji. In this paper we will discuss the technical issues that caused landslides in Batu

Busuk that has destroyed a few houses with the people in them. Then also it is delivered one of the prevention methods for stabilizing the slope using trees.

Figure 3. Evacuation process in galodo II

In general, the scale of the damage caused by the both Padang Galodo 2012 was about the same, but the second Galodo has casualties of 8 people. In addition it has flashed several homes. The heavy rain in that day also has triggered landslides at three points in the Batu Busuk. At the time of the Galodo in the region, hundreds of residents have been evacuated to the safer place after they were temporarily isolated in a few hours. It is more difficult condition to safe the people since the only access to location has to pass through an old bridge that built in the Dutch era. The bridge is already in an unsafe condition, but there has not planned a replacement bridge yet.

2. METHODOLOGY

In order to find out technical things that cause the landslides in Batu Busuk, the field investigations have been conducted in the location. The field survey in the field has carried out the geometry of the landslide area. In addition, the soil samples have been taken from the location in some point. The soil samples then were taken into the laboratory for physical and mechanical parameters tests.

The loss of stability of slopes in Batu Busuk is mainly caused by the presence of intrusive water due to the rain. The tests of the soil samples were carried out also in associated with soil behavior related to its interaction with water.

For that purposes, the experiment conducted on soil samples mainly are as follows:

a. Sieve analysis for soil particle composition. The test is aimed to determine the composition of the grain size that dominates in the soil structure of Batu Busuk. The test is performed using the sieves to separate the grains of the soil in certain sizes. Furthermore, the amount of grain that passes through the sieves was plotted in a graph to determine the dominant soil particle size. In general, the soil is classified into two main groups, those are fine-grained soil and coarse grained soil.

b. The Atterberg limits tests. These tests are aimed to obtain data of the water content in the soil that can change the consistency of the soil in the terms of plastic limit and liquid limit. In fact that if a soil has a moisture content that exceeds its liquid limit, then the soil mass will be easy to transform from a solid to a liquid form. The soil mass that has excessive water content in it, can flow as the behavior of liquids. In nature, this flowing soil mass is usually move together with the other objects and is known as the mud flow or debris flow.

c. Shear strength testing. This test is performed to determine the technical values of soil samples in terms of shear strength parameters. In general, soils have the shear strength that contributed by the adhesive (cohesion) and internal shear resistance (friction). The cohesion is trigerred by the chemical behavior of the soil particles and the shear resistant is affected mainly by the shape and size of soil particles. Coarse- grained soils have very little the adhesion between the grains, the shear strength of these soils are determined by the inter- particle friction resistance. The measurement of soil internal shear parameter values can be done by direct shear tests on soil samples both in the field and in laboratory. Meanwhile for the fine-grained soils, the shear strength is contributed mainly by cohesion between soil particles. The value of the cohesion parameter of these type of soils can be easily done by unconfined compression shear test (UCST).

d. The other physical parameters testing. The tests are performed to obtain the values of the natural water content, the specific gravity and the unit weight of the soil. These parameters are required to identify soil types and also needed as the input data for the slope stability analysis.

Once the results of the soil parameters tests for soil samples are collected, analyses of the slope stability can be performed. The slope stability analyses are conducted with the moisture conditions variations. The stability analysis considers also by assuming that the failure surface in the slope that has the same direction with the surface slope. The linear type of failure surface in slope is more suitable compared to the actual events in the landslide site. The depths of failure surfaces in the slope are determine the stability of the slope.

Finally, the critical depth of failure surface on the slopes is determined. The critical depth is the depth of potential failure in slope that greatly affected by changes of the water content. The changes in water content for the uncovered slopes are strongly affected by the weather (rain and drought seasons). Since the cover of the slope has been opened by landslide, the best remedial method on the slope of the Batu Busuk is the reforestation. The special plants to be planted on the slopes. The plant roots must increase the stability of slopes even for the weakest soil shearing resistance. The roots of selected plants should be able to reach the base area of erosion under the surface of the slope that determined as the critical depth.

3. RESULTS AND DISCUSSION

The slope geometry data has been taken from the location of Padang Galodo II (Figure 4). The undisturbed soil samples was also has been brought from the landslide area on 2 points. Based on survey data on location the slope representation is then performed on the slopes (Figure 5). Batu Busuk hillside is categorized as a steep slope since the slopes have average angle more than 45 degrees.

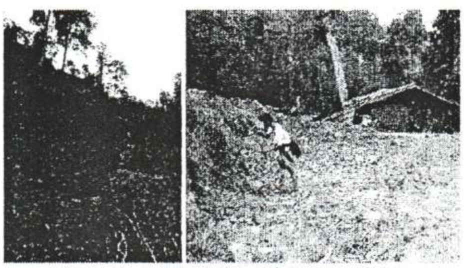


Figure 4. Post lanslide condition

Although the actual location there are many large rocks (boulder), but the behavior of the soil dominates the slope stability. During the landslide the boulders were moving together with the mudflow.

Table 1. The test results of soil samples 1 and 2

Jenis Pengujian	Parameter	Nilai		Satuan
		Sampel 1	Sampel 2	
Kadar Air	w	57.976	50.966	%
Berat Volume	γ	1.772	1.772	gram/cm^3
Spesific Gravity	Gs	2.647	2.653	
Analisa Saringan	Gravel	0.800	3.867	%
	Sand	47.467	50.567	%
Atterberg's Limit	LL	51.522	52.965	%
	PL	42.644	45.020	%
	PI	8.878	7.945	%
Direct Shear	c	0.075	0.089	kg/cm^2
	φ	32.278	36.646	°
UCST	qu uds	0.806	0.354	kg/cm^2
	qu remolded	0.306	0.181	kg/cm^2
	ST	2.639	1.959	
UCST remolded	qu PL	0.256	0.198	kg/cm^2
	qu LL	0.128	0.086	kg/cm^2

The laboratory test results of the two soil samples are shown in Table 1. From these results it can be seen that the hill of Batu Busuk are made of fine grain soil. The soil sample has approximately 50% of fine content. This indicates that the behavior of the slopes are following the behavior of fine-grained soil. Generally soil deposit has fine soil particle content of 30% and over, the mechanical behavior will be dominated by the fine-grained soil contains.

Based on the test result in terms of the water content at plastic limit and liquid limit, the fine grain soil can be classified as silt soil. Meanwhile the test results of natural water content, the soil is classified as having a very high water content. The natural water content of the soil in location is excess its liquid limit. This condition indicates that slope will be easily changing the consistency to liquid form. It means that the slope move down like a liquid due to a sufficient interference. Based an the internal friction angle that about 30 degrees, the slope will quickly move down if the is rain fall wetting the soil and the soil loss its cohesion. The reason is that the sloped of the hillside are lager than the average of internal shear angle of the soil.

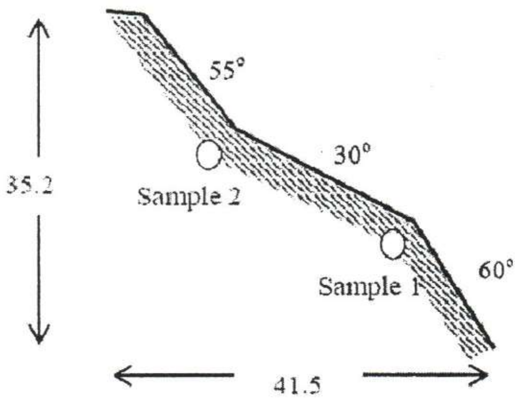


Figure 5. Slope geometry (units in m) and sampling points

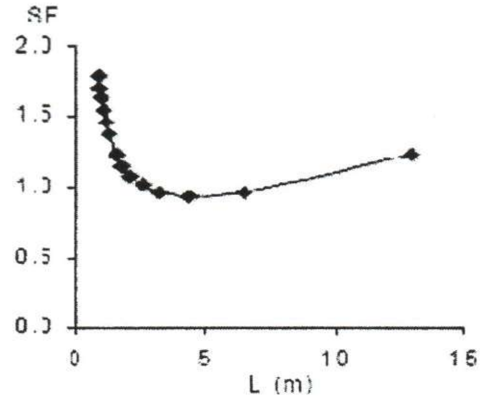
Based on the slope geometric and soil parameters obtained, it can be seen that the biggest of slope angle is 60 degrees. The related soil parameters is taken from the soil samples 1. Those soil data then are used to simulate the flat failure surface in slope stability analyses. The results show that the slopes are still in a actually location in a critical condition, with the lowest safety factor of about 1 (Figure 6). This indicates that the slopes have potential to slide down.

Furthermore, to determine the critical depth of the slope failure surface by assuming to be parallel to the surface, the critical depth of failure is calculated as follows [2]:

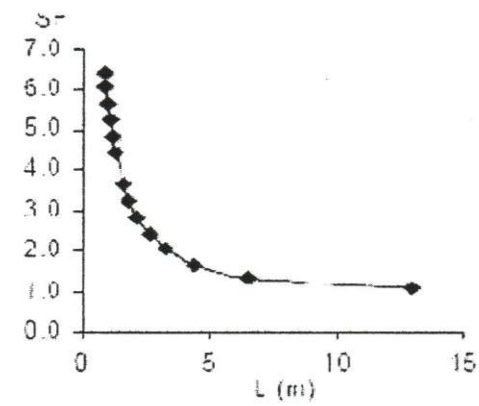
$$D_{cr} = \frac{c}{\gamma} \frac{H^2 + L^2}{HL} \quad (1)$$

The critical depth also calculated by assuming that the slope behaves completely dominated by the soil cohesion. The result shows the depth of the slope on the normal state (no rain) is 4.5m, while in the rain, to be 1.1 m. This means that in normal conditions, disturbance till the depth of 4.5m from the surface can lead the slope to be unstable condition. But in a worse condition and wet, then the interference with a depth of 1.1 m has led to unstable slopes and landslides.

Based on the calculation above, in order to prevent the landslides in the hillside Batu Busuk the action of re-planting should be done. Replanting of slope in addition serves to create a beautiful landscape also to reduce the influence of weather on physical and mechanical parameters of the soil. Replanting can be done by planting both tall trees and low plants. Types of trees will be planted should have a root to reach the depth exceeding 1.1 m. Technically, in order to maintain safety in heavy rain conditions that can lead to a reduction in soil strength, the recommended tree roots is one and a half times that of the critical depth that about 1.6m from the ground surface.



a. Direct shear Test data



b. Unconfined Compression Test data

Figure 6. The value of the safety factor for the length of the different collapse

4. CONCLUSIONS

Galodo Padang in 2012 has occurred twice. The first Galodo took place in July and the second in September 2012. The second Galodo has caused fatalities due to landslides. The results of the study conducted in the landslide area showed that the soil is dominated by fine-grained soil. The soil in the landslide are has the shear resistance that can decrease as the water content increases. In normal condition, it can be concluded that the slopes of the Batu Busuk area are in fairly stable condition, but on wet slopes become unstable and lead to landslide.

To prevent the disaster of the same event, then the slopes of Batu Busuk should be reforested by planting trees with strong and deep enough roots. To maintain the stability of slopes in the rain season, the planted trees technically advisable to have roots that can penetrate the soil to a depth of more than 1.6 meters from the ground surface.

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