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GEOTECHNICAL PROPERTIES AND GEOLOGI AGE ON CHARACTERISTICS OF LANDSLIDES HAZARDS OF VOLCANIC SOILS IN BALI, INDONESIA

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ABSTRACT: Landslides in ancient mountains in Indonesia have occurred in various types, scales and frequencies. Such variation seems to be determined by the weathering related to geological age. Hence, it is deemed essential to study the distinctive condition of landslide on ancient volcanic rocks. It is aimed to observe the features and avalanches that occur due to the geological age of ancient volcanic rocks in order to predict future events and the identification of instability. Geotechnical parameters on volcanic rocks and geological age were used for the interpretation of the instability. The interpretation of ancient volcanic rocks to the hazards of landslides in this study was as an attempt to create an early warning system against the vulnerability of landslides.The runoff movement is triggered by erosion in the channel valleys and the failure of the shear on soil due to sharp increase of groundwater levels. The presence of bulking in the sediment and the run off has led the surface material to be eroded from the upstream slope to the slopes. In comparison, landslides in a metamorphic rock area are in the form of translational and rotational complex movements, whereas in ancient volcanic rocks that formed at the pleistocene era, avalanches occur in the form of creep and the steep slope debris flow occurs where the material surface drainage occurs because the loose material is relatively low slope and strength parameters.

Keywords: Landslides, Volcanic soil; Geotechnical parameters; Stability

1. INTRODUCTION

Bali Province in Indonesia is a mountainous and hilly area covering almost 85% of the total region. The relief of Bali Island is a mountainous chain spread from the west to the east. Of these mountains, Mount Batur (1.717 m) and Mount Agung (3.140 m) are two active volcanoes. Several other inactive mountains as the ancient fire mountains could reach an altitude in the range of 1.000 - 2.000 m.These mountains have been formed at the beginning of the quarter era in which the excess of volcanic soil has experienced the weathering, especially in ancient mountains in the eastern region of Bali Island. The weathering of volcanic rock located above impermeable rock on the hill/ ridge with moderate to steep slope could be highly potential to create the landslides.

The study of ancient volcanic rocks at the type of avalanches in the ancient mountains of Seraya was conducted in Sega village, Abang subdistrict, Karangasem Regency in Bali province. This complex is located in the eastern Bali Island in which Mount Agung has the highest point with the height of 3.148 m. The latest eruption of Mount Agung occurred in March 1963. Mount Seraya (Fig. 1) has the different land characteristics compared to Mount Agung. This inactive ancient volcano erupted in the early quarter era; thus making a denudation process more dominantly to create a number of very deep valleys as a result of erosion and potentially to create soil movement in the form of subsidence and landslides (Fig. 2).

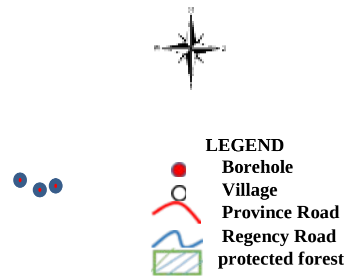

Fig.1. Borehole and location of research

2. RESEARCH METHOD

This study aims to identify the occurrence of landslides in earlier periods in comparison with the geotechnical characteristics. By comparing the characteristics of avalanches in the study area, it is possible to provide a complete and correct interpretation of the early warning. The locations of the landslides in the study area were identified based upon the interpretation of topographic and geological maps and field surveys. During the evaluation study, the geological map and the topographic map of Bali Province were at a scale of 1:250.000 and a scale of 1: 50.000, respectively. The validation of aerial photos was then performed through some field surveys. Research and sampling of the soil were compared with geological conditions and its effect on the landslide occurrence. The model of this research has not ever been previously conducted on the Seraya volcanic rocks - especially in Sega village, Karangasem.

a. fault creep

b. Translation into Debris flow

Fig. 2. The types of ground movement at Sega village

The field data was based upon the height, length, lithology and the direction of slope, and thickness and inclination of the sliding surface. It also included the analyses on the original geometry of the slope, the position of water level and the parameters of shear strength. The depth of the sliding plane was estimated from the experiment on the drill holes and the conditions of rock exposed. It was undertaken to study the morphology of the slide. The geotechnical parameters were obtained from the three drilling points to obtain the stability value of the cohesion (c) and the angle of inner friction (φ). In addition to test the properties of soil stability, a comprehensive laboratory testing was then conducted to obtain the parameter of volcanic soil (JJ Bommer et.al, 2013). Weathering of volcanic rocks will be residual soil, so more attention needs to be taken in finding the cohesion parameter of residual soils especially when dealing with residual soils possessing low cohesion (Asoudeh, A. and Oh, E., 2014) The use of geological and geotechnical data and the field interpretation were purposely to obtain the type of avalanches and to make some conclusions through the sedimentary rocks.

3. SITE CHARACTERISTICS

The morphology of volcanoes can no longer be found in Sega Village, which is backgrounded by Seraya Mountains. However, the appearance of the caldera with the fractions leading to the north side of Amed coast can still be found though the rocks that make up the mountainous area of Seraya are formed by the volcanic eruptions. Vessel (2001) stated that a volcano with an unideal shape is called ancient volcano that has experienced a huge explosion and the eroding process. A huge eruption commonly will create a circular caldera but the location of caldera is not found in Seraya area and its surrounding. For this, a number of methods can be performed to determine the location of the caldera either through the analysis of geomorphology, volcanic rock stratigraphy, physical volcanology, structural geology and petrology-geochemistry or through seismic data (Bronto, 2006).

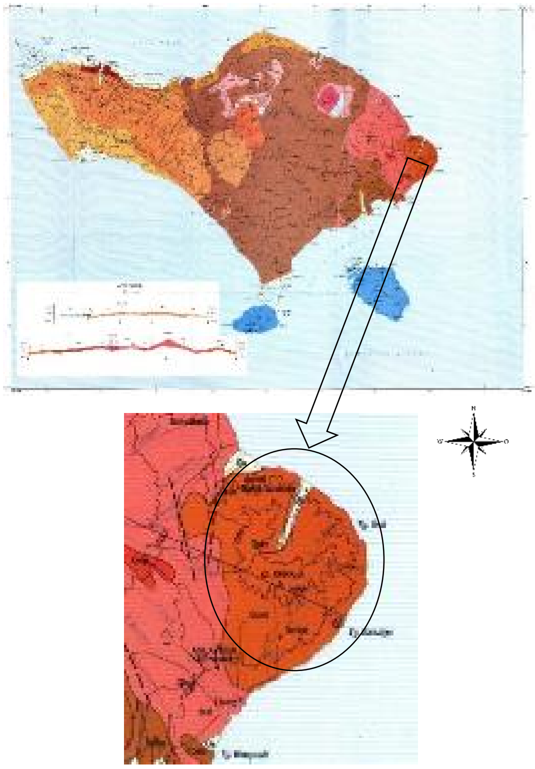

Fig. 3. Regional Geology.

In general, topography and geological conditions (Fig. 3) in a disaster area and surroundings are the area with the moderate to steep slopes. The location of the movement is on the height above 50 meters above sea level. Based upon the Geological Map Sheet of Bali (Purbohadiwijoyo MM, et al, P3G, 1998) prepared by the disaster area by structured Lava rocks of Mount Seraya comprising weathered lava rock alternating breccia (Qpvs).

4. RESULT AND DISCUSSION

Geologically, most of parts of Sega Village is composed of volcanic rocks in the form of products of old volcano formed in the early days of the quarter consisting of breccia sediment, lava, and tuff covering 47% of total region. The rock sediment covers 23% of total area with a few of limestone, surface sediment and intrusive rocks. The dominant rock types in Sega Village is silt sandstone and clay shale (Fig. 4 a), including andesite breccia that has experienced weathering due to denudation (Fig. 4 b). Meanwhile, the exposed formation of rocks in Sega Village in the research area consists of dark bluish dark gray clays. As stated by Wilopo and Agus (2005), the andesite rock and breccia are the factors triggering the occurrence of landslides for its waterproof. Thus the andesite and breccia rock can be used as a sliding plane for the occurrence of landslides. In a saturated state of the water in rainy season, coupled with the sandy loam soil texture on areas that have the andesite host rock is prone to landslides.

a. Sandstone silk with clay

b. Shale outcrop bluish gray clay

Fig. 4. Outcrops of volcanic soil of Sega village

The geotechnical parameter and weathering degree of volcanic rock are two factors determining the occurrence of landslides (JJ Bommer et.al, 2013). The weathering of rocks and soil in the study area is structured by volcanic breccia, breccia tuff and lava including the insertion of the sandstone and bluish gray clay, the surface part of which has experienced the weathering in the form of quite thick sandy-loam silty clay. Clay, sandy or silt soils are the types of soil that can easily pass the water. If the soil is located above the impermeable rock at a specific slope, then the incoming water will be retained and the soil at a certain slope will potentially slip to be a landslide. The recapitulation of geotechnical parameters based upon the results of sampling in field and laboratory testing is shown in Table 1 and Table 2.

Table 1: Undisturbed sample laboratory test

Laboratory Test	**B.1**	**B.2**	**B.3**
	Df=1.0m	**Df=1.0m**	**Df=1.5m**
Water Content (%)	11.55	18.04	18.28
Unit Weight (kN/m^3)	15.1	16.6	16.4
Specifik gravity (Gs)	2.605	2.630	2.622
Direct shear test			
Cohesion (c) (kN/m^2)	1	8	7.5
Angle of internal friction (φ) (o)	29.20	21.80	23.50
One dimensional consolidation test			
Preconsolidation presure (Pc) (kN/m^2)	-	85.1	96.2
Compression Index (Cc)	-	0.3116	0.3407
Coefficient of consolidation (Cv)	-	0.01966	0.02567

Table 2: Disturbed sample laboratory test

Laboratory Test	**TP.1**	**TP.2**
Hidrometer test (< 0.075 mm)		
Clay (%)	4.97	4.14
Silt (%)	31.27	24.72
Sieve Distribution Analysis		
Fine Sand (0,425 - 0,075mm) (%)	17.34	19.19
Medium Sand (2 - 0,425mm) (%)	22.77	15.03
Coarse Sand (4.75 - 2mm) (%)	9.88	8.59
Fine Gravel (19 – 4.75mm) (%)	13.76	28.32
Coarse Gravel (75 – 19mm) (%)	0.00	9.77
Atterberg Limits		
Liquid Limit (LL)	34.50	30.00
Plastic Limit (PL)	27.13	24.51
Plasticity Index (PI)	7.37	5.49
Soil Clasification	ML (Silt low plasticity)	ML (Silt low plasticity)
Permeabilty test (Falling Head)		
Coefficient of permeability (kv) (cm/second)	1.0403^{-3}	1.0251^{-3}

The percentage of soil grain in Sega village included 4% - 5% of clay. 24% - 31% oof silt, 8% - 22% of sand, and 0% - 28% of gravel with the average of permeability coefficient (kv) at 1.04×10^{-3} cm/sec. The average of any angles of internal resistance and cohesion were 21.80º to 29.20º and 1kPa to 9kPa respectively. The analysis was based on the geotechnical parameters for a ground movement was started from shallow avalanche creep and later to be found in areas that are not compacted well particularly on slopes. (Wang, et al, 2002). The slope in the study site was < 20º (Fig. 5a), and Debris flows (Fig. 5b) occurred in many locations regardless the relatively low elevation areas and little slope and the volume and range of debris if most of unsaturated volcanic rocks commonly start the sandy or clay/shale interlayer parts, but usually non-discrete, matrices having a low shear strength.

a. Creep/settlement

b. Debris flow

Fig. 5. The shape and behavior of ground motion in Sega Village

Cruden and Varnes (1996), explained that two avalanches in the mountains forming a steep valley can cause the failure of slope due to the rains with moderate intensity in a long period, and the landslide occurred would be debris flow. Meanwhile, the shallow avalanches occur due to the long term moderate rainfall involving the movement of debris, rock fragments, coarse and medium sand and vegetation slope (C Meisana, 2007). Landslide shows (Figure 5.) a combination of two or more types of movement as the accumulation of the complex types (Varnes, 1984) and can be triggered by a number of external factors, such as intense rainfall, changes in water level, storm surge, or erosion fast flow (Dai et. al, 2002). The geological structures were also found in the study area including rock fractures and bedding. Fracture was found mainly in the region that has a very steep slope experiencing the cut underneath.

5. CONCLUSION

Mountainous areas with constituent indigenous rocks in the form of weathered volcanic rocks such as volcanic breccia, tuffs and basaltic igneous rocks were proven from the soil thickness in the field only at 1 m to 1.5 m. The volcanic breccia of Sega has the solid and hard characteristics. The unit of tuffs and volcanic breccia making up the majority of the study area was formed in the Pleistocene era with the calendar age of 2.33 ± 0.12 million years to 0.77 ± 0.06 million years old compared with the Great Formation volcanic soil formed in the Holocene era. This volcanic rock is not compacted strongly, thus making this area to be included as the prone area for landslides.

In the research area the basalt and andesite intrusion and volcanic breccia were found Sega Village in which they have experienced some changes due to the mineral composition due to the alteration. The alteration process has produced chlorite, pyrite and calcite veining unisex mineral. The physical characteristics of the volcanic breccia rock with 36% of fresh-colored gray-green, weathered brownish black, pyroclastic rough texture, layered structure, gravel to sand grain, angular-sub-angular grain, mineral composition, chlorite, pyrite, igneous rock fragment material composition with a size of 14 cm, and the cement matrix in the form of tufa.

Field observations indicate that the landslide occurred on ancient volcanic rocks has a fault or discontinuity and shallow sliding plane. The fault surface in the avalanches starts as a slide and continues to remote such as mud/slide. The avalanche materials in the form of sandy colluvium soil were supported by loam soil matrix at approximately 58% resulted from the weathering of volcanic rocks. The characteristics of saturated silt soil matrix strongly contribute to the movement speed and distance of landslides in areas of volcanic rocks transformed into metamorphic rocks.

Based on field observations there are two characteristics of the landslide found, namely 1) creep/settlement (subsidence) and 2) the flow of material (debris flow) as a type of down movement of soil in the form of displacement of rock mass or loose material from a high to a lower place through deep valleys into the glide plane. This type of avalanche is composed of material rich in silt/clay and floating when wet, causing a reduction in the cohesive forces between grains of soil. In addition, local conditions of the research that is hilly and have a steep slope causes the landslides of this type are found.

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