Analysis of Soil Movement Hazards Trigger on Main Road Segment Denpasar-Singaraja in Baturiti District, Tabanan

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Abstract. The identification and assessment of the threat of ground motion need to be carried out with a combination of knowledge from field observations to visually identify the existing drainage system, slope, and analysis of the intensity of rainfall that causes infiltration and the geological conditions of the area. The assessment method uses aerial photography, geological observations, and research experience in ancient volcanic rock areas. The results of data processing show that the Baturiti District was an area that is prone to landslides because there are cavities with quite weathered rocks due to the overflow of ancient Buyan-Beratan Mountain with a thickness of 10-15 meters. Analysis of geological units and soil types was weathered rock or sandy silt sedimentary soil. The landslide trigger shows the slope between 60o – 70o, the road drainage wasn't good, the occurrence of additional vibration loads due to high traffic volume and increased rainfall intensity where the pore water pressure increases, the loose soil will be easier to escape.

Keywords: soil movement; traffic load; sandy silt

1. Introduction

Disaster data obtained from the Bali Provincial Government, BPBD Pusdalop in 2013-2016 Baturiti District often experienced landslides [1], especially in January-March several villages were recorded, namely Banjar Pacung, Baturiti Village, Banjar Mojan Mekarsari Village, Banjar Apuan Apuan Village, Perean Village, Apuan Village, Banjar Dinas Taman Tanda, Batunya Village, and Bangli Village, landslides often occur in residential areas, agricultural land and the Denpasar – Singaraja road.

Disaster risk management begins with disaster risk assessment and mapping. Learning for communities in landslide-prone areas is carried out intensively to visually assess threats to occur [2]. Regulation of the Minister of Public Works No.22/PRT/M/2007 concerning Guidelines for Spatial Planning for Landslide Disaster-Prone Areas [3], with these various regulations, is expected to realize an increasingly better quality of national spatial planning, in which in spatial planning and infrastructure development must meet the criteria; safe, comfortable, productive and sustainable.

The development of transportation infrastructure with the excuse of increasing the regional economy or shortening the reach time risks causing environmental damage, especially the natural drainage system, causing a landslide hazard [4]. Based on this, it is necessary to conduct research that will produce and find natural and man-made factors that

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affect slope stability in areas prone to landslides, which will serve as an early warning, and for the government as a reference in regional infrastructure development.

2. Literature Review

The need for information on land resources was critical, such as soil, climate, topography and geological formations, vegetation, and socio-economic conditions. Information on stratigraphy and local geological conditions will ultimately show the diversity of land properties which is very important in assessing land capability and actions to reduce threats that occur in the short and long term [5]. Climate information includes data on temperature, rainfall, wind speed, and direction significantly affect the ability of the soil to absorb water. Information on topography and geological formations have land height above sea level, degree of slope, and position in the landscape. These conditions indirectly affect the quality of soil or rock, including erosion threats and land potential for cultivation. Vegetation is one of the elements of land, which can develop naturally or result from human activities in the past or the present. Natural vegetation is a consideration and guide to environmental naturalness and health to determine land potential and suitability for infrastructure development or as water catchment areas [6].

Environmental damage causes changes in the texture of the soil surface on the slopes related to infiltration of rainwater into the soil so that there is the potential for soil movement to occur, which in the spatial analysis due to rain intensity and infiltration shows that: (1) Rain intensity 48.2–49.1 mm/day (9–13 days), SF value = 2.65–1.82 (low threat); (2) Rain intensity 87.32–92.27 mm/day (6–7 days), SF = 2.13–1.39 (moderate threat); (3) Rain intensity 155.375–210.114 mm/day (6 days), SF = 1.79–1.03 (high threat) [7].

Slope stability improvement was generally carried out to reduce the driving forces, increase soil shear resistance, or both. The driving forces can be reduced by; a) Excavating material in the unstable zone b) Reducing pore water pressure by flowing water in the unstable zone. Slope improvement methods are generally carried out by; a) Changing slope geometry, b) Controlling drainage and seepage, c) Construction of structures for stabilization, d) Demolition and removal, e) Protection of slope surfaces. Based on the geological factors that affect the landslide field in Abramson, 2002 as in Table 1.

Table 1 Geological factors influencing the shape of the potential failure plane [8]

Geological Condition	Potential Collapse Field
Cohesive soil Residual soil or *colluvial* over shallow rock Rigid fractured *clay* and marine shale in highly weathered zones	Translational with a small depth/length ratio (*D/L*)
Landslide block Inserted in rock or soil *dip* *Slickensided* or fractured material Rigid to hard cohesive soil on steep slopes	Single plane surface
Landslide block in rock mass Inserted weathered sedimentary rock Clay shale and rigid cracked clay Layered soil The heap beside the hill above the *colluvium*	Flat multi-plane surface
Residual and *colluvial* soil layers *Soft* marine *clays* and shales Soft to hard cohesive soils	The circular or curved shape

Geological hazards are a great danger to humans and their works. Hazards may exist as a consequence of natural events but are often the result of human activities. Slope failures, such as landslides and avalanches, can occur in almost any hilly or mountainous area or offshore, often with very frequent, and can be very destructive, events at the time of a disaster. Potential failures can identify potential failures, early warning is possible, but the actual time is unpredictable [9].

3. Method

The observation is on the Baturiti – Mekarsari road, Baturiti District, Tabanan Regency (Figure 1). The area's topography is located between an altitude of 300-990 m above sea level, with temperatures during the day between 21º - 25º C and at night 15º - 20º C, with humidity of 60 - 90%.

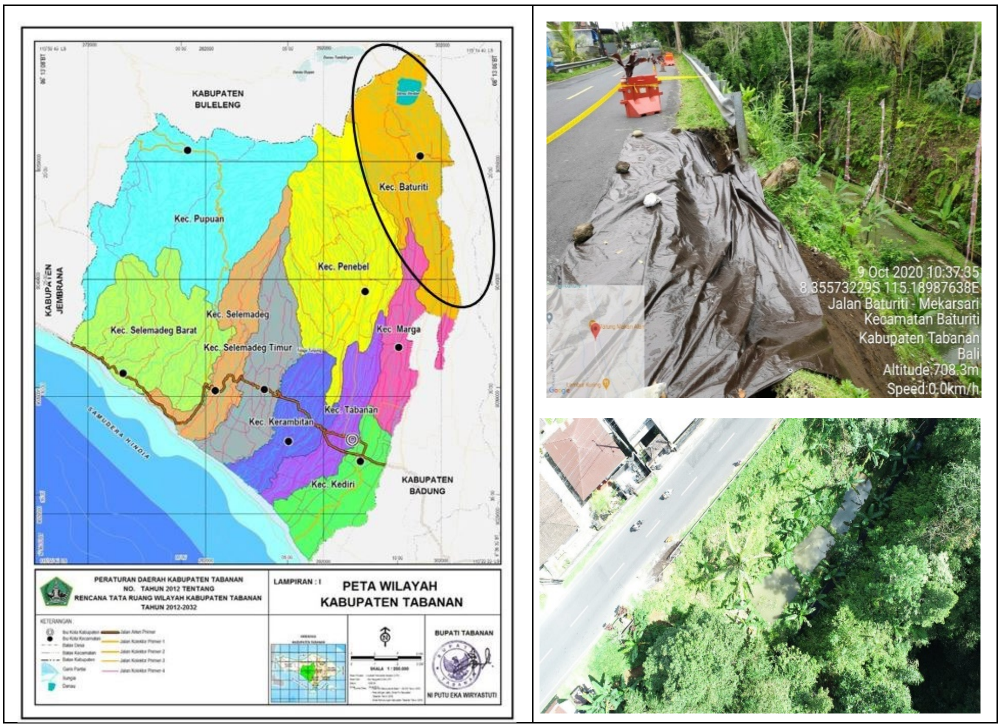

Figure 1. Research Location

The Conducted the research through library research based on previous research exploring the concept of geological disasters in civil engineering and natural disaster mitigation efforts. This paper presents scientific reasoning arguments from the results of literature reviews and the researchers' thinking, which was supported by data obtained from library sources in the form of research journals, theses, research reports, textbooks, papers, seminar reports, and scientific reports discussions, and others. Etc. These library materials were discussed critically and in-depth to support the argument of geological disasters and their mitigation with civil engineering science, especially the sub-field of geotechnical science. Data analysis was used to examine all available data from various sources, especially data from the researchers themselves, which have been published nationally and internationally. This research analyzes the data using the following methods:

In processing the data used; (1) method of content analysis (content analyzing). This method was used to analyze the meaning contained in the debris flow phenomena contained in literature sources, then grouped into identification, classification or categorization stages, then continued with an interpretation of technical disaster management and mitigation efforts. (2) Descriptive method aims to provide an overview or describe the data that has been collected so that researchers will not perceive that something is already the case.

As a reference and basic data in this study is the topographic map of the research area, the Geological Map of Sheet Bali with a scale of 1:100,000, a field survey was carried out to retrieve primary data in the form of soil drill data as shown in Figure 2 and outcrop observation and rock and soil sampling for analysis of rock and soil properties. Topographic measurements are carried out to calculate the estimated resources of the research area in use as roads and environmental damage.

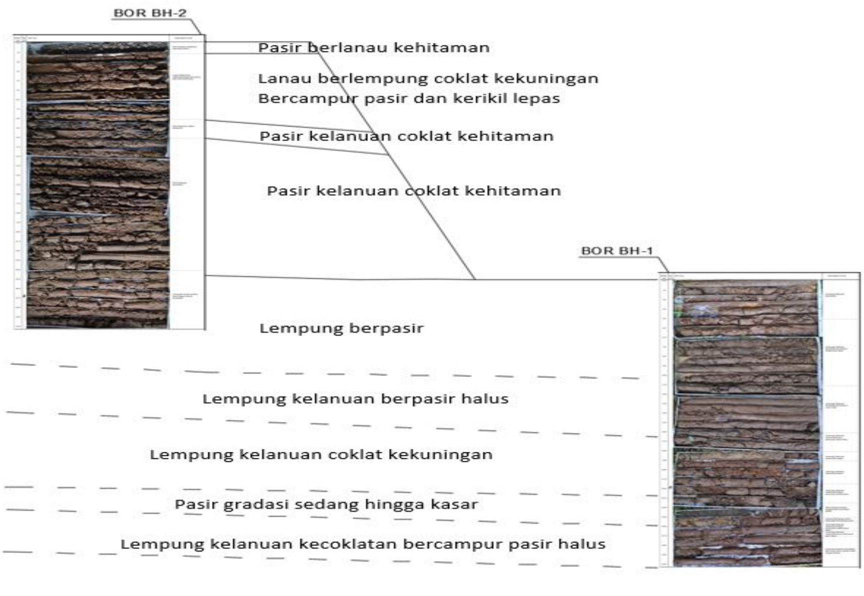

Figure 2. Data Drill

Based on the drill data, it can be seen the description of the soil in Figure 2. as follows: at depth of 0.00 from the topsoil to a depth of 1.00 meters in the form of blackish silty sand mixed with gravel. Then from a depth of 1.00 meters to 8.00 meters in yellowish-brown loamy silt mixed with sand and loose gravel. Then from a depth of 8.00 meters to 10.00 meters in the form of blackish-brown silty sand. Then from a depth of 10.00 meters to 24.00 meters in the form of brownish silty sand. Then from a depth of 24.00 meters to 30.00 meters in sandy loam with acceptable to medium brown gradations. The groundwater level was found at a depth of -26.80 meters.

4. Result and Discussion

The Geological Conditions based on geological map sheets of Bali Nusa Tenggara [10], the analysis was carried out with the help of Ar-GIS software to help overlay as shown in Figure 3, where the geological conditions at the project location are in mountainous areas, there are two rock formations, namely; extruded rock from Mount Batukaru and volcanic rock from the sub recent cones of Mount Pohen, Mount Sangiang, and Mount Lesong. The constituent rocks are Qv rocks which are volcanic rocks of the Lesong-Pohen Sengayang group, and there are Qpbb rocks which are volcanic rocks of the Buyan-Bratan and Batur groups, especially tuff and lava; there are no geological structures in the form of faults or faults in this area.

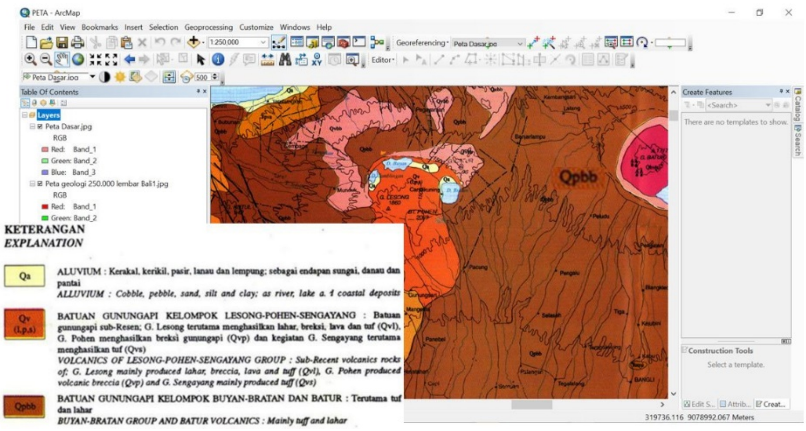

Figure 3. Geological Map of the Research Area

The stratigraphy of the observation site can be seen in the rock layers and rock interspersed between soft rock and hard rock or the alternation between a porous rock and impermeable rock. The results of the study illustrate that several factors, namely cause the potential for landslides:

- internal factors, namely the condition of the slope-forming material is the rock that has been weathered and destroyed due to intensive jointing, as well as steep slope conditions with a slope angle of more than 45%,
- external factors, namely human activities cutting the foot of the slope and high rainfall.

Hydrological analysis based on high rainfall intensity or moderate rainfall with a long duration (> 100 mm/day), the speed of rainwater entering the soil is slower than the speed of increasing the volume of rainwater that is accommodated and flows on the slope surface. Infiltration causes changes in the level of soil saturation where the value of the degree of saturation (Sr) in the initial condition is 40%, the soil mass is reduced, most of the soil pores will be filled with air which causes the bonding of the soil grains to decrease and the soil shear strength to decrease, Along with water suction due to the presence of soil saturation rain increases as well as that the shear strength of the soil increases at a certain saturation, in this study the degree of saturation was 56% and then the shear strength of the soil decreased to 37.62 o with the degree of saturation 78.46% (IN Sinarta et al., 2021).

This condition has a significant risk of debris landslides if the daily rainfall intensity is 125 mm/day, the highest in the 5-hour rain duration because there will be a decrease in the safety number <1 at the 2nd hour. the decrease occurred between 0.96 to 0.62 [11].

The trigger for landslides based on the results of the assessment shows that the threat of landslides on the Denpasar – Singaraja road section in Baturiti District is as follows:

- There is a water pipe leak on the side of the road, a leaking water pipe on the top side of the slope causes a push on the slope, and the retaining wall above it
- Heavy rain that happened before, Heavy rain just before the landslide caused the water to push against the slopes and walls even more.
- The position of the existing retaining wall that hangs, The retaining wall that is not supported on hard soil causes the wall to be pushed away due to water pressure.
- Steep slope conditions, Slopes with steep conditions (approximately 60-70 degrees) so that the thrust of the slope is quite large
- A load of passing vehicles, the road that connects Denpasar and Singaraja is quite densely traversed by vehicles so that passing vehicles cause additional loads and vibrations on the slope.

Stabilizing a complex avalanche often involves internal and external control of the flow of water. Water that falls and flows on a sloping land surface must be drained and endeavored not to remain in place. On some slopes, it is necessary to make the water flow smoothly and avoid getting water trapped on the shoulders of the slopes. Prevent the flow of water into the rock fractures, and the rock must be covered with asphalt or impermeable material. The water flow should be reduced to avoid increasing the frictional resistance of the rock.

5. Conclusion

Based on aerial analysis and observation, the location of the landslide was on the slopes of the Denpasar-Singaraja road; at the foot of the slope there is a soil irrigation channel dominated by sandy silt, the main cause of landslides is a leaking water pipe, followed by heavy rain that followed then the wall Soil support that does not provide adequate support is steep slopes and the last is a load of passing vehicles.

The condition of the slope rock is weathered volcanic rock, with sandy soil types having high permeability but very easy to be eroded by water during heavy rains. Although there are no joints in the rock, with a slope between 60o – 70o, it becomes the trigger for the highest threat due to exposure to rainwater and a poor drainage system.

Prevention of landslides by a drainage system on the slopes, where the slopes need to be made so that the flow of water was smooth and avoid getting water trapped on the shoulders of the slopes, to prevent the flow of water into the rock from fractures, the rock must be covered with asphalt or with an impermeable material. Underground water flow should be reduced to avoid increasing the frictional resistance of the rock.

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