DEBRIS FLOW HAZARD ASSESSMENT BASED ON RESISTIVITY VALUE AND GEOLOGICAL ANALYSIS IN ABANG MOUNTAIN, GEOPARK BATUR,BALI

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ABSTRACT

A detailed assessment of the landslide-prone area needs to be carried out with a combined knowledge of soil resistivity and geological analysis. The assessment method uses resistivity analysis with the Wenner configuration and geological analysis by observing rock outcrops on the slope. Resistivity rocks value the Abang Batudinding Village was prone to landslides because there were cavities with fairly weathered rocks, at depths of 2-3 meters. Terunyan Village the surface part was andesite rocks with high resistivity, and some consist of weathered rocks with rock at a depth of 3-3.5 meters. The slope-forming rock, on average of the Andesite Breccia, has a volume above 60% of weathering rocks or sedimentary rocks. Weathered Andesite breccias produce intensive cracks in the horizontal direction and are easily released. The analysis shows the research area has a very high risk of debris flow, especially when the intensity of rain is high where the soil water level increases, so that the pore water pressure increases too. The loose soil will be easier to release debris flow.

Keywords: Debris flow, Andesite Breccia, Geological, Resistivity


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1. INTRODUCTION

Abang Batudinding Village and Terunyan Village were the tourist destination villages. The location of the village is in the mountain area precisely under the foot of the slope of Mount Abang. This area is part of the Mount Batur Geopark in Kintamani District, Bangli, Bali. The Batur caldera geopark measures about 13.8 × 10 km, and another caldera structure was formed in the middle with a diameter of 7.5 km and a subsidiary of Mount Batur with the highest peak of +1,717 m [1]. Figure 1 shows the locations of Abang Batudinding Village and Terunyan Village within the Mount Batur Geopark, which was located between 115°13'43", BT - 115°27'24" East and 8°08'30" LS - 8°3'07" LS. The Mount Batur caldera geosite with lake Batur and lava abundance recorded from 1849 - 1974 (Figure 1), gives a uniqueness to the geological conditions. Mount Abang, as part of the geopark, is a parasitic volcano from ancient Batur Mountain, which was cut off in caldera formation. Evidence as a volcano was found in dike on walls and foot slopes [2].

![Figure 1. Research Location at Mount Batur Geopark](image)

Abang Batudinding Village and Terunyan Village which is under the foot of the slope of Mount Abang, which is Mount Purba Batur, causes the area to be prone to landslides due to soil movement [4], [5]. Avalanches most often occur in the rainy season at moderate rainfall levels with an extended frequency [6]. Assessment of landslides hazards in Bangli Regency said most of the areas are in the lower boundary zone and the upper boundary of the landslide, while the most potential landslide zone occurred in Kintamani Subdistrict, which is around the Mount Batur caldera and the slope of Mount Abang with the number of landslide points 208 points and a small part is on the west side north of Bangli Regency [7]. Analysis of landslide stability using the Sinmap method in the area, the study shows that this area belongs to the upper and lower boundary zone of the landslide and approaches landslides with potential ground movement in the form of debris flow or flash floods [8].

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Disaster risk management begins with disaster risk assessment and mapping. Learning towards communities in landslide-prone areas is carried out intensively to be able to assess hazards occurring visually [9]. Based on this investigation, soil resistivity values and geological analysis are carried out to determine the hazards of landslides, especially landslides.

1.1. Geolistrik and Resistivity

Geoelectric resistivity is one method in geophysics that studies the electrical resistivity (resistivity) properties of a layer of rock beneath the earth's surface [10]. The type of rock layer can be known from the differences in the electrical properties of the rock by flowing electric current into the earth, and then the resistivity of each rock layer is calculated. The principle of this method is to measure variations in the conductance of vertical and horizontal electric currents as indicative of positions, boundaries, and apparent obstacles of various subsurface conditions. Materials that have high resistivity mean that it is increasingly difficult to pass an electric current. If the formation is porous and contains water, the resistivity will be low. Based on the sensitivity generated through Wenner testing can be correlated with the type of rock as in Table 1.

**Table 1. Correlation of Rock and Sediment Resistivity [13]**

<table>
<thead>
<tr>
<th>Rock and Sediment Type</th>
<th>Resistivity value (ohm m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andesite</td>
<td>4.5x10⁴ – 1.7x10⁷</td>
</tr>
<tr>
<td>Sand stone</td>
<td>1 – 6.4x10⁸</td>
</tr>
<tr>
<td>Silty stone</td>
<td>50 - 10⁷</td>
</tr>
<tr>
<td>Clay</td>
<td>1 – 100</td>
</tr>
<tr>
<td>Sand</td>
<td>4 - 800</td>
</tr>
<tr>
<td>Water</td>
<td>1-100</td>
</tr>
</tbody>
</table>

In this study, using the Wenner configuration provides alignment of four electrodes in a straight line with a constant distance, and therefore the apparent resistivity calculation assumes the same value. Varying the position of the electrodes is possible to get the three combinations shown with alpha, beta, and gamma shown in Figure 2 [11].

**Figure 2. Wenner configuration**

In Figure 3, it can be seen that C1 and C2 are the sources of electricity that will flow, then P1 and P2 are receivers of power, with a being the distance of delivery. Geometric factors due to alpha, beta, and gamma configurations can see in Equation 1 for an alpha, Equation 2 for a beta, Equation 3 for gamma.

\[
\begin{align*}
  k_wα &= 2\pi a \\
  k_wβ &= 6\pi a \\
  k_wγ &= 3\pi a
\end{align*}
\]
The investigation is the ability of the electrode configuration to map the maximum depth that can penetrate. To get the maximum depth that can be assigned, multiply the electrode spacing "a" maximum or the length of the maximum stretch of "L" by the depth factor. Horizontal data coverage is the ability of the electrode configuration to produce large amounts of data in the lateral/horizontal direction, and this capability is instrumental in 2D surveys [12].

1.2. Geological

The map of the geological conditions of the Mount Batur caldera region was shown in Figure 3. Based on the geological map of the Bali sheet [14], the rocks making up this area are breccias and lava originating from the Buyan-Beratan Ancient rock volcano group (Qpbb), which consists of tuffs and the volcanic deposits of Buyan-Beratan and Batur volcanoes which are in the upper quarters. Geological formations that are in the lower quarters are around Mount Batur, including Mount Abang, which is vomit rock from the ancient Buyan-Beratan volcano and Ancient Batur. Around the slopes of Mount Batur there are younger rocks, which are volcanic rocks of Mount Batur.

Geological conditions prone to landslides consist of tuffs and andesite breccias which make up most of the mountainous terrain formed in the Pleistocene era with a dating of 2.33 ± 0.12 million years to 0.77 ± 0.06 million years, very easily eroded due to rain [15], [16].

![Figure 3. Geological map of Kintamani District](image)

**LEGEND:**
- **Qa**: Aluminum
- **Qvbb**: Volcanic Rock of Batur
- **Qpbb**: Volcanic Rock of Buyan-Beratan
- **Qrbb**: Volcanic Rock ancient group of Buyan-Beratan
- **Street**: Street
- **River**: River
- **Counter Indeks**: Counter Interval
- **Lake**: Lake

2. RESEARCH METHOD

This research was located in Terunyan Village, and Abang Batudinding Village, which is prone to landslides, identification of ground motion is carried out using the Geoelectric method with the alpha Wenner configuration to determine the type and thickness of the soil. In this study, five sections of geoelectric testing drawn, three sections were in Abang Batu Dinding Village, and two more sections were in Terunyan Village. The testing section can be seen in Figure 4 (a) and Figure 4 (b). The test results are then read in the data logger and exported to the computer as shown in Figure 5.
Based on Geological analysis sightings, and outcrops on slopes in the study area. The slope outcrops carried out a review of the types of constituent rocks and the composition of the constituent rocks, which is then conducted a study using the literature. As shown in Figure 6 is the outcrops of the slopes in the study area, most of the slopes exposed to weathered rock conditions with a composition of 60% volcanic breccia and as a small are still in fresh condition.

3. RESULTS AND ANALYSIS

3.1. Resistivity Test

Soil resistivity testing with geoelectric equipment at a distance of ± 200 Tests in Abang Batu Dinding Village (GL-1, GL-2, GL-3) can see in Figure 6, Figure 7, and Figure 8 and testing in Terunyan Village (GL-4, GL-5) in Figure 9 and Figure 10.
Based on this test, it can be seen that soil conditions in the Abang Batudinding village area are dominated by yellow with a sensitivity value of ± 516 ohms m, then green with a resistivity range of ± 252 ohms m. There are red and brown colors which have a resistivity value ranging between ± 516 ohms m to ± 1057 ohms m. Based on the correlation value of the resistivity of the rocks, that the value given by the geoelectric test can be estimated that the soil layers are sand, sandstone, and andesite with different densities, in addition the field conditions show a surface layer consisting of sandy layers mixed with gravel and loose rock.

The test results in the Terunyan Village (GL-4, GL-%) resemble those in the Abang Batu Dinding Village, but in the GL-4 geoelectric test, there is a low geoelectric value, which is likely to be water or water movement. Data processing results also show that the Abang Batu Dinding Village area (GL-1, GL-2, and GL-3 trajectories) is an area prone to landslides because there are cavities with fairly weathered rocks, at a depth of 2-3 meters. Terunyan
Village, for the GL-4 track on the surface, is an andesite rock with high resistivity and the GL-5 track consists of weathered rocks with rocks at a depth of 3-3.5 meters.

3.2. Geology Analysis
Based on the analysis of Figure 4, the Bali-Nusa Tenggara sheet of Geological Map in terms of age shows that the geological formations of the Lower Quaternary age are around Mount Batur, including Mount Abang which is spit rock from the Buyan - Bratan Purba volcano and Purba Batur. The rocks from the Lower Miocene age to the upper part are estimated to be around the Kubu Region, which consists of volcanic breccias, lava, tuffs with limestone inserts, which is the Ulakan Formation (the oldest Formation in Bali).

Visual observations and interpretations such as Figure 5 show the slope outcrop that around the slopes of Mount Batur, there are younger rocks which are volcanic rocks of Mount Batur so that they have the potential of andesite stone, lava, and sand. Around the southeast edge of Lake Batur, there are colluvium deposits. This unit field appearance gives a fresh appearance (Figure 5.a). Still, there are also weathered features (Figure 5.b) where the average of the Andesite Breccia rocks has a volume above 60% of the weathering rocks, or sediment soil. Weathered Andesite breccias produce intensive cracks in the horizontal direction.

4. CONCLUSIONS
Based on the research conducted, it can conclude that in general, the layers of soil in Abang Batudinding Village and Terunyan Village in the form of sandy silt, sandstone, and andesite. Abang Batudinding Village is an area that is prone to landslides because there are cavities with fairly weathered rocks, at a depth of 2-3 meters. Terunyan Village, for trajectories on the surface, is high resistivity andesite rocks, and some consist of weathered rocks with rocks at a depth of 3-3.5 meters. This layer of soil has the potential to experience landslides when it has a steep slope, plus the influence of rain that can cause erosion and water entry into crevices of sand and gravel so that it can encourage debris flow.

While the southern Batur caldera wall with constituent rocks comes from the rocks of the Buyan-Bratan and Batur volcanoes (Qpbb) consisting of rock sand too loose and porous silt sand, the slope-forming rock unit on average of the Andesite Breccia rocks has a volume above 60% of weathering rocks or sedimentary rocks. Weathered Andesite breccias produce intensive cracks in the horizontal direction. The condition of the soil tends to be quickly released so that with the intensity of moderate rainfall with a high frequency, it will cause ground movements in the form of a landslide.

Based on the results of the analysis of the value of soil resistivity and geological conditions in the study area is an area with a very high threat of landslides, especially when high rainfall intensity so that soil water content increases causing pore water pressure increases, the loose soil will be more easily released.

REFERENCES


