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Investigation of groundwater table under rock slope by using electrical resistivity imaging at Sri Jaya, Pahang, Malaysia

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Investigation of groundwater table under rock slope by using electrical resistivity imaging at Sri Jaya, Pahang, Malaysia

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Abstract. Over the years, rock slope will undergo the natural phenomenon of weathering, leading to the weakening of strength and physical properties of the slope material. In Malaysia, one of the causes of the weathering of rock is due to the presence of water, which can form groundwater table in the subsurface of rock slopes. The weathering of rock material in slopes can have significant effect on the stability. In Sri Jaya, Pahang, a large body of rock is exposed in cut slope, where different weathering grade was observed on the surface. The study aims to investigate the groundwater table under the rock slope surface and determine the extent of weathering of the rock slope. For that purpose, the electrical resistivity imaging (ERI) was chosen as a geophysical method to map the subsurface condition of the slope. Resistivity values from the survey were interpreted based on established work that correlates weathering condition of rock material with resistivity value. Different zones of weathering grade and groundwater were determined based from the profile.

Keywords: Electrical resistivity, Electrical Resistivity Imaging, Weathering, Rock slope stability

1. Introduction

Large rock slopes are commonly formed from blasting of rock body to create path for the construction of the expressway or other development. The remains of the blasted rock slope are exposed, where it would then undergo weathering process that can affect the rock material properties of the slope and reduce its stability [1]. The main cause for the weathering of rock slopes is movement of groundwater, which forms through seepage of rainwater and others sources [1]. However, the process required to detect and map subsurface groundwater on rock slope typically require costly drilling of boreholes. Electrical resistivity is a geophysical method that has the strength to detect zones of subsurface water [2-3], without the need for extensive drilling of borehole. In addition, various works have also shown that capability of the method in determining the weathering condition of the subsurface of rock slope [4-10]. This study aims to study the location of groundwater and its effect to the weathering of rock slope. The location chosen for this research is an area in Sri Jaya, where a large rock slope is exposed. The method involved for this research is the conducting of electrical resistivity imaging (ERI) survey [2], which provides resistivity reading of the subsurface material. The software used for the processing of the data is RES2DINV. The research will contribute in analysing possible failure based on the mapping of weathering of rock slope and the location of groundwater. Further actions can be taken for mitigating possible slope failure in the future.

2. Methodology

The ERI method was conducted by using the instrument Terrameter LS2. The instrument consists of sets of cable, electrodes and transmitter [11]. Before the survey was conducted, a proposed line was determined based on the accessibility of the highest part of the slope and targeted depth of survey (Figure 1-2). The protocol used for the survey is Schlumberger, which was chosen due to it providing good vertical resolution and is able to give clear image of groundwater and clay boundaries in weathered rock as horizontal structures [12]. The data from the survey was extracted with the elevation data of each point of the electrode. Then, the data was inverted into resistivity profile by using RES2DINV software for data interpretation, where RES2DINV software, where the elevation of the electrodes was used in providing the topography of the slope where the survey was carried out.
The location of groundwater was determined by referring to the values in the work by [13] (Table 1), which shows the type of subsurface material from resistivity reading. The study [8] concluded that correlate resistivity value with the different weathering grade igneous rocks is consulted for the interpretation process of the weathering grade of the rock slope (Table 2).

Figure 1. Resistivity line of the ERI survey

Figure 2. View of the slope

Table 1. Materials classification according to resistivity reading [13]

Materials	***Resistivity range (Ωm)***
Alluvium	10–800
Sand	60-1000
Clay	1-100
Groundwater(fresh)	10-100
Sandstone	8-4 x10^3
Shale	20-2 x10^3
Limestone	50-4 x10^3
Granite	5000-1000000

Table 2. Resistivity interval for the weathering profile of studied rock mass (ultramafic rock) [8]

Weathering grade	***Resistivity range (Ωm)***
I – Fresh	>4200
II – Slightly weathered	2500 – 4100
III – Moderately weathered	1200 – 2500
IV – Highly weathered	400 – 1200
V – Completely weathered	200 – 400

3. Results and discussion

The interpretation of the resistivity profile is as shown in Figure 3. The profile shows that the subsurface could be separated into three different zones of resistivity values:

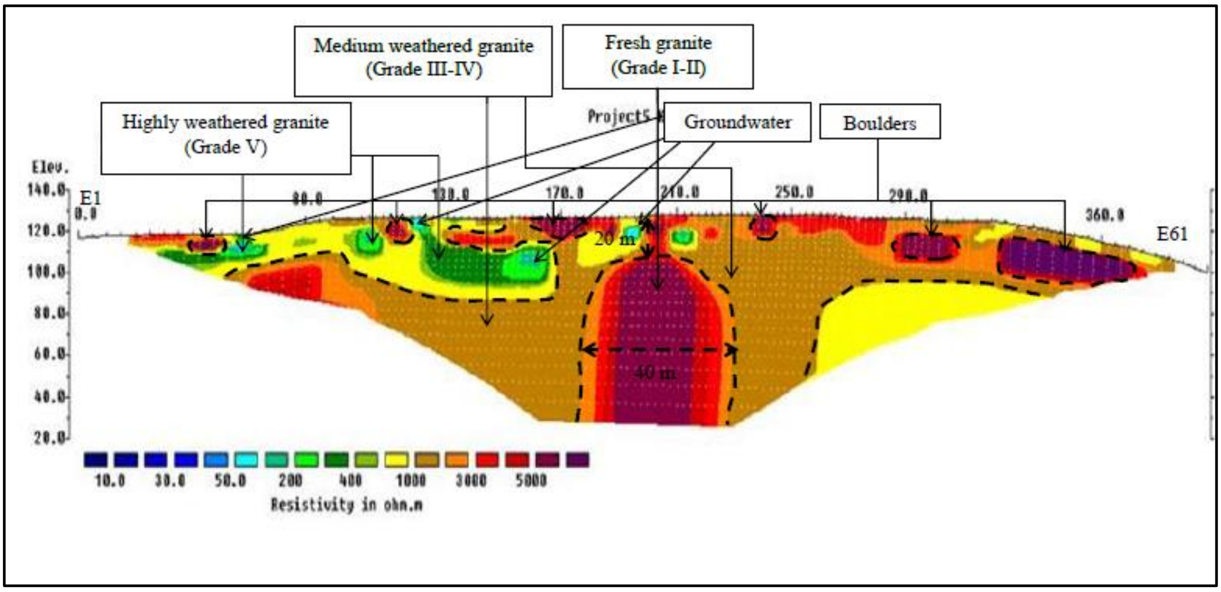

Figure 3. Profile of resistivity line, with interpreted weathering zone and groundwater zone

The first zone is an area of resistivity values of more than 2500 Ωm, is represented by dark red and purple in the profile. This zone is interpreted as a weathering grade of I-II of the granite, or fresh section of the granite. This zone is interpreted to form the bedrock of the rock mass, and is found along the 180 – 220 m of the resistivity line, at a width of about 40 m, with a depth of 20 m from the surface to the bottom of the profile. Similar zones of resistivity values could also be found across the survey line, in small individual pockets, from the surface to a depth of about 10 – 20 m. These smaller zones are interpreted as the fresh granite boulders, where they are found to 'float' in the larger zones of lower resistivity values. The second zone is the area of resistivity values between 700 Ωm to 2500 Ωm, and is shown as yellow and orange colour in the resistivity profile. This zone is interpreted as a weathering grade of III-IV of the granite, or medium weathered granite. This zone surrounds the fresh granite body found in the centre of the profile, and forms the majority of the granite rock mass. The third zone is the area of resistivity lower than 700 Ωm, shown as green and blue colour in the resistivity profile. This zone is interpreted as the weathering grade V of the granite, or highly weathered granite. This zone is found at the outermost section of the slope, at 20 – 160 m section of the line, from the surface to a depth of about 20 m. The light blue area in this zone is interpreted as the location of groundwater table, with extremely low resistivity value of less than 50 Ωm. Surface mapping of the zone where the subsurface show these low resistivity value show the presence of water movement, in addition to highly weathered rock (Figure 4). It can thus be shown that groundwater table plays a role in the rapid weathering process to the rock slope.

Figure 4. Completely weathered zone (Grade V) with the presence of groundwater on weathered zone's surface

From the interpreted electrical resistivity profile, a general profile for the weathering grade of granite is constructed. Figure 5 shows the proposed weathering zone of the granite based from the resistivity values and observed weathering condition of the slope surface. The range of resistivity values and interpreted weathering grade is shown in Table 3.

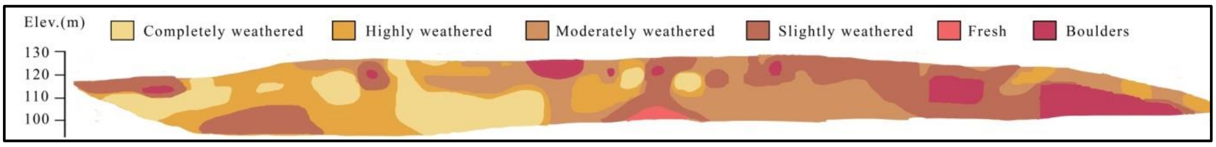

Figure 5. Proposed weathering zone for granite of the slope based on electrical resistivity values

Table 3. Proposed resistivity range for weathering grade of granite

Weathering grade	***Material description***	***Resistivity range (Ωm)***
I	Fresh rock	>5000
II	Slightly weathered	2500-5000
III	Moderately weathered	1000-2500
IV	Highly weathered	700-1000
V	Completely weathered	<700
	Groundwater zone	10-50

4. Conclusion

In conclusion, the electrical resistivity can be used in the mapping the groundwater and the weathering zone of rock slopes. The study have found that the rock material of the slope in the study area to be divided into three zones that consists of five weathering grade, along with zones of groundwater. The higher weathering grade of the rock slope were mostly found adjacent to the zones of groundwater, which shows the role that groundwater have in the weathering of rock material of slopes. For future research using similar method, the interpretation of the slope's subsurface can be correlated with engineering properties of the rock slope such as from borehole data and laboratory testing of materials to further study the potential of the method as a tool for characterizing the engineering properties of rock slopes.

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