Correlation between Resistivity and Ground Penetrating Radar (GPR) Methods in Understanding the Signatures in Detecting Cavities

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Abstract. The research was conducted using Resistivity and Ground Penetrating Radar (GPR) methods in detecting in-filled cavities and air-filled cavities. The importance of this study is to see the difference in conductivity value of the in-filled and air-filled cavity. The first study location is which the known target is air-cavity located at School of Language, Literacies, and Translation (SoLLAT). The next study location is at Desasiswa Bakti Permai, which the known target is a bunker with both were located at Universiti Sains Malaysia, Penang and the location at Gua Musang, Kelantan which suspected in-filled cavity. The result from Gua Musang is compared with both of the results that have been done at Universiti Sains Malaysia. The resistivity value of the first location that indicates the possible tunnel is about 500 Ωm to 800 Ωm and the conductivity value is about 0.0017 S/m. The resistivity value for the second location is about 50 Ωm to 250 Ωm and the conductivity value is about 0.1104 S/m. The resistivity value from Gua Musang is about 50 Ωm to 100 Ωm and the conductivity value is about 0.0101 S/m. The velocity of the in-filled cavities is much lower compared with the velocity of the air-filled cavities. Based on the characteristics, Gua Musang area was dominated with in-filled cavities.

1. Introduction

Universiti Sains Malaysia largely consists of granite which is an igneous type of rock while Gua Musang, Kelantan mostly made up from limestone. Detecting cavities or voids by applying geophysical methods have gained wide interest in the past few decades. Geophysical methods play a fundamental role in a process to identify the evidence of cavities at the three different places. The resistivity method used in this research in order to study the electrical properties and electrical conductivity of the subsurface area. Electrical methods utilize direct currents or low frequency alternating currents to investigate the electrical properties of the subsurface [1]. The resistivity method is a method using artificially-generated electric currents is injected into the ground and measured potential differences at the surface. Ground Penetrating Radar (GPR) is a non-destructive and cost-effective geophysical survey method that can be used in solving many environmental problems such as assessing construction sites and environmental objects [2]. The short bursts of electromagnetic (EM) wave being reflected with a range of frequencies and transmitted into the ground and the reflected pulses were recorded as functions of time and the position of the antenna pair along with a survey line.
The application of GPR on dry soils will give a better resolution of the buried structures since the electromagnetic (EM) wave can penetrate deeper [3]. There are many GPR antennas such as 500 MHz, 250 MHz, and 100 MHz antennas that can be used with each one of them will give different depth penetration. The most important parameter in GPR is the frequency used in the studies because it constrains the values of many other parameters to obtain a good GPR profile with better resolution depends on the suitable frequency. GPR signals can be collected rapidly and sufficiently with all the data are recorded digitally. The initial interpretations of GPR data can be made with minimal data processing required, making the GPR is suitable for shallow geophysical studies [4].

2. Study Area
The study for this research was conducted at Universiti Sains Malaysia (USM), Penang, Malaysia from Figure 1 and Batu Papan at Gua Musang, Kelantan from Figure 2. The study area covered at different locations as shown in Figure 1. The first study location was at School of Languages, Literacies and Translation labelled (A) at Universiti Sains Malaysia, starting from N 5°21’23.24”, E 100°18’25.72” to N 5°21’23.24”, E 100°18’26.20”, second location was at Bakti Desasiswa hostel labelled (B) also at Universiti Sains Malaysia starting from N 5°21’21.8”, E 100°18’00.5” to N 5°21’22.8”, E 100°18’00.9”, the final location is at Gua Musang, Kelantan labelled (C) start with N 04°51’04.5540”, E 101°57’03.4596” and the end point is at N 04°51’05.1588”, E 101°57’04.3668”.

![Figure 1. Survey area at USM, Penang, Malaysia [5].](image1)

![Figure 2. Survey area at Gua Musang, Kelantan, Malaysia [5].](image2)

3. Methodology
The minimum electrode spacing at the air-cavity area, (A) is 0.5 m spacing, at the bunker area, (B) is 1.5 m spacing and the minimum electrode spacing for the survey area at Gua Musang, (C) is 2.5 m spacing. The type of array used in the resistivity survey at the air-cavity study area, and the bunker is Pole-Dipole while at the Gua Musang is Wenner-Schlumberger. The length of the resistivity survey
line at the tunnel is 20 m, at the bunker is 60 m and at the Gua Musang is 100 m. The distance for Ground Penetrating Radar (GPR) survey lines lies on the same line as for the resistivity survey lines for all the study areas. The total length of the GPR survey line at all study areas are 30 m.

4. Results and Discussions
Based on the inversion profile of the resistivity data, the possible location of the suspected cavity is about 1.50 m in depth from Figure 3. Water or clay-filled and air-filled features produce low and high resistivity anomalies respectively [6]. High resistivity value between 500 Ωm until 800 Ωm indicates the suspected cavity that being filled with air at a distance from 11 m until 13 m. The conductivity value obtained from the resistivity data is 0.0016 S/m and the calculated conductivity value is 0.0017 S/m. The data at Location A shows the hyperbolic curve which indicated as the target of suspected cavity (Figure 4). From Figure 4 the suspected cavity was located at depth about 1.57 m

From the inversion profile of the resistivity data (Figure 5), the depth of the bunker is about 1.0 m from the subsurface area. The resistivity value that indicates the bunker is between 50 Ωm until 250 Ωm at a distance starting from 23 m until 55 m. The conductivity obtained from the resistivity data is 0.0909 S/m while the calculated conductivity value is 0.1104 S/m. The velocity at Location B is lower compared with the Location A due to the sedimentation and concrete structure. Location B acts as the model for the in-filled cavities. The presence of soil or air-filled void can be represent by a bigger scale of the hyperbolic curves taking an inverted chevron shape, while a homogeneous materials such

![Figure 3. Inversion profile of the resistivity data at Location A.](image1)

![Figure 4. GPR profile at Location A with the target of suspected cavity.](image2)
as clay-rich soils, bedrock or groundwater will have a reflection free pattern because all the three materials are considered as highly conductive dissolved minerals that generate the attenuation process of the EM wave produced by the GPR antenna [7]. The data at location B shows the suspected target at 0.87 m depth which represents by a hyperbolic pattern at the bunker located at Desasiswa Bakti Permai (Figure 6).

![Figure 5. Inversion profile of the resistivity data at Location B.](image1)

![Figure 6. GPR profile at Location B with the target of a bunker.](image2)

The inversion profile of the resistivity data from Figure 7 indicates the possible cavities at a certain depth between 0 m until 10 m. The resistivity value of 50 Ωm until 100 Ωm at a distance starting from 10 m until 90 m represents the possible cavities at the subsurface area. The conductivity value obtained from the pseudosection is 0.009764 S/m and the calculated conductivity value is 0.0101 S/m. The velocity of Location C is lower compared with Location A and Location B. The resistivity value at Location C is lower, and that indicates the in-filled cavities. Based on the GPR data (Figure 8), there are two types of pattern that clearly can be seen at Location C. The attenuation pattern is because of the reclaimed area between 0 m until 17 m in length. The hyperbolic curve can be seen on the starting from 18 m until 30 m in length of the survey line. The possible hyperbolic curve that represents the cavity is at depth 1.70 m from Figure 8.
6. Conclusion
The higher resistivity value which in between 500 Ωm until 800 Ωm represents the air-filled cavity while the lower resistivity value between 10 Ωm until 250 Ωm represents the in-filled cavity. The resistivity value of 50 Ωm until 250 Ωm represents the in-filled cavity associated with the concrete structure while the resistivity value of 50 Ωm until 100 Ωm represents the in-filled cavity associated with the sediment filled cavity. The lowest conductivity value is represents the air-filled cavity with 0.0017 S/m. The conductivity value for the in-filled cavity associated with the concrete structure is 0.1104 S/m and the in-filled cavity associated with the sediment filled cavity conductivity value is 0.0101 S/m. Resistivity and Ground Penetrating Radar (GPR) are two geophysical methods that are effectively can be used to study the cavities and able to distinguished between air-filled cavity and in-filled cavity.
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