Determination Asphalt Layer using Ground Penetrating Radar (GPR)

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Abstract. Ground Penetrating Radar (GPR) is one of a new instrument in the field survey that has emerge along with the advancement of the world technology. The non-destructive technique (NDT) that was introduced along with the GPR instrument is able to be used in assessing the condition of pavement structure and condition. This data can be used to assess the underground features and thus detect any anomalies and buried features such as cable pipe. The current technique used to assess the pavement structure is very destructive and cost a lot of time to be conducted. This paper aim to evaluate the performance of GPR in assessing the pavement layer with regards to JKR standard specification. The GPR will be equipped with two different types of frequencies which are 250 MHz and 700 MHz to determine the most suitable frequencies for pavement assessment. The obtain result will then be compared with the specification from JKR in order to evaluate whether the GPR is suitable or not. Based on the result, 700 MHz or higher frequencies are more suitable for pavement layer assessment as it can produce detailed and higher resolution of radargram. The comparison results also determined that the GPR can be used for pavement layer assessment as the measured thickness is within the JKR specification.

1. Introduction

Ground Penetrating Radar (GPR) is a near surface geophysical tool that complies with the non-destructive technique to image on underground surface structures. It propagates electromagnetic wave that react to electromagnetic properties changes across the subsurface materials. This instrument is proved to be reliable as a replacement for conventional method where the environment is disturbed. This instrument is made up of 3 main component which are antenna to transmit and receive signal, control unit and battery as its power source. It also can be used together with other technology such as Global Navigation Satellite System (GNSS) for more accurate positioning method. GPR provides wide range of application based on the frequency used. A higher frequency will produce clearer and detailed radargram but not able to penetrate deeper. For a deeper penetration, a lower frequency will be used as it has a longer wavelength which can travel farther compared to high frequency. However, the produced radargram resolution is lower and for clearer identification as the wavelength may miss smaller detail in the underground.
In principle, pavement structure is crucial for traffic user as it grant friction for the vehicle to operate besides transferring the vehicle load to the natural surface. The structure should be durable and serviceable to withstand the continuous load from the vehicle. A guideline has been specified by Jabatan Kerja Raya (JKR) to assist the construction personnel to build pavement that is safe to be used by the public. Generally, the pavement structure consists of several layer that was constructed on top of each other. The layer can be categorized as sub-grade, sub-base course, base course and asphalt layer or surface course that consist of two smaller layer which is binder course and wearing course. Each of the layer was specified their respective minimum and maximum thickness so that the pavement structure is suitable and safe for public usage.

The method used by JKR to confirm whether the structure was constructed according to its standard specification is very conventional and not suitable for modern usage as it cost a longer time and destructive to the structure. Therefore, this research was conducted to verify the capability of the GPR in assessing the pavement structure condition so that it can replace the conventional method practiced by JKR. The selected road will be scanned using GPR and measured the asphalt layer thickness of the road. The measured thickness will then be compared with JKR standard specification in order to verify the GPR accuracy in identifying the layer thickness especially for asphalt layer.

2. Methodology
This research consists of four main phases throughout its completion duration. Figure 1 shows the general research methodology flowchart for this study.

![General Research Methodology Flowchart](image)

**Figure 1.** General Research Methodology Flowchart
2.1 Project Planning
The site was selected by considering the available hazard on the site and whether it is suitable to achieve the objective of the research. Besides, the selection of the equipment and software to be used is also done during this phase.

2.1.1 Study Area. The selected site for this study is located at the border of Seksyen U13 and Seksyen U12 Shah Alam, Selangor which involve a few parts of the same road. The location of the site is highlighted as shown in Figure 2. The road was divided in several parts to provide different result of radargram for the purposes of comparison analysis.

![Figure 2. Study area located at Seksyen U13 and Seksyen U12 Shah Alam](image)

2.1.2 Instrument and Equipment. In this study, data collection was performed using Opera Duo Ground Penetrating Radar (GPR) for scanning the asphalt layer using two different frequencies which is 700 MHz and 250 MHz on three part of the road for approximately 20 meter long each part. The instrument was scanned slowly along the road in order to allow more time for the electromagnetic wave to penetrate the road for clear image.

2.2 Underground Data Acquisition
This is the most crucial part in the research study as the data acquired is compulsory for the analysis purposes. The data was acquired by scanning the GPR instrument on the selected road. The road is divided into three (3) parts to allow more data collected. The scanning was carried out for approximately 20 meters for each part. A spray paint is used to mark the start and end point of the scanned road. The GPR is scanned slowly along the road in order to allow more time for the electromagnetic wave to penetrate the road for a clear image. Figure 3 shows the GPR scanning process during the data acquisition phase.
Figure 3. On-site GPR scanning process for underground data acquisition phase

2.3 Image Data Processing and Interpretation
The parabolic radargrams were filtered in this phase in order to enhance its clarity and accurately depth determination. The enhanced radargram will then analyse to determine the asphalt layer thickness. The output will then be compared with the JKR standard specification. The filtration process was carried out in post processing method using uNext software to remove the irregularities and noise error that occurred during the data acquisition phase. The uNext software provide button that allow the user to enhance the clarity of the radargram based on the user interpretation, so that the identification of the layer thickness can be determined in systematic way. The uNext software also provide two different radargram of the same data that was obtain using two different frequencies which is 250 MHz for deep scanned radargram and 700 MHz for shallow scanned radargram.

3. Result And Analysis
The filtered radargram as final outputs were used for the last phase of this research which is included in result and analysis. The thickness of the asphalt layer of the scanned road was measured every 5 meter and compared with the standard specification provided by Jabatan Kerja Raya (JKR). Table 1, table 2 and table 3 indicate the comparison values between measured thickness from GPR and standard specification from JKR for Road 1, Road 2 and Road 3 respectively.

| Target placement on the road (m) | Measured Thickness (cm) | JKR Standard Specification (cm) |
|----------------------------------|-------------------------|---------------------------------|
| 1.00                             | 10                      | 9 – 15                           |
| 5.99                             | 10                      | 9 – 15                           |
| 11.02                            | 11                      | 9 – 15                           |
| 15.97                            | 12                      | 9 – 15                           |
| 21.00                            | 12                      | 9 – 15                           |
Table 2. Road 2 asphalt layer comparison

| Target placement on the road (m) | Measured Thickness (cm) | JKR Standard Specification (cm) |
|----------------------------------|-------------------------|---------------------------------|
| 1.00                             | 10                      | 9 – 15                          |
| 6.06                             | 9                       | 9 – 15                          |
| 11.02                            | 10                      | 9 – 15                          |
| 16.04                            | 10                      | 9 – 15                          |
| 20.87                            | 9                       | 9 – 15                          |

Table 3. Road 3 asphalt layer comparison

| Target placement on the road (m) | Measured Thickness (cm) | JKR Standard Specification (cm) |
|----------------------------------|-------------------------|---------------------------------|
| 1.04                             | 11                      | 9 – 15                          |
| 5.99                             | 10                      | 9 – 15                          |
| 11.05                            | 10                      | 9 – 15                          |
| 16.01                            | 12                      | 9 – 15                          |
| 21.03                            | 10                      | 9 – 15                          |

The minimum thickness for asphalt layer has been specified by JKR to be at 9 centimetre while maximum thickness should be at 15 centimetres. The layer is constructed according to the JKR specification if the measured thickness is within the specification range. Table 1, Table 2 and Table 3 shows the comparison of the measured asphalt layer thickness with JKR specification. Based on the tables above, the asphalt layer on each road was constructed according to the JKR specification as their thickness is within the specification range. Figure 4 shows the distribution of the collected data that is within the JKR specification range of minimum and maximum thickness allowed for asphalt layer. Based on line graph, all the measurement on asphalt thickness for Road 1, Road 2 and Road 3 are within standard specification from JKR which is within tolerance 9 cm to 15 cm in asphalt thickness.

Figure 4. Distribution of measured thickness within JKR standard specification range
4. Conclusion
Based on the final research outcomes, it can be concluded that 700 MHz frequency provide a clearer and focused image that allow more detailed interpretation on a shallow data compared to 250 MHz where the image is harder for layer classification due to less resolution obtained. This proved that 700 MHz or higher frequency will be more suitable for pavement assessment due to its capability to identify the layer at shallow detection. Besides, the scanned road was deemed to be constructed according to the specification provided by the JKR. Although there is slight discrepancy on the layer thickness, it may have been caused by the traffic load that uses the road on a daily basis as it has been constructed and open for use for sometimes. The standard deviation calculation has assisted to prove that the road was constructed correctly. Overall, the GPR has been proved to be an easier and reliable method for pavement structure assessment. JKR may consider applying this technique as it also is a non-destructive technique (NDT) which will be beneficial for a long-term.

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