International Journal of Infrastructure Research and Management
Vol. 11 (S), September 2023, pp. 31 - 40

UTILITY DETECTION IN CONCRETE STRUCTURES BY 3D SCANS USING GROUND PENETRATING RADAR

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ABSTRACT
Ground Penetrating Radar (GPR) is a non-invasive geophysical tool to detect utility in concrete structures and below the ground surface. In Malaysia, most contractors are still using traditional ways such as trenching to locate the utility in the structures. The purpose of this study is to determine the applicability of GPR in detecting rebar, utilities, wiring, etc. within the concrete structure. Data acquisition for GPR is carried out by using 1600 MHz antenna to scan 50 cm inside the concrete structure. Results of the 3D scans are enhanced using the RADAN software to interpret accurately the utility in the concrete structure. Based on the results obtained in this study, it can be concluded that GPR is applicable in detecting the utility in concrete structures.

Keywords:
GPR, concrete structure, 3D scan, utility detection, non-invasive.

INTRODUCTION

Ground Penetrating Radar (GPR) is a non-invasive geophysical tool to detect utility underground and in structures. GPR system consists of three basic units which are antenna, control unit, recorder and display unit. The radar generates a brief pulse of electromagnetic energy that is transferred to the object. Radar signal propagation relies on the material's electromagnetic characteristics, primarily dielectric permittivity and electrical conductivity. Differentiation in the dielectric constants (Table 1) and conduciveness of both materials dictate the quality of reflection (Ranjit & Mohamed, 2020; Desai, et al., 2016; Jaw & Hashim, 2013).

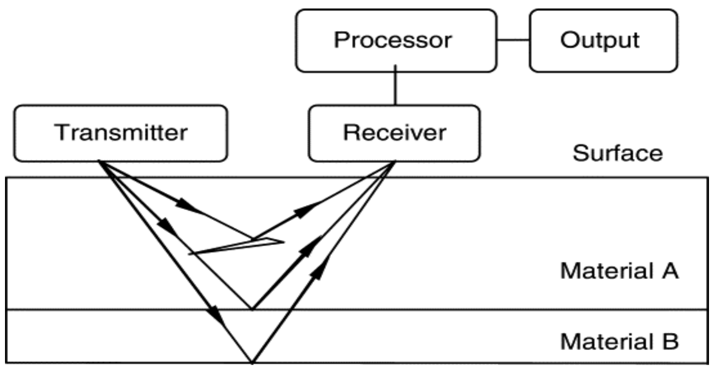

Figure 1: GPR System (Dong & Ansari, 2011)

Table 1: Wave Velocities and Dielectric Constants (Lester & Bernold, 2007)

Medium	Velocity (m/ns)	Dielectric Constant
Air	0.3	1
Water	0.033	81
Rocks	0.15–0.087	4–12
Sand dry	0.15–0.12	3–5
Sand wet	0.055	20–30
Clay dry	0.11–0.09	2–6
Clay wet	0.052	15–40
Concrete	0.10–0.087	9–12

The utility industries still lack exposure to comprehensive guidelines, requirements, procedures and precision of subsurface utility mapping. Cutting into concrete at random without scanning is reckless and potentially dangerous. There is a chance when digging into unscanned concrete that one might encounter an unknown subsurface object or hazard such as pipes, conduits, post tension cables, utilities, live wires, rebar, voids, and more. It can harm and possibly even electrocute workers. Striking subsurface objects can also result in extended delays and injuries. Often, clients will call for GPR scanning after they have already hit an unknown object by accident or surprise. Repairs are needed to fix the damage done by the accident before anything else can be done which further increases delays. GPR provides a clear picture of a proposed cut, core, and trench area, so one might know exactly how it needs to be addressed. This will increase the overall productivity of a project (Barrile & Pucinotti, 2005).

GPR has been successfully used by construction agencies from other countries to locate flaws in a wall (Dérobert, et al., 2008; Lai & Poon, 2012; Orlando & Slob, 2009, Xie, et al., 2013). However, in Malaysia, construction agencies are still using the old traditional ways such as trenching to locate the utility in the structures. This study is to determine the applicability of GPR in detecting rebar, utilities, wiring, etc. within the concrete structure. The objectives of this study are as follows:-

i. To apply GPR to scan inside the structure of a building.
ii. To locate, identify and analyse the subsurface utilities in both vertical and horizontal orientations.

METHODOLOGY

The procedure of application for GPR consists of data collection, downloading of data, processing of data, analysing and identifying the utilities. The flowchart of the methodology of this study is depicted in Figure 2.

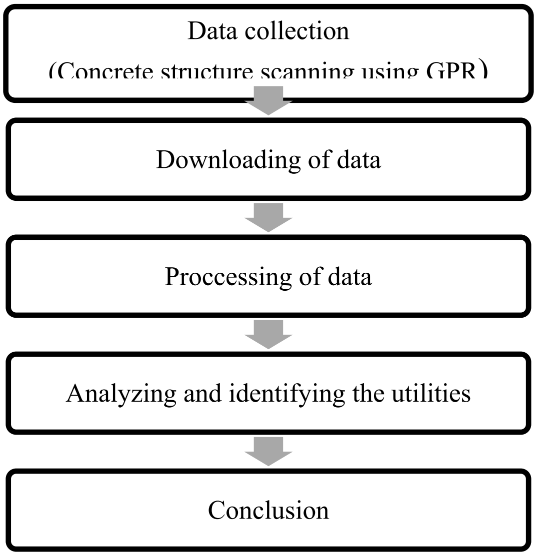

Figure 2: Flow Chart of Methodology

This study uses a battery-operated GSSI handheld GPR unit with 1600 MHz antenna. The maximum penetration depth in concrete structure is 50 cm for the detection of subsurface utilities such as pipes, conduits, cables, wires, rebar, voids, etc.

The 3D scan data is downloaded into a laptop for further processing using the RADAN software. The 3D scan data can then be analyzed to differentiate both metallic and non-metallic utilities such as pipes, cables, rebar, etc. and the depth of utilities.

RESULTS

Six areas have been selected to perform the structural scan using GPR at Block 9, Infrastructure University Kuala Lumpur (refer to Figure 3 to Figure 8). The grid line used in this study has a dimension of 15 cm x 15 cm with a length of 90 cm and a width of 75 cm. The GPR will start the data collection on the x-axis followed by the y-axis. The GPR must be moved slowly in a straight line on the x-axis and y-axis.

Figure 3: GPR Scanning On Area 1 (Wall)

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Figure 4: GPR Scanning On Area 2 (Floor)

Figure 5: GPR Scanning On Area 3 (Wall)

Figure 6: GPR Scanning On Area 4 (Column)

Figure 7: GPR Scanning On Area 5 (Column)

Figure 8: GPR Scanning On Area 6 (Column)

The results obtained from the 3D scans are analysed based on the selected Area 1 to Area 6 as below:

i. Area 1 (Wall)

The result of the GPR scan in 3D for Area 1 (wall) is shown in Figure 9. The GPR scan data shows three hyperbolas in the vertical direction. The hyperbolas represent the detected utilities inside the wall which are the rebars. The diameter of the rebars is about 30mm. Further checking reveals that there is a column located behind the wall (Figure 10). The rebars are only detected in the area where the column is located. As can be seen in Figure 9 only vertical rebars are available in the column.

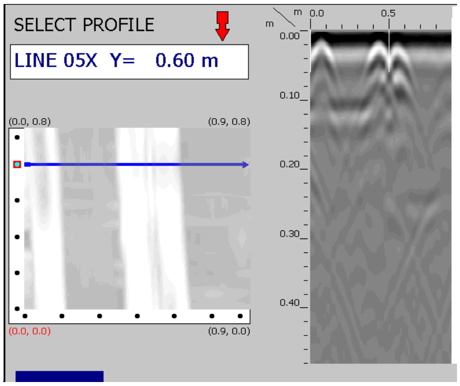

Figure 9: 3D Scan of Area 1

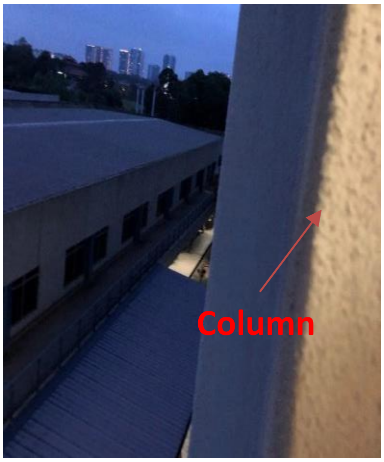

Figure 10: Column Behind the Wall

ii. Area 2 (Floor)
Figure 11 shows the result of GPR scan in 3D for Area 2 (floor). As can be seen from the 3D scan there is no utility detected in Area 2.

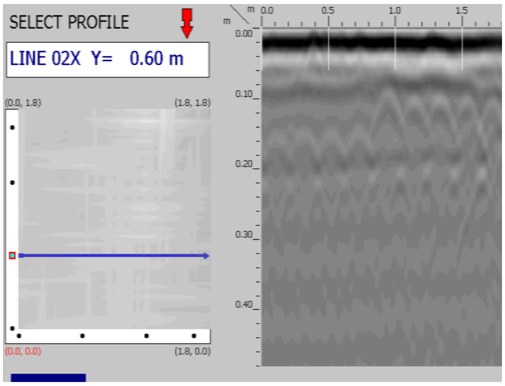

Figure 11: 3D Scan of Area 2

iii. Area 3 (Wall)
Figure 12 shows the result of the GPR scan in 3D for Area 3 (wall). There is no visible hyperbola in the 3D scan therefore there is no utility detected in Area 3.

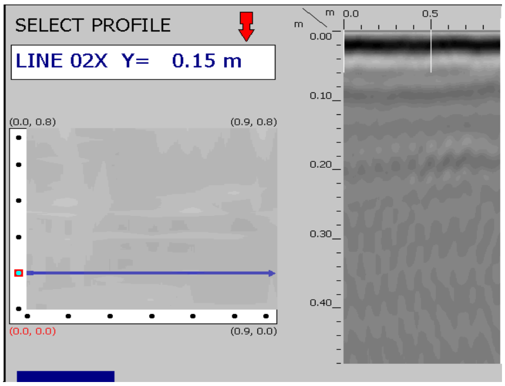

Figure 12: 3D Scan of Area 3

iv. Area 4 (Column)

Figure 13 shows the result of the GPR scan in 3D for Area 4 (column). There is no utility detected in Area 4 as shown in the 3D scan. There is no visible hyperbola in the 3D scan. It can be assumed that this area is near the edge of the column and the rebars in the column should be in the centre of Area 4 which cannot be accessed by the GPR as it is sealed off by a wall.

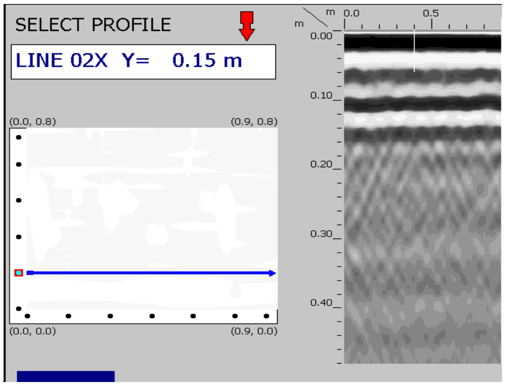

Figure 13: 3D Scan Of Area 4

v. Area 5 (Column)

Figure 14 shows the result of the GPR scan in 3D for Area 5 (column). It can be noticed from the 3D scan that the distance between the vertical rebars is not consistent and the depth of the vertical rebars is not the same. It can be seen that some rebars are placed below the other rebars. Whereas as shown in Figure 15 the distance between the horizontal rebars is consistent and the depth of the horizontal rebars is almost the same. The inconsistent depth of the vertical rebars (Figure 14) may cause failures such as cracking, etc. to the column in the future. It can be presumed that this column is using 30mm rebar size based on the size of the hyperbola in Figure 14.

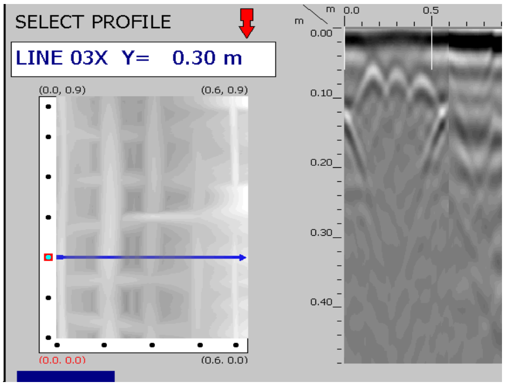

Figure 14: 3D Scan Of Area 5 Showing The Vertical Rebars

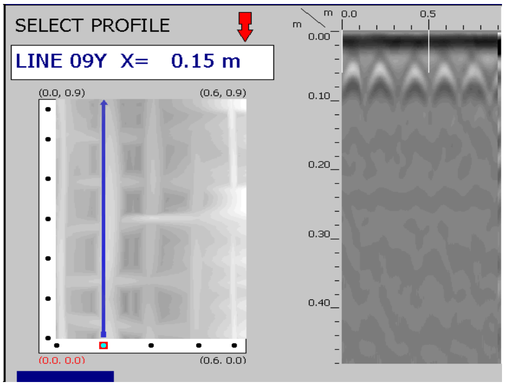

Figure 15: 3D Scan Of Area 5 Showing The Horizontal Rebars

vi. Area 6 (Column)

Figure 16 and Figure 17 show the results of the GPR scan in 3D for Area 6 (column). It can be noticed from the 3D scan that the distance between the vertical rebars is not consistent and the depth of the vertical rebars is not the same. This condition is the same as Area 5 (Figure 14 and Figure 15). It can be presumed that Area 5 and Area 6 have the same structural mechanism since the distance between these two columns is about 20m apart.

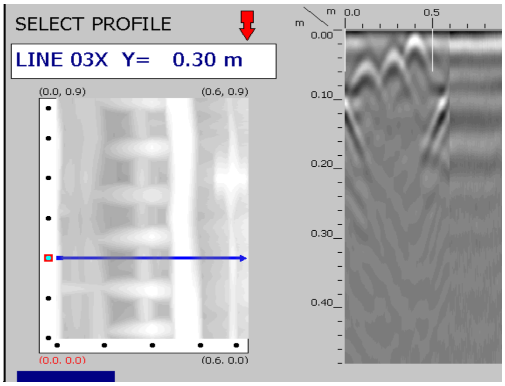

Figure 16: 3D Scan Of Area 6 Showing The Vertical Rebars

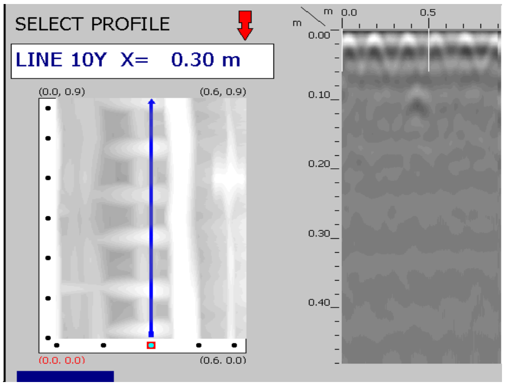

Figure 17: 3D Scan Of Area 6 Showing The Horizontal Rebars

The summary of the GPR scan is depicted in Figure 4.1. It can be summarized that vertical rebars are detected in area 1, no utilities were detected in areas 2, 3 & 4, and vertical & horizontal rebars are detected in areas 5 & 6. The size, depth and distance between the rebars can be obtained from the 3D scan data.

No	Area	Utility
1	Area 1	Vertical Rebars
2	Area 2	No utility
3	Area 3	No utility
4	Area 4	No utility
5	Area 5	Vertical & Horizontal rebars
6	Area 6	Vertical & Horizontal rebars

Table 2: GPR scan Summary

CONCLUSION

Based on the results of the GPR scans in 3D, it can be concluded that GPR is applicable in detecting the utilities in the concrete structure. The distances and the depths of the utilities can also be determined. Any inconsistencies in the location of the utilities can also be determined. The scan data can be used to determine the cause of any failures to a structure and also to avoid any damage to the utilities during the renovation or repairing works. GPR can be a useful tool for the contractors before carrying out any construction works on an existing structure.

AUTHOR BIOGRAPHY

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