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REVIEW ARTICLE

CAVITY DETECTION UNDER RE-ENFORCED CONCRETE FLOOR USING

GROUND PENETRATION RADAR

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ARTICLE DETAILS

ABSTRACT

Article History:

Received 26 June 2018 Accepted 2 July 2018 Available online 1 August 2018 Voids underlying engineering re-enforced ground floor could be hazardous and may hinder proposed project objectives, if not adequately detected. Ground penetration radar is non-penetrative and non-destructive technique that is used successfully in this study to identify these cavities. The short radar pulses from antenna sources within microwave band of radio spectrum adequately images the subsurface to appreciable depth of interest (<1m) below re-enforce concrete floor. This technique is recommended for void detection in engineering work in very sensitive areas like gas areas like gas flow station because of its safe operation.

KEYWORDS

Voids, radagram, ground penetration radar, survey grids, transmitter, receiver, antennas, dielectric constant.

1. INTRODUCTION

There are natural and artificial subsurface voids all of which may constitute be engineering hazard. This include underground storage tanks, washouts or settlement gaps beneath roadways or floor slabs, bubbles in concrete pours, tunnels, mine workings, vaults, natural limestone (karsts) caves or solution cavities and incipient sinkholes or soil pipes. All of these can be detected and delineated using nonintrusive geophysical techniques [1-14]. Voids of large volume can be investigated using microgravity survey while ground penetration radar (GPR) is used for smaller voids. Deeper subsurface voids are investigated using seismic survey. Where boreholes are present cross hole seismic or electrical tomography, gravity and radar could be used to detect voids [15]. It is possible to determine the content of a void by combining two or more geophysical techniques.

A review of the state-of-the-art non-destructive technologies applicable to voids detection includes:

- (1) Electromagnetic (Ground Penetrating Radar, Microwave and Millimeter Wave, Infrared Thermography, Magnetic Fields, Electrical Resistivity/Conductivity, Spontaneous Potential, Visual Inspections),
- (2) Transient Load (Seismic Waves, Impact-Echo, Heavy Weight Deflectometer, Rolling Deflectometers, Vibratory Loading Systems, Rolling Dynamic Deflectometer, Ultrasound, Acoustic Reflection Sounding, Acoustic Emission, Audible Acoustic Reflection Sounding), and
- (3) Others (Video Taping, Soil Penetration, Quasi-Static Load-Deflection Devices, Gravitational). This paper takes into consideration the evaluation of voids using ground penetration radar.

Ground-penetration radar (GPR) uses radar pulses within the microwave band (UHF/VHF frequencies) of radio spectrum to image the subsurface. GPR uses transmitting and receiving antennas or only one containing both functions. The transmitting antenna radiates short pulses of the high-

frequency (usually polarized) radio waves into the ground. When wave hits a buried object or boundary with different dielectric constants, the receiving antenna records the variation in the reflected return signal [16]. The principle involved is similar to reflection seismology, except that electromagnetic energy is used instead of acoustic energy, and reflections appear at boundaries with different dielectric constants (Table 1) instead of acoustic impedances.

The investigation depth range using GPR method is dependent on the electrical conductivity of the ground, transmitted centre frequency of antenna's and the radiated power [17-20]. Ground-penetrating radar antennas may be in contact with the ground to achieve the strongest signal strength; however, or GPR air launched antennas can be used above the ground

Table 1: Bulk dielectric constant (ϵ_r measured at 100MHz) of common earth materials.

Material	ε _r (Davis and Annan, 1989)	ε _r (Daniels, 1996))
Air	1	1
Distilled water	80	
Fresh water	80	81
Sea water	80	
Fresh water ice	3-4	4
Sea water ice		4-8
Snow		8-12
Permafrost		4-8
Sand, dry	3-5	4-6

Sand, wet	20-30	10-30
Sandstone, dry		2-3
Sandstone, wet		5-10
Limestone	4-8	
Limestone, dry		7
Limestone wet		8
Shales	5–15	
Shale, wet		6-9
Silts	5-30	
Clays	5-40	
Clay, dry		2-6
Clay, wet		15-40
Soil, sandy dry		4-6
Soil, sandy wet		15-30
Soil, loamy dry		4-6
Soil, loamy wet		10-20
Soil, clayey dry		4-6
Soil, clayey wet		10-15
Coal, dry		3.5
Coal, wet		8
Granite	4-6	
Granite, dry		5
Granite, wet		7
Salt, dry	5-6	4–7

GPR can be applied in utilities investigation, mining, hazardous waste evaluation, archaeology, road, railway and environmental studies which could be related to engineering or transportation [21,22]. A significant limitation of GPR method in geo-scientific studies is observed in areas rich in highly conductive materials such as clays and salt contaminated soils. In addition, expertise is required for design, conduct and interpretation of results (Radargram) in GPR survey. The GPR device has relatively high energy consumption level which must be put into consideration and adequate measures planned when embarking in extensive field survey [23-26].

2. DATA ACQUISITION AND PROCESING

Reconnaissance survey of the study area is required to identify all environmental condition. The study area is gridded, and transient profile path X and Y are defined with interval of 0.5m for X and 1m for Y (Figure 1).

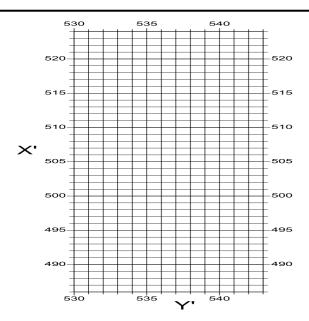


Figure 1: Survey grids showing independent transient path in X and Y direction.

Based on the depth of penetration of interest and spatial resolution, antennas of specific frequency are selected. The frequency need to acquire information for a desired spatial resolution R is given by:

$$f = \frac{150}{R\sqrt{K}} \tag{1}$$

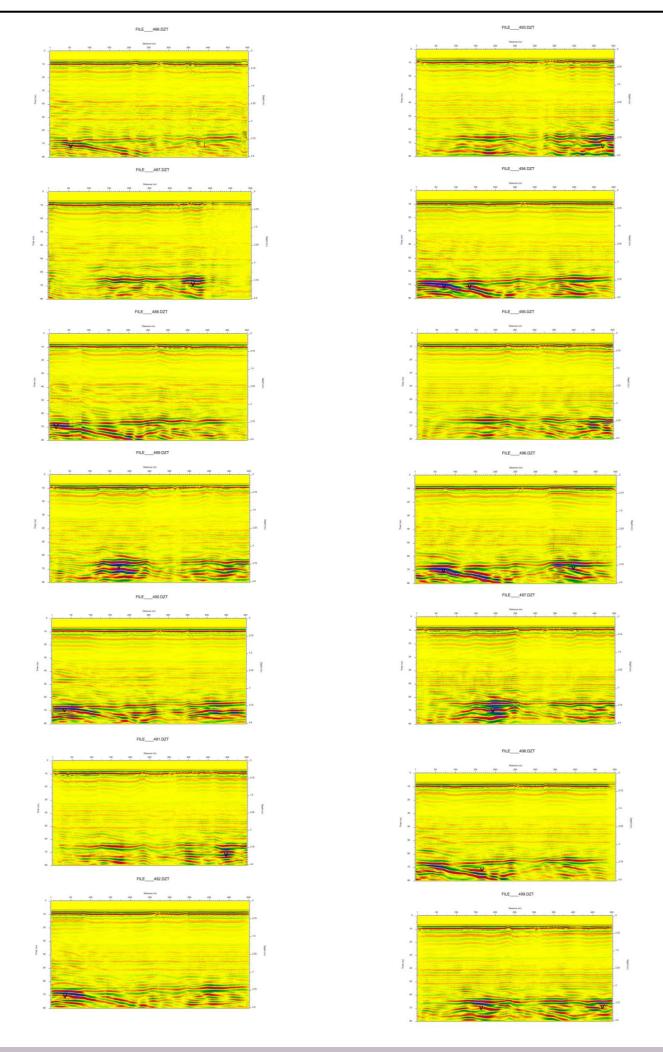
K - Relative permittivity (dielectric constant) of most material R -Spatial resolution (Generally, R about 25% of the desired target depth)

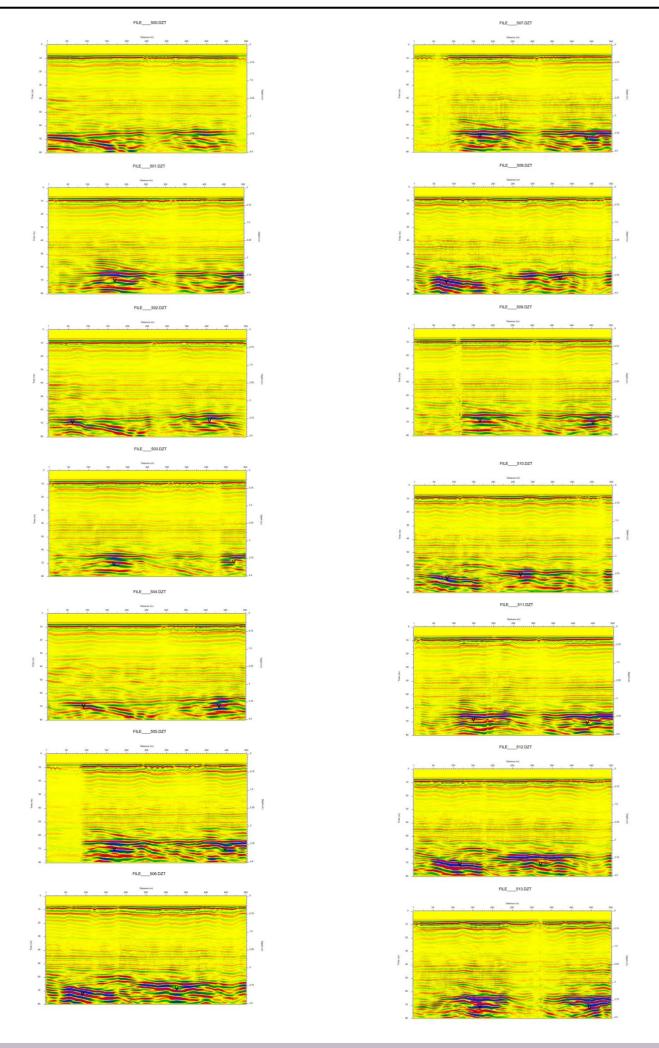
Generally, all survey lines should be oriented perpendicular to the strike of the target if the target has a preferred strike direction, which does not apply in void detection. For a successful survey to be achieved, it is advisable that the sampling rate be approximately six times the centre frequency of the antenna being utilized.

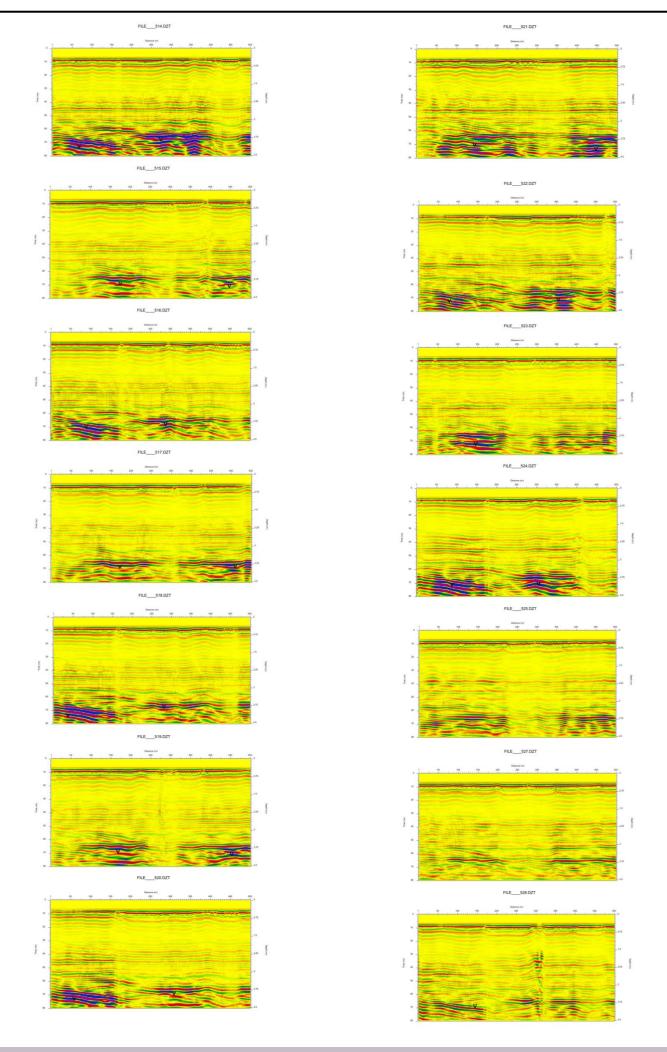
The GPR tool setting is adjusted to achieve better resolution during site testing along each defined transient path and data is saved in files. This data is transmitted into software that can read the file format generated by the GPR tools. The saved data file undergoes distance normalization, filtering, deconvolution and gain processing depending on what improves resolution.

3. RESULTS AND DISCUSSION

Transient path X encompasses surveys recorded sequentially and saved as file 530, 531, 532, 543 in .dzt extension format while transient path Y includes radagram sections of line 486, 487, 488, 524 in .dzt. The survey approach utilized an alternate start point positioning (from start to end and then end to start position) along directly adjacent lines [27]. On intersection of any void alone a transient path, a pattern of reflection were produced by the GPR device which identifies voids.







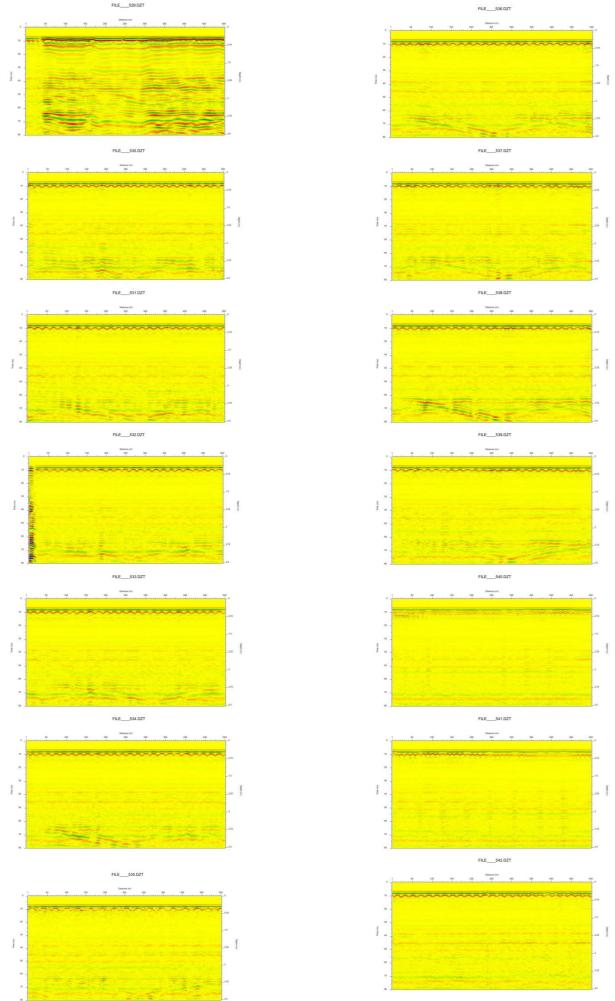


Figure 2: Radagram of evaluated transient path.

The SIR 2000 device was utilized with 400MHz antenna in survey and acquisition of data was set continuously with 120ns time range. The GPR radagram sections show high interference at shallow depths due to presence of rebar's in the cemented floor at less one-meter (<1m) depth, resulting in very chaotic reflections but hyperbolic reflection pattern were identified at depth range of 3.5m to 4m within study area [28].

The radagram images from transient path X showed higher distortions (Figure 2) because the device was alignment in motion tangentially to the metals used to re-enforce concrete floors during survey, preventing high surface resolution. The voids identified are mapped (Figure 3) and the overall ground activity is revealed in each radagram.

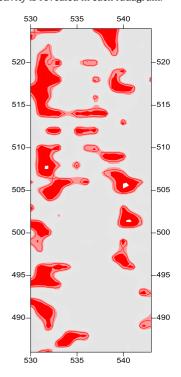


Figure 3: GPR spatial data interpretation showing voids (in red) beneath re-enforced floors.

Generally, the cavity density is high with relatively linear to pseudo structures depending on the stability of the underlain building to soil foundation system. These voids are air-filled and their lateral dimensions are adequately inferred using GPR techniques.

4. CONCLUSION

The presence of cavities under re-enforced concrete floor poses a threat to the re-engineering facility project plan that requires mounting of very heavy machines which may result in ground break or collapse in void filled areas. In this study, ground penetration radar is systematically used to survey successfully high cavity zones which are difficult to locate and are relatively expensive to handle using modern intrusive techniques.

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