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Research Article

Ground Penetrating Radar as a Non-Destructive Evaluation Method of Concrete Slabs

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Abstract

Ground penetrating radar (GPR) has gained increasing popularity in quality control surveys of several structures in the field of civil engineering due to its greatest advantages as non-destructive testing in comparison to the other traditional methods as well as costs are low and surveys can be performed quickly and data collection can be 2D or 3D displayed. In this paper GPR is applied to six concrete slabs. Radar measurements were performed using a 1000 MHz RAMAC GPR CU-II. Two concrete slabs weren't reinforced, two have simple reinforcement, and the last two have artificial gaps in their reinforcement. Experiments resulted that some features can be inspected in the radargram image.

Keywords: *Ground Penetrating Radar, Non-Destructive Testing Method of Concrete, Concrete Features, Microwave, Concrete, Imaging.*

1. Introduction

Ground-penetrating radar (GPR) is widely used by a diverse group of service providers that include agronomist, archaeologists, criminologists, engineers, environmental specialists, foresters, geologists, geophysicists, hydrologists, land use managers, and soil scientists. In engineering applications include non-destructive testing (NDT) of structures and pavements and locating buried structures etc. In recent years, GPR has gained recognition in the search for terrorism and military hazards. In many soils, high rates of signal attenuation severely restrict penetration depths and limit the suitability of GPR for a large number of applications. In saline soils, where penetration depths are often less than 10 inches (Daniels, 2004). GPR is a relatively new geophysical tool that has become increasingly popular due to its high resolution and the need to better understand near-surface conditions (Chen, 2001). Microwave remote sensing techniques are employed to classify soil with the traditional classification method and to detect buried pipes in soil and compare the results. This research study detected the pipes in soil by using iron and plastic pipes with different diameters to determine and study the changes in reflection coefficient (Hasanen, 2010). GPR technique used antenna frequency 250 MHz for detecting shallow subsurface features within the ancient UR city in Nasiriya province of Dhi-Qar Governorate SW Iraq. The study was focused to investigate the ancient archaeological features such as walls and buildings etc. that are covered with soil (Alkafaji, 2011). The feasibility explored to quantify the field scale soil water dynamics through time series of GPR measurements, which bridged the gap between point measurements and field measurements (Pan *et al.*, 2012). Several inspections were applied to study the effect of changing the operating setting parameters of GPR on the data accuracy and interpretation for paved roads damages and the pavement layers thicknesses in the University of Technology Campus. The results demonstrated that when using 250 MHz antenna, showed the possibility of identifying buried plastic pipe and the flexible pavement layer (Al-Qaissi, 2013). The pavement surface density variations were mapped using dielectric measurements from ground penetrating radar. The work was carried out as part of an Asphalt Intelligent Compaction demonstration project on SR 539 in Lynden, WA (Maser *et al.*, 2015). The limitations of GPR were examined and evaluated for the leak detection. To fulfill this aim, model test, artificial leak in general road was created and general road scanning measurement has been carried out (Sarmad S. M., 2016).

2. Ground Penetrating Radar Basic Principles

GPR methods use electromagnetic energy at high frequencies (10 to 4000 MHz) to probe the subsurface, and the propagation of the radar signal depends on the

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electrical properties of the ground at the high frequency (Davis and Annan, 1989). The GPR methods measure the velocity and attenuation of the radar waves, and these can be used to determine the dielectric constant or relative permittivity, which is the major electrical property of geological materials at high frequencies (Hubbard *et al*., 1997).

GPR as a non-destructive method uses electromagnetic radiation in the microwave band (UHF/VHF Frequencies) of the radio spectrum, and detects the reflected signals from subsurface structures. The impulse of Ground Penetrating Radar (georadar) is a precise transmitting-receiving measuring device, which implements the phenomenon of reflection of electromagnetic waves (Daniels, 2000) (Figure 1).

GPR is highly suited to most applications in dry sands and gravels, where penetration depths can exceed 160 feet with low frequency antennas (Smith and Jol, 1995). The penetration depth of GPR is determined by antenna frequency and the electrical conductivity of the earthen materials being profiled (Daniels, 2004).

Electrical conductivity is directly related to the amount, distribution, chemical composition, and phase (liquid, solid, or gas) of the soil water (McNeill, 1980). At a given frequency, the attenuation of electromagnetic energy increases with increasing moisture contents (Daniels, 2004).

Ground penetrating radar operates by transmitting electromagnetic wave that is radiated from a transmitting antenna down into the ground. The electromagnetic wave is reflected from various buried objects or distinct contacts between different earth materials that have contrasting dielectric properties, such as at the boundary between soil and a landmine or between soil and a large rock. The reflections are created by an abrupt change with the dielectric properties in the ground. These electrical properties are namely, relative permittivity, relative permeability and conductivity.

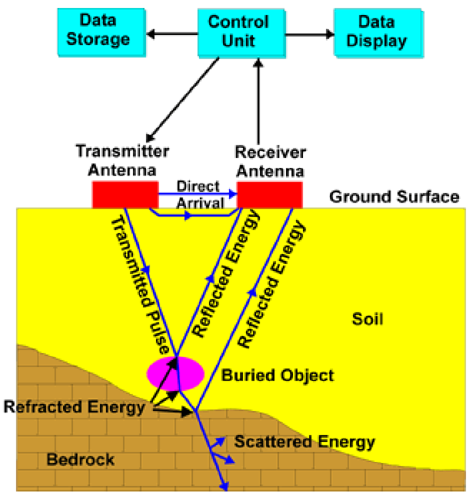


Fig.1 GPR schematic, (from Environmental Protection Agency, Web site)

3. Experimental Materials Details

Details used in the experimental work illustrated as follow:

3.1. Radar Measurements

The penetration depth of GPR is determined by antenna frequency and the electrical conductivity of the earthen materials being profiled (Daniels, 2004). For higher accuracy site requirements, 1000 MHz RAMAC GPR CU-II was used in cooperation with the Ministry of Science and Technology/ Department of Communications and Space.

3.2. Concrete Samples

In this study, six simply supported slab specimens were cast. All slabs were of same dimensions of 600 mm width, 1000 mm length and 80 mm thickness. Two slab specimens were reinforced with bottom steel bars of size 4 mm with 550 mm spacing in both directions. Two slab specimens were reinforced with bottom steel bars of size 4 mm with 850 mm spacing in both directions. And finally two non-reinforced concrete slabs, slab 3 was mixed and vibrated to get a homogeneous texture, while slab 4 was not in intension to create artificial voids. All the experiments were conducted at room temperature in Constructions Laboratory at the University of Technology.

4. Experimental Results and Discussion

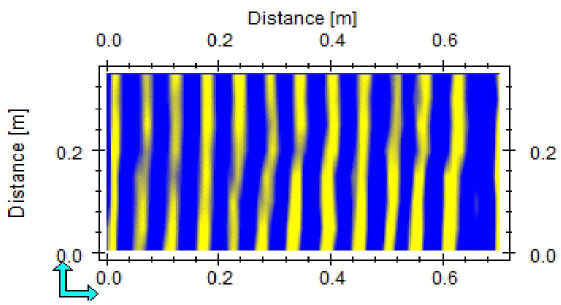
Results obtained from experimental work are shown and discussed as follows:

4.1 General Data Processing

Individual files were combined into a solid model to produce the 3D imaging using the Easy 3D (v.1.2.1) software.

4.2 Reinforcement Bars and Condition Assessment

Three dimensional imaging were achieved. The three dimensional grid radargrams were done as follows: in horizontal lines and for x-y directions, z amplified, Figures (2) to (7) shows the 3D imaging of the slabs before loading. Filters applied in easy 3D are: average, DC adjustment and HFIR.



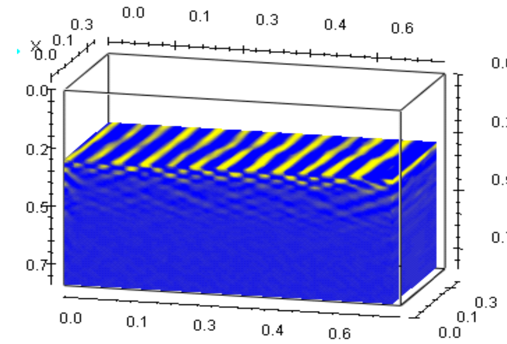


Fig.2 Three-dimensional imaging for slab 1W

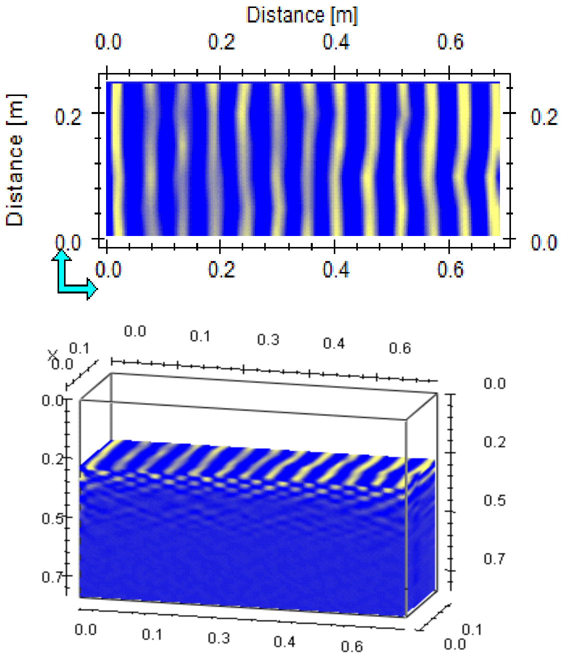


Fig.3 Three-dimensional imaging for slab 1W/O

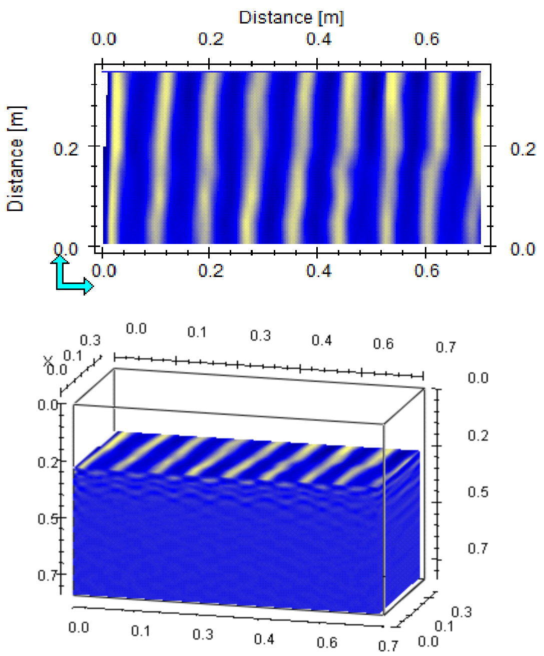


Fig.4 Three-dimensional imaging for slab 2W

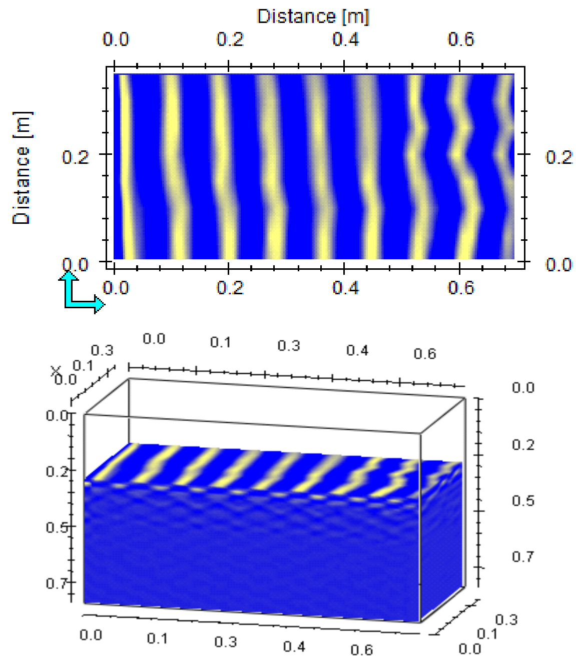


Fig.5 Three-dimensional imaging for slab 2W/O

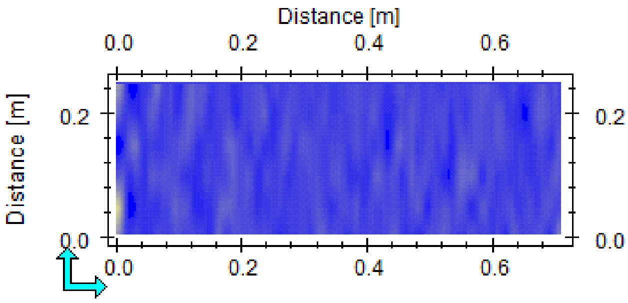


Fig.6 Three-Dimensional Imaging for Slab 3

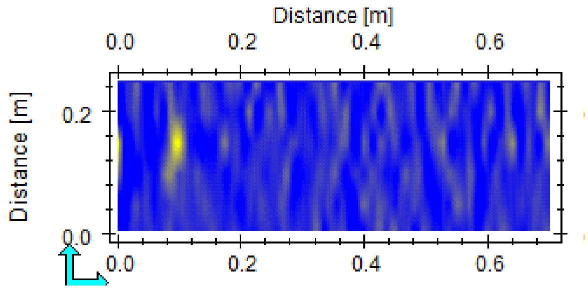


Fig.7 Three-dimensional imaging for slab 4

It is clearly obvious from these radargarms that the inspected bars of single layering reinforcement in each slab. The concrete and reinforcement condition in slabs (1w/o and 2w/o) are expected to be in accepted condition and no damages area are noticed either by the impact effect or other environmental conditions, While for slabs (1w and 2w) the concrete is in accepted condition and no damages are noticed but the reinforcement bars have several random gaps. For slab 3 there's no damage and the concrete is in a good condition but slab 4 severe from artificial voids which are clearly inspected in the radargram image.

Conclusions and Future Work

From the intensive implementation of the GPR technique for six different slabs, the following conclusions are achieved and introduced as follows:

1) 3D and 2D imaging radargrams gained by using 1 GHz offer massive data collection on a concrete slab that can be uses to distinguish concrete damaged areas.
2) The GPR technique can detect subsurface features in concrete in a very detail 3D image. It can detect cracks in the concrete
3) Project imaging technique by GPR can be useful to detect gaps in reinforcement which are of length 3.5 cm and above, while smaller gaps (1 cm- 3cm) were not detected.
4) The prediction of accurate air void of the mixture can be achieved when an appropriate model is used.

References

Daniels, D. J., (2004), Ground Penetrating Radar, 2nd Edition, *The Institute of Electrical Engineers, London, United Kingdom.*

Chen, J., (2001), Bayesian Approaches for Subsurface Characterization using Hydro Geological and Geophysical Data, Ph.D. Thesis Engineering, *Civil and Environmental Engineering. University of California, Berkeley.*

Hasanen Fat'hiy, Hijab B.R., (2010), GPR Method and its Engineering Application in Baghdad University Site, M.Sc. Thesis*, College of Science, University of Baghdad.*

Al-kafaji, M.A. H., (2011), Investigation of The Subsurface Archaeological Features Using Ground Penetrating Radar (GPR) in Ancient UR-city (Southwest Nasiriya /Iraq), M.Sc. Thesis, *College of Science, University of Baghdad.*

Pan, X., Wollschlager U., Gerhards H., and Roth K., (2012), Optimization of Multi-Channel Ground-Penetrating Radar for Quantifying Field-Scale Soil Water Dynamics, *J. Appl. Geophys., 82, 101–109.*

Al-Qaissi, A. M. M., (2013), Geophysical Evaluation of Flexible and Rigid Pavement Conditions Using GPR Technique, M.Sc. Thesis, *Building and Construction Engineering Department of University of Technology.*

Maser, K., and Carmicheal, A., (2015), Ground Penetrating Radar Evaluation of New Pavement Density, Paving Project - SR 539 in Lynden, WA, *Final Report Submitted to Washington State Department of Transportation Research Office.*

Sarmad Sadoon Mahmud, (2016), Pipe Leakage Detection Using Ground Penetration Radar, M.Sc. thesis, *Building and Construction Engineering Department, University of Techology.*

Davis J. L. and A. P. Annan, (1989), Ground Penetrating Radar for High Resolution Mapping of Soil and Rock Stratigraphy, *Geophysical Prospecting, V.37, P.P. 531-551.*

Hubbard, S., Peterson, J.E., Majer, E.L., Zawislanski, P.T., Roberts, J., Williams, K.H. and Wobber, F., (1997), Estimation Of Permeable Pathways and Water Content Using Tomographic Radar Data, *The Leading Edge of Exploration, 16(11), 1623-1628*,

Daniels J.J., (2000), Ground Penetrating Radar Fundamentals, *Published Report, Department of Geological Sciences, Ohio State University, 21 pages.*

Smith, D. G. and H. M. Jol, (1995), Ground-Penetrating Radar: Antenna Frequencies and Maximum Probable Depths of Penetration in Quaternary Sediments, *Journal of Applied Geophysics* 33: 93-1.

McNeill, J. D., (1980), Electrical Conductivity of Soils and Rock, Technical Note TN-5, *Geonics Limited, Mississauga, Ontario.*