GROUND PENETRATING RADAR (GPR) FOR IDENTIFYING THE DEPTH OF SPUN PILE GAS STATION AT BATAM

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Abstract. Ground Penetrating Radar (GPR) is a geophysical imaging technique used for subsurface exploration and monitoring. The ground penetrating radar (GPR) method involves the transmission of electromagnetic waves into the material under investigation. The reflections of these waves at interfaces and objects within the material are analyzed to determine the location (horizontal distance from a reference point) and depth (vertical distance from the surface) of the detected interfaces and buried objects. These reflections of GPR waves are detected by the receiving antenna and converted into electrical signals. The recorded reflections can be analysed in terms of shape, travel time and signal amplitude to provide information about the size, depth and properties in relation to the material object. Spun pile is a round and hollow pile in the middle. Method making of spun pile is centrifugal for concrete compaction process, that is with how to spin (spinning), there is no possibility will produce an unequal compressive strength on the thickness of the pole wall. The sight of the slurry layer will be possible affecting friction with filler concrete. This study to discuss the friction between the inner concrete of spun pile so new concrete as filler.Determining the thickness of concrete pavement is an important consideration for construction quality assurance of structural capacity estimation of existing. This information is essential for pavement management systems in order to maintain the safety, serviceability, and durability of pavement networks. the depth of spun pile in the area 1, which consisted of two locations, showed that piles rested on 16 m and 20 m below ground. The area 2 which consisted of four spun piles showed the depth of those piles were 13 m, 13 m, 20 m and 17 m for GPR 1,2, 3 and 4 respectively. These results were to confirm as built drawing that showed that the depth of all piles rested on 20 m below ground.
Keywords: Ground Penetrating Radar (GPR), Spun Pile Gas Station, Batam

1. Introduction

Ground Penetrating Radar (GPR) is a tool that uses radar pulses to image the subsurface. This nondestructive method uses electromagnetic radiation in the microwave band (UHF/VHF frequencies) of the radio spectrum, and detects the reflected signals from subsurface structures. GPR is a well-established non-destructive method of investigating the internal composition of many naturally occurring materials such as rocks, earth and gravels as well as manmade materials like brick, concrete and asphalt, etc.. It can be used to detect metallic and non-metallic pipes, sewers, cables, cable ducts, voids, foundations, reinforcing in concrete and a whole host of other buried objects. It is also used to investigate the depth and make up of different strata layers. A common use has been to scan areas of land before excavation takes place.

GPR components for the measurement of subsurface conditions usually consist of a control unit, transmitter and receiver antennas. The transmitter and receiver antenna modes on GPR consist of monostatic and bistatic modes. The monostatic mode is when the transmitter and receiver are combined in one antenna, so there is no separation distance whereas the bistatic mode when the two antennas have separation spacing. The application of the GPR method is not only limited to the geophysics case study but also to one of the NDT methods in the geotechnical field. Some researchers utilize the efficacy of GPR methods for geotechnical research ([4], [5], [6], [8], [9]).

A Square Engineering Service is consultant and construction located in Batam, required soil investigation at location of SPBG Gagas Batam. One of those investigation is to measure the depth of spun pile which support the construction of storage tank and its machines. Two method was implemented for this application on the project namely points identification (time domain) and continuous identification (distance domain). Whereas the continuous identification is method of collecting data with moving GPR along the line that has been marked. The statement method of the first method as follows; (i) Identifying location of spun pile, (ii) Marking the lines and points for GPR collection data, (iii) Calibrating the GRP, (iv) Positioning the GPR at first start and collecting the data, (v) Moving the GPR on marking positions and collecting the data again.

2. Methodology

2.1. Electromagnetic Wave Theory

The working principle of GPR tool is by transmitting radar waves (Radio Detection and Ranging) into the target medium by the transmitter antenna and then the wave is reflected back surface and received by the receiver radar antenna (receiver), from the reflection that the various objects can be detected and recorded in radargram. The GPR method is based on the Maxwell equation which is a mathematical formulation for the physical laws underlying all electromagnetic phenomena. The Maxwell equation consists of four field equations, each of which can be viewed as the relationship between the source distribution field (charge or current) in question. [10] Through mathematical manipulation using the above equations we will find Helmholtz equation for electric field strength E which has the form:

$$\Delta E - \sigma\mu_0\mu_r\frac{\partial E}{\partial t} - \varepsilon_0\varepsilon_r\mu_0\mu_r\frac{\partial^2 E}{\partial t^2} = 0 \tag{1}$$

Where, σ is Conductivity (Siemens/m), ε is Medium permittivity (Farad/m); $\varepsilon = \varepsilon_0\varepsilon_r$, ε_r is Medium relative permittivity, ε_0 is Vacuum space permeability = 8.885 x 10^{-2} (Farad/m), μ is Magnetic medium permeability, μ_r is Magnetic medium relative permeability and μ_0 is Magnetic permeability in vacuum space = 4μ x 10^{-7} (Henry/m). From the equations above, we will find 2 equations describing the propagation of electromagnetic waves in the medium, i.e. velocity v and attenuation coefficient α or skin depth τ:

$$v = \frac{\omega}{\beta} = \frac{C}{\sqrt{\frac{\mu r\, \varepsilon r}{2}\sqrt{1+\left(\frac{\sigma}{\varepsilon_0\varepsilon r\omega}\right)2+1}}} \tag{2}$$

$$\alpha = \frac{\omega}{C} = \frac{C}{\sqrt{\frac{\mu r\, \varepsilon r}{2}\sqrt{1+\left(\frac{\sigma}{\varepsilon_0\varepsilon r\omega}\right)2-1}}} \tag{3}$$

$$\tau = \frac{1}{\alpha} = \frac{C}{\sqrt{\frac{\mu r\, \varepsilon r}{2}\sqrt{1+\left(\frac{\sigma}{\varepsilon_0\varepsilon r\omega}\right)2-1}}} \tag{4}$$

Electromagnetic properties include electrical properties and magnetism properties. The electrical properties are the permittivity ($\varepsilon = \varepsilon_0\varepsilon_r$) and the conductivity σ, whereas the magnetized properties are magnetic permeability $\mu(\mu = \mu_0\mu_r)$. Conductivity is the opposite of resistivity $\rho\left(\sigma = {}^{1}/_{\rho}\right)$.

2.2. *GPR Method*

The GPR working mechanism and radargram recording example are depicted in The function of these components are as control unit, control unit serves to generate trigger signals simultaneously to the transmitter and receiver. These pulses control the transmitter and receiver in generating the waveform of the reflected pulse. The computer will provide complete information on how the procedure should be done. In addition, the control unit will keep track of each position and time. As well as storing raw data in a temporary buffer and when needed can be retrieved and transferred directly to the computer.

The transmitter antenna generates EM wave pulses at a certain frequency according to the antenna characteristics. This unit produces electromagnetic energy and sends it to the surrounding area to be observed. The energy in the form of this pulse is transferred to the antenna part, then is transformed and amplified depending on the particular frequency used. The third is receiver. Convert the received signal of the antenna to an integer value form. Each scan will be displayed on the monitor screen called radargram, as a two-way travel time function, i.e. the travel time of the EM wave radiating from the transmitter-target-receiver.

The transmitter and receiver antenna are a transducer that converts electric current to antenna metal elements that transmit electromagnetic waves to propagate to the material. The antenna radiates electromagnetic energy when there is a change of current acceleration on the antenna. The GPR system is digitally controlled and data is recorded post-survey processing and display. Digital controls and GPR system display sections Comprises micro-processor, memory and storage media for storing field measurement data. A micro - computer and standard operating system are used to control the measurement process, store data, and set user defined interfaces.

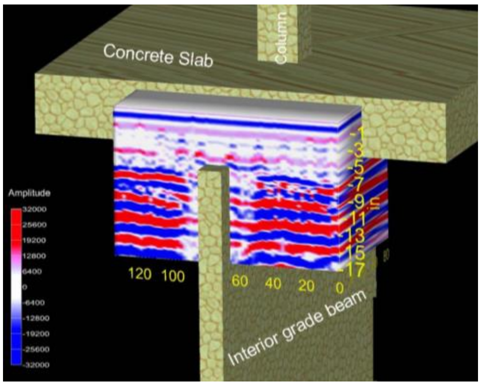

Figure 6. 3D GPR Model of Interior Grade Beam [7]

High-frequency radar signals will produce higher resolution with limited depth, otherwise low-frequency radar signals will result in deep depth penetration but low resolution [1]. The frequency of emitted radar waves can be adjusted by replacing the antenna. The dimensions of the antenna vary with the frequency of the radar wave, for example a 1 GHz antenna is 30 cm in size while the 25 MHz antenna has a length of 6 m [2].

3. Results and Discussion

Photo 1 and 2 show collecting data using GPR with frequency of 1 Ghz and 100 Mhz respectively. The reading was identified as point tracking versus the time and depth. Photo 3 shows collecting data using GRP with frequency of 100 Mhz outside location of pile as comparison with data collection in the center of spun pile. Photo 4 and 5 show collecting data using GPR with frequency of 1 Hhz for tracking lines of 201 and 202 respectively.

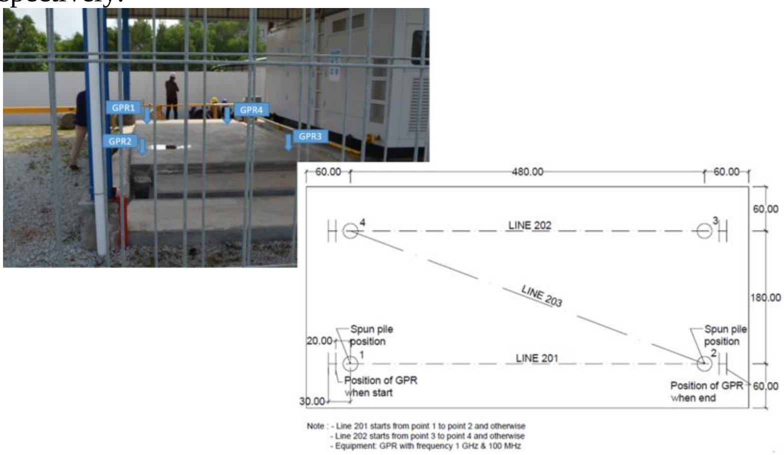

Figure 7. Gas station area and sketch GPR survey at SPBG Gagas Batam

The line 201 shows continuous reading in collecting data which cross two center of two spun piles (GRP 1 and 2). Whereas the line 202 shows continuous reading in collecting data which cross two center of two spun piles (GPR 3 and 4). Fig. (8a, 8c) shows the relationship between amplitude and depth of GPR 1 and 4 in time series using GPR with antenna of 100 MHz at area 1.

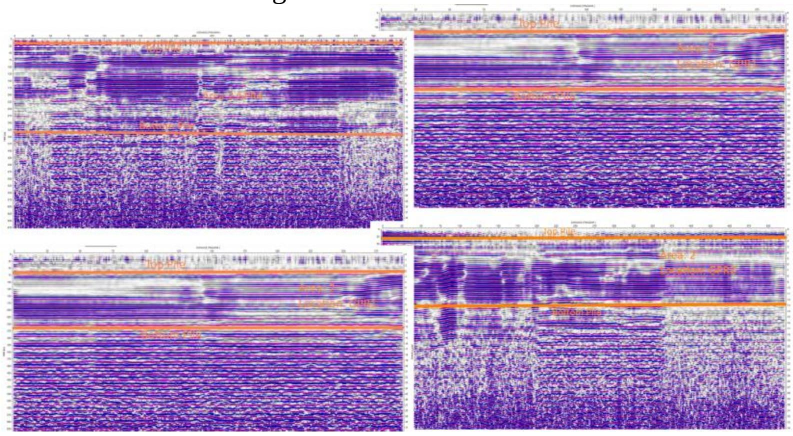

Figure 8. The result of GPR processing for spun pile detection at gas storage area-2

Fig. (8b) shows image on the center of Pile 102 where concrete layer rest until 20 m depth from ground. Below the 20 m depth, the image shows soil layer. On the other hand, Fig. (8d) shows image outside the pile (GPR 4). It shows that at the depth from 0 to 1 m, the concrete layer was found. Below depth of 1 m, the image only shows amplitude of soil layer.

Figure 9 shows result from other spun pile spot still in the area 1 (GPR 2). It shows that bottom spun pile rest on the depth of 16 m below ground level. Below this level, the image shows amplitude of soil layer. Fig. 13 and Fig.14 show the relationship between amplitude and depth of GPR 1 and GPR 2 respectively in time series using.

GPR with antenna of 100 MHz at area 2. Concrete slab lays from depth of 0 to 1 m. From this image, depth of the spun pile rested on 13 m from ground level. Below this level, the image shows amplitude of soil layer. From this image, depth of the spun pile rested on 20 m from ground level. Below this level, the image shows amplitude of soil layer. From this image, depth of the spun pile rested on 17 m from ground level. Below this level, the image shows amplitude of soil layer. The image shows amplitude for layer of concrete which smother compared with amplitude of soil which a bit disturbed rough amplitude.

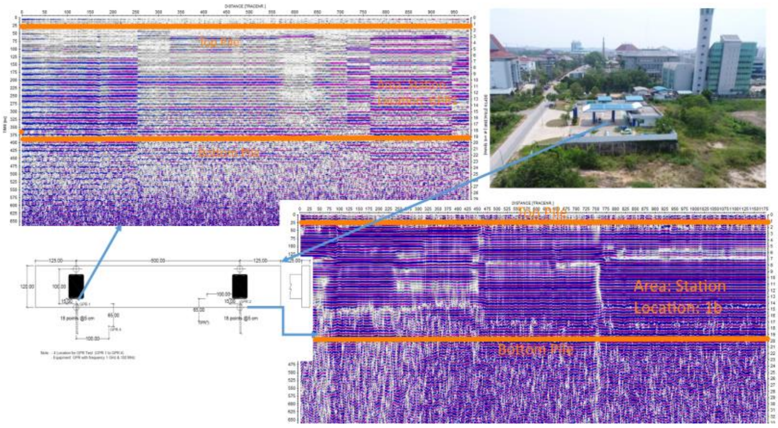

Figure 9. The result of GPR processing for spun pile detection at gas station area-1

4. Conclusions

Based on our study, we can summarize the depth of spun pile in the area 1, which consisted of two locations, showed that piles rested on 16 m and 20 m below ground. The area 2 which consisted of four spun piles showed the depth of those piles were 13 m, 13 m, 20 m and 17 m for GPR 1,2, 3 and 4 respectively. These results were to confirm as built drawing that showed that the depth of all piles rested on 20 m below ground.

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