SUBSURFACE INVESTIGATION USING NON-DESTRUCTIVE TESTING (NDT) METHODS

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ABSTRACT

This paper will review several Non-Destructive Testing (NDT) method that probably suitable for performing a subsurface investigation. Subsurface investigation research and studies has been carried out to collect the information about physical properties and characteristics of the subsoil material and what is lying underneath the ground using several NDT method such as Ground Penetrating Radar, Ground Electromagnetic Measurement (GEM), Nuclear Density Gauge, Pipe and Cable Locator (PCL), and lastly a Metal Detector.

ABSTRAK

Kertas kerja ini akan mengkaji beberapa kaedah Ujian Tidak Memusnahkan (NDT) yang mungkin sesuai untuk melakukan penyelidikan bawah permukaan. Penyelidikan dan kajian penyelidikan di bawah permukaan telah dilakukan untuk mengumpulkan maklumat mengenai sifat fizikal dan ciri bahan tanah dan apa yang terbentang di bawah tanah menggunakan beberapa kaedah NDT seperti Radar Penembusan Tanah, Pengukuran Elektromagnetik Tanah (GEM), Tolok Ketumpatan Nuklear, Pencari Paip dan Kabel (PCL), dan terakhir adalah Pengesan Logam.

Keywords: Ground Penetrating Radar, Highway evaluation, Non-destructive method

INTRODUCTION

Non-Destructive Testing (NDT), Non-Destructive Evaluation (NDE) and Non-Destructive Inspection (NDI) are the terms used in this connection to represent the techniques that are based on the application of physical principles employed for the purpose of determining the characteristics of materials or components or systems and for detecting and assessing the inhomogeneities and harmful defects without impairing the usefulness of such materials or components or systems.

According to the Common Ground Alliance (CGA), over the last 20 years improperly located or not located subsurface utilities have caused $1.7 billion in damages and resulted in 1,906 injuries with 421 fatalities. Most––if not all––of these losses could have been avoided through a detailed site investigation using multiple technologies and highly trained personnel.

Subsurface utility mapping is an important technique for extracting subsurface information about buried utilities such as electric and telephone cables, water and sewage pipes and other infrastructure (different types of utility networks including electricity cables, gas pipelines, fiber optic cables, water and sanitary sewer pipelines and street lighting circuits).

Furthermore, the growing demand for increased and enhanced utility services has resulted in extensive construction of new utility installations as well as maintenance repair of existing systems.

Information about shallow subsurface utility infrastructures is a key issue affecting resident safety and the progress of development [1,7]. Developments in big cities required to upgrades to the subsurface utilities beneath the road surface, but it is often difficult to locate the position of these facilities directly from the surface. Moreover, many failed excavation processes are reported worldwide, sometimes causing interruptions in the supply of utility services or hazardous pipeline explosions and other serious accidents [2,4,6]. Non-destructive, fast and accurate techniques to acquire knowledge of shallow structures are therefore vital for city planning and hazard excavation prevention [3].

SUBSURFACE INVESTIGATION

Good knowledge about a site is very important in the safe and economic development of the site. A thorough investigation of the site is, therefore, an essential preliminary to the construction of any civil engineering works. As a matter of fact, in many countries, public building officials usually require soil data together with the recommendations of the geotechnical consultant prior to issuance of a building permit. Not only for civil engineering works, the maintenance comes after that also required some knowledge so there is no unnecessary digging occur and spoil the structure and condition of the ground.

In the subsurface investigation, the main objective is to characterize the subsurface conditions which to determine if the soils beneath a facility exhibit properties that ensure the facility will remain stable under static and seismic conditions during construction and operation and after it is closed. Characteristics to be measured include, but are not limited to, shear strength, liquefaction potential, compressibility, phreatic surface elevations, piezometric surface elevations, and the water content of the soil materials.

NDT METHOD

Ground Penetrating Radar (GPR)

Generally, ground-penetrating radar (GPR) is a non-destructive system that utilizes high-frequency electromagnetic waves to explore the near-subsurface features in a continuous, fast and relatively high-resolution manner. Commonly, the GPR system consists of a control unit, antenna (with different frequency bands). The antenna transmits specific electromagnetic pulses into the subsurface and then receives the reflected signals from the subsurface targets. Electromagnetic wave propagation in the subsurface is controlled by the physical properties of the medium [7]. The dielectric constant (e), is the most important subsurface property controlling the signal propagation velocity, the vertical and horizontal resolution and the reflection coefficient. The dielectric constant is simply defined as the relative measure of the dielectric permittivity of the medium to the dielectric permittivity of a vacuum.

In the civil engineering field, GPR is currently used for inspection, monitoring and design purposes. The detection of utilities and buried objects, as well as the surveying of road pavements, bridge decks, tunnels, and the measurement of moisture content in natural soils and manmade materials, are the main applications. In addition, interesting examples concerning the use of the GPR in structural, geotechnical and railway engineering have to be mentioned.

Before, there are studied called SIM, Subsurface Investigation Methodology. Which this study is a guide to using the locating technologies of an electromagnetic receiver and ground-penetrating radar combined with a proven training approach to achieve a very low investigation error rate. SIM does not involve the practice of geophysics, geology, land surveying or engineering. SIM contains three primary elements, the human asset, technology asset and methods applied in the field. The best site results are accomplished when the experienced, trained field technician can utilize multiple technologies in a comparative analysis of results from each technology. Thus, a highly skilled technician can locate the same target using multiple technologies resulting in confirmation of findings and results.

Their result is this high level of precision in a SIM investigation is possible due to the use of GPR and an electromagnetic receiver. However, if one of the technologies suffers inconclusive results based on site interference or an unfavourable soil type, one technology may need to be accepted as providing the only reliable results [5].

When GPR is used to scan concrete for embedments the control unit will image the targets inside of the slab. The targets are displayed for the technician to mark out. System adjustment is automatic. Accuracy and precision are a function of the manufacturer's software.

Figure 1: Field Technician marking and schematic diagram

In addition to GPR being used to image steel reinforcement in the slab, SIM also calls for a passive sweep of the pipe locator/EM receiver to confirm the area has no energized conduits. GPR is capable of imaging a plastic pipe in concrete but cannot determine if the conduit is energized [5].

This paper concludes with the investment in developing people and using the best technologies to gain the best results. Thus, GPR used in this study can be considered as one of the suitable technology to perform subsurface investigation or study.

Ground Electromagnetic Measurement (GEM)

There is a study where a GEM-2 has been tested at several environmental sites for subsurface investigation [9]. A hand-held, digital, multi-frequency sensor based on an earlier, similar helicopter-towed sensor, GEM-2 operates in a frequency range of 90 Hz to 22 kHz and can transmit an arbitrary waveform containing multiple frequencies. The unit is capable of transmitting and receiving any digitally-synthesized waveform by means of the pulse-width modulation technique. Owing to the arbitrary nature of its broadcast waveform and high-speed digitization, the sensor can operate either in a frequency-domain mode or in a time-domain mode. Depth of exploration for a given earth medium is determined by the operating frequency. Therefore, measuring the earth response at multiple frequencies is equivalent to measuring the earth response from multiple depths. Hence, such data can be used to image a 3-D distribution of subsurface objects. Results from several environmental sites indicate that the multifrequency data from GEM-2 is far superior in characterizing buried, metallic and non-metallic targets to data from conventional single-frequency sensors.

From their conclusion, of the many geophysical sensors, the EM method provides significant advantages for shallow environmental characterization. Unlike seismic or ground-penetrating radar methods that involve heavy logistics and labour-intensive fieldwork, GEM-2 requires only a single operator, does not touch the earth (thus, is less intrusive), and can operate at stand-off distance. An instrument like GEM-2 is ideal for many environmental and geotechnical applications including mapping underground storage tanks, landfill and trench boundaries, certain contaminant plumes, and buried ordnance. In addition, GEM-2 has applications for finding shallow orebodies for the mineral exploration industry. With the advent of digital, multifrequency data, it opened a new dimension in data quality and quantity for imaging and characterizing buried subsurface features [9].

Later on, there are studied performed by Yaccub and Brabham where they discuss one of the contaminated sites at the Barry Dock which has the multiple sources of the contamination using the integrated geophysical and geochemical technique [10], which geophysical technique used was GEM-2.

In this study, The GEM-2 is an active method that uses an electromagnetic (EM) signal to detect variations in subsurface electrical conductivity. These currents result in a secondary electromagnetic field that is measured together with the originally transmitted signal, using a receiver coil on the EM instrument (Figure 2). The secondary field is then separated into two orthogonal components, the real and imaginary (quadrature) components, representing respectively the vector components of the field in phase and 90 degrees out of phase with the primary. The quadrature component provides a measure of the apparent ground conductivity whilst the real (in-phase) component is responsive to buried metallic objects. Figure 3 shows the field setup for the GEM and GPS.

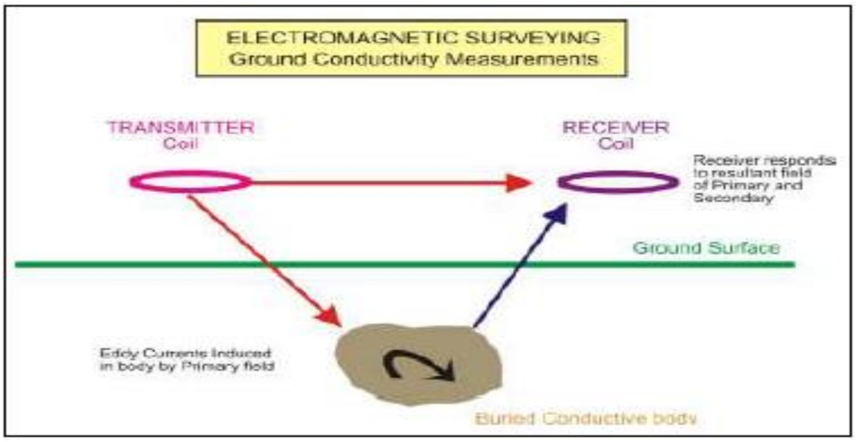

Figure 2: The schematic diagram showing the principle of the EM technique for site investigation [10]

Figure 3: Showing the setup of GEM-2 and the GPS device [10]

From this study, Using the Gem-2 instrument, a survey of five different depths of electrical conductivity layers has been obtained [10].

We can conclude here GEM also suitable and useful in the subsurface investigation, especially for shallow subsurface.

Nuclear Density Gauge

As shown in Figure 1, a nuclear density gauge measures in-place Hot Mix Asphalt (HMA) density using gamma radiation are commonly used because it is a non-destructive method and able to provide a reasonably accurate estimation of the in-situ asphalt mixture density. Gauge usually contain a small gamma source (about 10 mCi) such as Cesium-137 on the end of a retractable rod. Figure (4) shows the thin lift nuclear density gauge.

Figure 4: Nuclear Density Gauge

Gamma rays are emitted from the source and interact with electrons in the pavement through absorption, Compton scattering, and the photoelectric effect. A Geiger-Mueller detector counts gamma rays that reach it from the source. Pavement density is then correlated to the number of gamma rays received by the detector. Nuclear density gauges are usually operated in two modes which are direct transmission and backscatter. Direct transmission is the retractable rod is lowered into the mat through a pre-drilled hole. The source emitted gamma rays, which then interact with electrons in the material and lose energy or are scattered away from the detector are not counted. Backscatter, the retractable rod is lower so that it is even with the detector but still within the instrument. The source emits gamma rays, which then interact with electrons in the material and lose energy and or are scattered. Gamma rays that are scattered towards the detector are counted.

The advantages of using Nuclear Density Gauge are it is portable. Most nuclear gauges allow both one and four-minute readings. These are much quicker than typical densities obtained from cores which could take from several days to several weeks. It also requires only a small penetration into the finished mat approximately 20 mm in diameter and about 50 mm deep [8].

Pipe and Cable Locator (PCL)

Pipe and cable locator are used for tracing utility lines and metallic pipes, and clearing excavation and drilling locations. These utility locators consist of two main parts, a transmitter and a receiver. The transmitter emits a frequency selected by the operator that induces onto nearby pipes and cables. The receiver detects these radio frequencies, and the operator is able to accurately locate and trace the pipes and cables.

This method could help in the subsurface investigation in mapping underground utilities. Underground utility locating requires the use of a few different methods in order to accurately mark buried lines. Pipe and cable locator can determine the location and depth of almost all types of underground utilities and it is portable and easy to handle. This equipment works in almost all soil conditions. However, this equipment cannot locate non-metallic or non-conductive utilities unless there is access to snake them. The target signal can often “bleed” onto non-target lines. Multiple lines laid next to one another cannot be resolved into multiple targets. In some industrial setting, there is too much background signal interference to produce a reliable active signal [11].

Metal Detector

A metal detector contains a coil of wire (wrapped around the circular head at the end of the handle) known as the transmitter coil. When electricity flows through the coil, a magnetic field is created all around it. As you sweep the detector over the ground, you make the magnetic field move around too. If you move the detector over a metal object, the moving magnetic field affects the atoms inside the metal. In fact, it changes the way the electrons (tiny particles "orbiting" around those atoms) move. Now if we have a changing magnetic field in the metal, the ghost of James Clerk Maxwell tells us we must also have an electric current moving in there too. In other words, the metal detector creates (or "induces") some electrical activity in the metal. But then

Maxwell tells us something else interesting too: if we have electricity moving in a piece of metal, it must create some magnetism as well. So, when you move a metal detector over a piece of metal, the magnetic field coming from the detector causes another magnetic field to appear around the metal.

It's this second magnetic field, around the metal, that the detector picks up. The metal detector has a second coil of wire in its head (known as the receiver coil) that are connected to a circuit containing a loudspeaker. As you move the detector about over the piece of metal, the magnetic field produced by the metal cuts through the coil. Now if you move a piece of metal through a magnetic field, you make electricity flow through it (remember, that's how a generator works). So, as you move the detector over the metal, electricity flows through the receiver coil, making the loudspeaker click or beep. This indicates the detector is found something. The closer you move the transmitter coil to the piece of metal, the stronger the magnetic field the transmitter coil creates in it, the stronger the magnetic field the metal creates in the receiver coil, the more current that flows in the loudspeaker, and the louder the noise [12].

Generally speaking, metal detectors work at a maximum depth of about 20–50cm (8–20in).

- The size, shape, and type of the buried metal object: bigger things are easier to locate at depth than small ones.
- The orientation of the object: objects buried flat are generally easier to find than ones buried with their ends facing downward, partly because that creates a bigger target area but also because it makes the buried object more effective at sending its signal back to the detector.
- The age of the object: things that have been buried a long time are more likely to have oxidized or corroded, making them harder to find.
- The nature of the surrounding soil or sand you're searching.
- The type of detector and the frequency (or frequencies) it's using.

CONCLUSION

NDT technique can be applied for subsurface investigation. This because, either then it could detect utilities underground faster and efficiently, NDT method also has a lot of benefits such reductions in cost and reduce accidental damage, provide benefits for the provider, customer and the general public and most crucial are environmentally friendly. This proves when NDT method can be assigned not only at finishing product but also during various stages of manufacturing. From the review of previous researches and studies, all method mentioned are preferably used together for more accurate and desirable result could be obtained.

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