Ground Penetrating Radar Applications

[Excerpts from http://www.malags.com/home and Application of Ground Penetrating Radar to Civil and Geotechnical Engineering" by Richard J. Yelf, http://www.emph.com.ua/18/pdf/yelf_01.pdf]

1.0 Introduction

Ground Penetrating Radar (GPR) is a safe, non-destructive and non-invasive imaging technique that can be effectively used for advanced inspection of composite structures and for diagnostics affecting the whole life-cycle of civil engineering works.

GPR provides high resolution images of structures and subsurface through wide-band electromagnetic waves.

2.0 Application

GPR is an effective tool for subsurface inspection and quality control on engineering construction projects. The numerous applications of GPR include the following:

- Mapping pipes (including PVC pipes), cables and other buried objects.
- Continuous inspection of layers in road pavements and airport runways. Due to the rapid data acquisition rates, it can be used at highway speeds to monitor changes in subgrade and asphalt pavement layers.
- Mapping cavities or voids beneath road pavements, runways or behind tunnel linings.
- To monitor the condition of railway ballast, and detect zones of clay fouling leading to track instability.
- Detailed inspection of concrete structures, location of steel reinforcing bars and pre- and post-tensioned stressing ducts. GPR can be used in 3-D mode to map multiple layers of steel in buildings, in order to avoid damage when drilling through such structures.
- Inspection and quality control of pre-cast concrete structures, such as bridge deck beams.
- Detection of zones of honeycombing, voiding and chloride attack in concrete.
- Mapping zones of deterioration and delamination on bridge decks.

Besides these applications it can be employed for geotechnical foundation investigations, mapping geological information, hydrogeological studies, investigation of active geological fault zones, archaeological studies, forensic studies, as well as for several other purposes.

The key advantages in subsurface investigations: Locates metallic as well as non-metallic utilities – Easy user interface – Portable – Low cost GPR solution for the utility locate professionals – Fast – precise locating.

Some of these applications in civil engineering field along with their specific advantages have been discussed briefly:

2.1 Utility Locating

The utility buried services are assets that need to be protected, whilst to the construction industry they can represent a major hazard. Precise and reliable information about the presence, location and depth of these metallic and non-metallic utilities and other buried infrastructure is therefore essential and can be easily located by a GPR survey (Fig. 1).

Fig. 1: GPR survey for locating utility services on a road

2.2 Utility Mapping

To locate and map utilities before any excavation begins is a concern to everyone involved. GPR is a beneficial tool due to its capability to locate both metallic and non-metallic utilities. When using GPR, both position and depth can be marked out on site and later also visualized into 3D reports (Fig. 2).

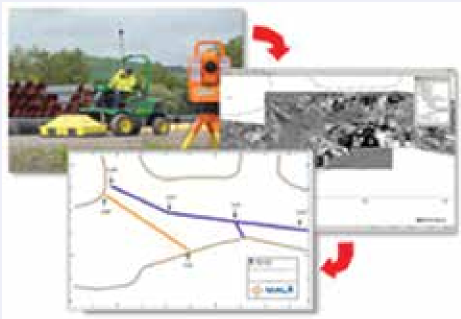

Fig. 2: GPR survey for utility mapping and their location mapping (bottom drawing) along with their 3D view of the location (top right)

2.3 Buried Void Detection

Buried voids are a hazard, both to engineers and the general public. They can impede construction operations, undermine building foundations and be the cause of destructive ground subsidence. Problems associated with hidden voids come in many forms. Naturally formed cavities and sinkholes in karstic limestone terrain, unknown basements and culverts, abandoned wells and mineshafts, all of which present possesses serious hazards can be detected by a GPR survey (Fig. 3).

Fig. 3: GPR survey for detecting buried voids below the ground surface

2.4 Underground Storage Tank (UST) Location

GPR can locate Underground Storage Tanks (UST) and any associated underground piping. This non-destructive inspection and geophysical survey can determine the location and depth of a UST or provide the location of a former tank vault (Fig.4).

Fig. 4: GPR survey for detecting underground storage tank

2.5 Tunnel Assessment Surveys

To investigate possible quality deterioration within and above tunnels, GPR has proven to be an effective tool. When using GPR the condition of lining, location of hidden construction shafts, voids and delamination (Fig. 5) can be made both safe and cost-effective.

The key advantages such as: Ground penetrating radar is the most well-established technique because of its rapid data acquisition and versatility.

Fig. 5: GPR survey for detecting defects in a tunnel

2.6 Post- Pre-tension Cable Location

The imaging system allows scanning concrete structure simply and safely and presents data clearly for real-time and in-the-box data acquisition, display and analysis.

Key advantages: GPR is a real-time NDT technique that quickly locates the position of post tension cables (Fig.6), rebar, and electrical conduits embedded in concrete, eliminating dangers associated with cutting or drilling and the high costs required for their repair if cut or damaged.

Fig. 6: GPR survey for locating post-pre- tension cables

2.7 Rebar Location

Ground Penetrating Radar is an effective tool for detection of embedded rebar in concrete (Fig. 7) floors and walls. GPR can detect the depth and orientation of electrical conduit, utility cables and water lines.

Key advantages: Ground Penetrating Radar (GPR) is a valuable tool in commercial construction. It's a safe, non-destructive method for detecting hidden elements in concrete.

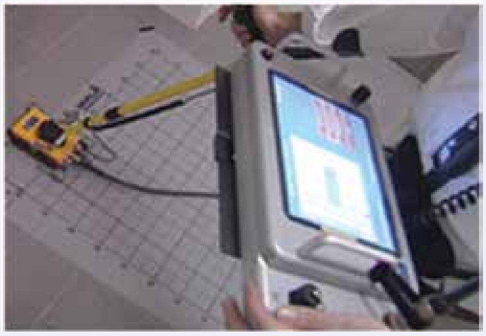

Fig. 7: GPR survey for locating embedded rebars in concrete

2.8 In-Slab Conduit Location

GPR is used to locate electrical conduits embedded in or below slabs (Fig. 8) prior to saw cutting or core drilling, thereby minimizing the risk of electrocution to the operator and reducing the risk of building systems shutdowns.

Key advantages: Accurate target location within a concrete slab on-grade, wall, or supported slab can be achieved more quickly, safely, and economically with GPR instead of other existing techniques.

Fig. 8: GPR survey for locating embedded electrical conduits in concrete

2.9 Void Detection in Concrete

The presence of voids in concrete which impacts the structural stability can be detected by a GPR survey (Fig.9). Key advantages such as: GPR is superior to radiography (X-Ray—the only other NDT technique capable of "seeing" through a structure) in speed, efficiency, and cost-effectiveness.

Fig. 9: GPR survey for detecting voids inside concrete

2.10 Slab Thickness Measurement

GPR can determine and record the slab thickness (Fig.10) for both slab-on-grade and suspended slabs, determine rebar depth to measure concrete cover in slabs, beams, and columns.

Fig. 10: GPR survey being used for measuring the depth of RCC slab

Key advantages: GPR is a safer and less disruptive than X-Raying. GPR equipment is safe to use around people without any safety constraints or setup requirements. Because of these features, interruption of operations can be eliminated or minimized.

2.11 Concrete Evaluation

GPR is a great tool for concrete evaluation and to determine concrete deterioration (Fig.11), slab thickness, rebar spacing, bar elevation, and amount of concrete cover over the rebar.

The key advantages such as: – A fully integrated GPR solution for concrete imaging, – Collecting data three different measurement modes, – Providing the highest resolution and detail of data, – Combines both GPR and EM technology simultaneously, – Multiple antenna frequencies.

Fig. 11: GPR survey being used to evaluate the deterioration of RCC slab

2.12 Road Evaluation

Pavement engineers use ground penetrating radar to determine physical properties and characteristics of the pavement (Fig.12) or subgrade. GPR helps engineers to determine the thickness of a pavement structure without resorting to excavation. A test method and the procedure are given in ASTM D 4748 for the non-destructive determination of thickness of bound pavement layers using short-pulse radar. This test method permits accurate and non-destructive thickness determination of bound pavement layers. This test method is widely applicable as a pavement system assessment technique.

Fig. 12: GPR survey being used to evaluate the characteristics of road pavement

Key advantages: A new breakthrough in GPR infrastructure technology for evaluating pavement, base and sub-base thicknesses. It is an extremely portable, user-friendly and cost-effective ground coupled platform that provides unmatched performance.

2.13 Bridge Deck Evaluation

The GPR technology can be used without the costly removal of the asphalt overlay in bridge deck (Fig.13). Quantitative data results can be compared from one year to the next. In addition construction companies that have been contracted to repair bridges can also use GPR to identify specific areas in need of repair. This allows companies to repair specific problem areas with bridges. Ease of repair will help in the problematic funding issues currently plaguing many DOT's.

Fig. 13: GPR survey can be used to evaluate the condition of bridge deck

2.14 Railway Ballast Evaluation

Ground Penetrating Radar is an excellent non-destructive tool to inspect miles of railroad track (Fig.14) in a matter of minutes. It is capable of looking into the ground and quickly and accurately analyzing miles of data to determine where undercutting procedures should be focused.

Fig. 14: GPR survey being used to evaluate the railway ballast

2.15 Runway Evaluation

Airport managers are now expending significant efforts to ensure that operating pavements are adequately engineered, or are reconstructed to cope with such demands. It is vital to detect at an early stage, defects such as sub-surface voids, rocking pavement slabs and de-bonding of materials and layers within the pavement and its sub-base. As increased traffic volumes and growth in aircraft movements restrict access to runways and other areas, rapid yet comprehensive survey techniques that avoid disturbing existing paved surfaces are becoming extremely valuable.

GPR survey can be used to evaluate the condition of runway pavement of an airport (Fig. 15).

Fig. 15: GPR survey being used to evaluate the runway pavement of airport

3.0 Types of GPR Products

IDS GPR products and services for the Civil Engineering industry are based on two different kinds of technologies that meet the varying needs and necessities of the customers. The first category is on-contact application such as Aladdin, RIS Hi-BrigHT, RIS One & RIS Plus where these GPR systems can use the combination of multiple frequency antennas to provide faster and more accurate inspections. The 2nd category is remote based application known as Interferometric Radar solution such as IBIS-FL and IBIS-FS and these radars can be operated remotely and there is no need for direct contact with the target being monitored. This technology allows the remote monitoring of movements of structures such as dams, bridges, towers, buildings with sub-millimeter accuracy.

4.0 Limitations

- GPR does not work well in saline conditions, in high-conductivity media and through dense clays which limit signal penetration.
- Highly trained personnel needed for application of this instrument.
- The detail calibration procedures have not been standardized.

5.0 Conclusion

GPR is a powerful diagnostic tool for civil and geotechnical engineering. To obtain the best results it must be applied correctly by properly trained personnel, who are familiar, both with the physical principles of the method and also of its limitations. The resultant data should be interpreted carefully, combining the relevant information of above ground and subsurface features. Calibration of the results using boreholes or test pits or concrete sample as applicable must be recommended.