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Subsurface Utility Engineering – A Cost Effective Method To Investigate Underground Without Excavation

Dr. Sanjay Rana
Director
PARSAN Overseas (P) Limited

ABSTRACT

Various latest technologies including Trenchless Technology are being used for laying of pipes and cables in India at an increasing rate. The successful use of these technologies, and benefits in terms of speed and least inconvenience to people, are well known. One of the problems being faced, however, is the damage to existing utilities in the process. The rate of such damages is especially high in India due to missing utility records and unavailability of a one-point contact where database of existing utilities is available.

Technological advancement in the fields of GIS, Remote Sensing and Geophysics provide an answer to the problem. Using these techniques it is possible to create accurate maps of the area, with information on underground utilities, to decide on important aspects like alignment, safe depth etc.

Data on soil profile, rock, local heterogeneities and subsurface conditions is also critical for safe and successful execution. There exist various geophysical techniques capable for providing these subsurface data in quick, totally non destructive and economical manner. These advanced technologies can very effectively be used to handle the present day complex problems related to optimum utilization of available resources and infrastructure.

Present paper discussed various tools available for mapping (GIS & Remote Sensing) and non-destructive detection of underground utilities (Ground Penetrating Radar etc.). The paper also provides an overview of various non-destructive geophysical techniques available for underground investigations. Basic principle, application areas, advantages and limitations of various techniques has been presented.

INTRODUCTION

Population explosion and resulting demand of appropriate infrastructure facilities are posing serious challenges for the administrators and planners. Trenchless technology has emerged as a major technique for laying utilities without opening trenches. The data on existing utilities however is of utmost importance to avoid damage to existing utilities and safety of personnel. Effective management and planning requires updated maps and information. Recent developments in the area of Science and Technology have provided powerful tools such as Geographical Information System (GIS), Global Positioning System (GPS), Remote Sensing and Geophysics (including Ground Penetrating Radar). These advanced technologies can very effectively be used to handle the present day complex problems related to optimum utilization of available resources and infrastructure. Today it is possible to create on 1:1000 scale Digital Map using high resolution (one meter) satellite imagery and preparation of GIS database in same scale using State Of The Art GIS technology. Further geophysical tools such as Ground Penetration Radar (GPR) can be used for the accurate mapping of the underground infrastructure facilities (Electrical &

telecommunication cables, pipelines etc.) to be placed on these maps accurately, rather than relying on historical data, which more often than not is incomplete and inaccurate.

Geophysical tools such as Ground Penetration Radar (GPR), Seismic Refraction, Seismic Reflection, Electrical Imaging etc., can be used for the accurate mapping of the underground infrastructure facilities (Electrical & telecommunication cables, pipelines etc.), soil-rock interface, geological identification of soil, water table mapping, dimension of a sub stratum, elastic properties of the medium, geometry of various layers and other subsurface features.

These geophysical techniques also are used for various applications in the field of civil engineering, mining, marine, infrastructure and natural resources. The techniques are totally non-destructive in nature and investigations are completed in a very short span of time.

The subsurface information like soil properties, depth to rock, hardness of rock, water table etc., are also of great importance before execution of these projects to save on over run costs and litigations. Geophysical tools like seismic refraction, Electrical Imaging etc., provide detailed insight into subsurface conditions enabling accurate planning and anticipation of difficulties. The non-destructive nature of these techniques make them faster to apply and cost effective.

WHY USE GEOPHYSICS?

Geophysical surveys should be a routine part of most site investigations and often represent the only way of getting total coverage for what lies within the subsurface. The points below outline the clear advantages of using geophysical services...

- **Low Cost** – Geophysical investigations often cost less than a fraction of traditional investigation cost. The value of the data acquired combined with the reduced costs from being able to optimally design an invasive investigation easily exceed the original outlay - not to mention the legal implications of failing to use all the common tools for site investigation available.

- **Rapid Coverage** - Up to 2 hectares of land can be typically surveyed in one day. If surveys are carried out along profiles, then up to 5km can be acquired depending on method
- **No exposure to buried hazards** - because geophysics is non-invasive, operators or people on site are not exposed to buried hazards.

- **Minimal Surface Disturbance** - again, since little or no ground penetration is required, the surface is not disrupted which is ideal in urban areas, highways or landscaped areas.

- **Easy to Integrate** – Geophysical Consultancy firms take special care to present their findings in a format that can be easily understood and integrated by non-geophysical specialists. Thus data is presented as scale engineering sections or annotated plans.

- **Integrated Capability** – There are various geophysical tools available, which enable geophysicists to arrive on site and select the most suitable method to use.

What if it doesn't work?

Some customers may be wary of using geophysics - either because they have had a bad experience in the past or they feel they don't want to take any risks. Consequently many geophysical firms around the world undertake to offer a competitive price that fits in with a site investigation budget and if, due to various limiting factors on the survey, the data is not useful the firm charges a reduced fee and issue a short report explaining why the application was unsuitable. This approach has proven very popular in the past with many innovative customers who use geophysics routinely to investigate the subsurface.

WHAT IS GIS?

In the strictest sense a GIS is a computer based program capable of assembling, storing, manipulating and displaying geographically referenced information i.e.; features existing on the ground and their attribute information. Maps and attribute data are stored systematically in this system so that GIS makes it possible to perform following complex analyses:

- Information retrieval: Any required specific information could be retrieved at will from the huge database using simple query operations.
- Overlay: Relationship between various layers (administrative boundaries, buildings, road, rail, and other infra-structural facilities) can be determined.
- Data output: A critical component of a GIS is its ability to produce maps on the screen or paper, which convey the analysis results for the planners and administrators to take decisions. Using GIS planners and decision-makers can map quantities, densities, find what is inside, what is nearby and change detection.

REMOTE SENSING

National Remote Sensing Agency (NRSA) is involved in the Aerial surveys using variety of satellites for more than last 25 years. NRSA is continuously receiving satellite data on various resolutions. IRS-1C PAN and LISS-III data has been used extensively by the planners and decision-makers in the past for micro level planning.

Recently NRSA has started selling 1-meter resolution satellite data of Space Imaging (IKONOS). This high-resolution satellite data has added the higher degree of accuracy in the mapping. Small features such as road dividers, buildings, ponds etc. can be identified very easily.

BASE MAPS PREPARATION

Preparation of a reliable basemap is the first step towards data management. Using the tools of GIS and Remote Sensing, base maps can be prepared in a speedy and economical manner:

- Satellite Data of 1-meter resolution (IKONOS) can be purchased from NRSA.
- Satellite images are then registered in the required projection system so that digitized output is achieved in the real ground units.
- Satellite images are digitized in the different layers depending upon the variety of features available on the ground.
- Topology of the various features digitized are created so that actual attribute information of the corresponding feature on the ground can be linked to it.
- Ground surveys are conducted to update the features, which are not visible on the satellite image (Transformers, manholes, electrical poles, telephone poles, etc) and to collect the actual names of the buildings, roads, etc.
- Ground survey data are integrated with the attribute table of the corresponding feature.

SUBSURFACE UTILITY ENGINEERING

Most of Indian cities have an extremely complex network of utilities, typically characteristic of a developing country. The records on existing utilities underground are either simply non-existent or inaccurate. With ever-increasing use of trenchless technology, requiring accurate information on underground utilities, accurate techniques for non-destructive detection of such utilities are extremely important. Poor records, improper notification, and excavation errors all contribute to making subsurface utility breaks an often costly but preventable problem. Subsurface Utility Engineering (SUE) is a discipline dedicated to the determination of the exact location of existing underground facilities. Use of SUE makes sure that utilities are accurately picked up and plotted on site plans. This in turn reduces costs, delays, and public inconvenience. In addition, by eliminating the risk of utility breakage, the project will be safer for both construction personnel and the general public, hence reducing liability concerns. Subsurface Utility Engineering, or SUE is a new discipline that utilizes modern techniques to detect underground utilities in a total non-destructive manner. This process results in a digital map that will identify utilities within the project area.

Indian experiment with trenchless technology has been very encouraging, except for the damages to existing utilities, causing inconveniences and heavy costs. Information obtained from other sources such as municipalities, is rarely accurate enough safe borepath determination. In addition, depth information is almost never available. Most of the information on past utilities has never been documented in systematic manner. SUE contractors on the other hand gather the primary data, and prepare an accurate and precise location map. This not only provides great insight to the subsurface conditions, but eliminates the unknown variables and contingencies designers face everyday.

Various steps involved in data collection for existing utilities consists of various steps, starting from quick reconnaissance to detailed investigations. Various techniques used are:

Historical Utility Records Research

The data collection under this stage is aimed at obtaining basic information on possible locations, congestion and orientation of utilities. Such information is highly inadequate for use by trenchless contractor, but immensely useful for SUE contractor to plan density and orientation of survey lines, choose the right equipment, and plan the survey operations.

Designation

Designation is the process where by the approximate horizontal location of a utility is determined. Following a rough approximation of the general location of facilities provided by Historical records research and visual site assessment, a number of geophysical technologies can be used, selected by applicability, for identifying the horizontal locations of particular utilities.

Induction Utility Locators

Induction utility locators operate by locating either a background signal or by locating a signal introduced into the utility line using a transmitter. There are three sources of background signals that can be located. A utility line can act like a radio antenna, transmitting electromagnetic signals that can be picked up with a receiver. AC power lines have a 50HZ signal associated with them. This signal occurs in all active AC power lines regardless of voltage. Utilities in close proximity to AC power lines or used as grounds may also have a 50HZ signal that can be located with a receiver. A signal can be indirectly induced onto a utility line by placing the transmitter above the line. Through a process of trial and error, the exact above position can be determined. A direct induced signal can be generated using an induction clamp. The inductor clamp induces a signal on specific utilities. This is the preferred method of tracing, where possible. By virtue of the closed loop, there is little chance of interference with the resulting signals. When access can be gained to a conduit, a flexible insulated trace wire can be used. The resulting signal loop can be traced. This is very useful for non-metallic conduits. Finally, these signals can be located horizontally on the surface using a receiver. The receiver is moved across the estimated location of the utility line until the highest signal strength is achieved. This is the approximate horizontal location of the utility. The receiver is then rotated until minimal signal strength is achieved. This will give the approximate orientation of the utility. Vertical depth, however, derived from this equipment is subject to gross error.

Magnetic Locators

Ferrous Metal or Magnetic locators operate by indicating the relative amounts of buried ferrous metals. They have limited application to locating and identifying utility lines but can be very useful for locating underground storage tanks (UST's) and buried manhole covers or other subsurface objects with a large ferrous metal content.

Electromagnetic Surveys

Electromagnetic survey equipment is used to locate metallic utilities. This method pulses the ground and records the signal retransmitted back to the unit from subsurface metal. Particularly useful for locating metal pipelines and conduit, this device also can help locate other subsurface objects such as UST’s, buried foundations (that contain structural steel), and pilings and pile caps (that also contain steel).

Ground Penetrating Radar

Ground Penetrating Radar (GPR) is an electromagnetic method that detects interfaces between subsurface materials with differing dielectric constants (a term that describes an electrical parameter of a material). The GPR system consists of an antenna, which houses the transmitter and receiver; and a profiling recorder, which processes the received signal and produces a graphic display of the data. The transmitter radiates repetitive short-duration EM signals into the earth from an antenna moving across the ground surface. Electromagnetic waves are reflected back to the receiver by interfaces between materials with differing dielectric constants. The intensity of the reflected signal is a function of the contrast in the dielectric constant at the interface, the conductivity of the material, which the wave is traveling through, and the frequency of the signal. Subsurface features which may cause such reflections are: 1) natural geologic conditions such as changes in sediment composition, bedding and cementation horizons, voids, and water content; or 2) man-introduced materials or changes to the subsurface such as soil backfill, buried debris, tanks, pipelines, and utilities. The profiling recorder receives the signal from the antennae and produces a continuous cross section of the subsurface interface reflections, referred to as reflectors.

Depth of investigation of the GPR signal is highly site specific, and is limited by signal attenuation (absorption) of the subsurface materials. Signal attenuation is dependent upon the electrical conductivity of the subsurface materials. Signal attenuation is greatest in materials with relatively high electrical conductivity such as clays and brackish groundwater, and lowest in relatively low conductivity materials such as unsaturated sand or rock. Maximum depth of investigation is also dependent on antennae frequency and generally increases with decreasing frequency; however, the ability to identify smaller features is diminished as frequency decreases.

The various GPR antennas used are internally shielded from aboveground interference sources. Accordingly, the GPR signal is minimally affected by nearby aboveground conductive objects such as metal fences, overhead power lines, and vehicles.

A GPR survey is performed by towing an antenna across the ground along predetermined transect lines. The antennae is either pulled by a person or towed behind a vehicle. Preliminary GPR transects are performed over random areas of the site to calibrate the GPR equipment and characterize overall site conditions. The optimum time range settings are selected to provide the best combination of depth of investigation and data resolution for the subsurface conditions at the site. Ideally, the survey is performed along a preselected system of perpendicular or parallel transect lines. The configuration of the transect lines is designed based on the geometry and size of the target and the dimensions of the site. The beginning and ending points of the transect lines and grid intersection points, or nodes, are marked on the ground with spray paint or survey flags. A grid system is used to increase the probability of crossing the short axis of a target providing a more definitive signature in the data. The location of the antenna along a transect line is electronically marked on the cross section at each grid intersection point to allow correlation of the data to actual ground locations. The location of the targets can be marked on the ground surface using spray paint or survey flags.

Acoustic Location Methods

Acoustic location methods generally apply to waterlines. A highly sensitive Acoustic Receiver listens for background sounds of water flowing; (at joints, leaks, etc.) or to sounds introduced into the water main using a transducer. This method may have good identification results, but can be inaccurate. Acoustics can also being utilized to determine the location of plastic gas lines.

Non-Destructive Air-Vacuum Excavation

This information provides the highest level of accuracy presently available. It involves “locating”; the use of non-destructive digging equipment to expose buried utilities at critical points. When surveyed and mapped, precise plan and profile information is available for use in making final design decisions. The use of nondestructive digging equipment, particularly vacuum excavation, eliminates damage to underground utility facilities traditionally caused by backhoes. By knowing exactly where a utility is positioned in three dimensions, the designer can often make small adjustments in design elevations or horizontal locations and avoid the need to relocate utilities. Additional information, such as the composition, condition, and size of the underground utility, soil contamination, pavement thickness, etc., also assist the designer and the utility owner in making important decisions.

Non-destructive Air-Vacuum Excavation is used to determine the exact horizontal and vertical location of facilities. The process involves removing the surface material over approximately a 1' x 1' area at the electronically determined approximate horizontal location produced during the designation stage. The air-vacuum process proceeds with the simultaneous action of compressed air-jets to loosen soil and vacuum extraction of the resulting debris.

This process ensures the integrity of the utility line during the excavation process, as no hammers, blades, or heavy mechanical equipment comes into contact with the utility line, eliminating the risk of damage to utilities and personnel. The process continues until the utility is uncovered. Normally, the following information (if applicable) is recorded for each vacuum excavation: the utility type, material, size, depth, condition, location (x, y, z), orientation, roadway section materials and depths, soil type and water table.

Air-Vacuum Excavation can also be used at a proposed boring location to excavate below the "utility window" which is usually eight feet. This reduces the risk to utilities during the initial drilling process. Soil samples can be taken during the air-vacuum excavation process. Frequently, contaminants move along utility line trenches. Air-vacuum excavation can be used to obtain soil samples adjacent to utility lines without risking damage.

Data Management

Equipped with this EXACT information, the Data Management aspect of SUE can begin. These four categories of invaluable information can be utilized to provide extremely accurate subsurface "photographs" for designers. The unique blending of all four of these distinct procedures produces the most exact CADD map possible. After concluding the air-vacuum stage, the exact utility data is then translated into a computer generated three-dimensional map. This computer-generated map then becomes a critical weapon for the designer, allowing for exact instructions to be crafted for excavation. The sum total of benefits to the client when SUE is utilized is the virtual elimination of utility breaks and work stoppages, cost overruns, safety hazards, adverse publicity, and the ensured health and safety of the general public all related to subsurface utility breaks.

When all of these procedures are blended together and applied, a clear and exact visual representation of the position of underground utilities in an area of excavation is produced. Each of these tools, applied independently, offers a limited and only partial representation of the subsurface utilities. The benefits derived from the application of these procedures are maximized when each is fully utilized to complement one another.

The two-fold end result of performing a complete SUE survey is:

- A precise subsurface map that eliminates utility breaks, safety hazards or claims, and public outcry, and
- Confidence to provide the client or owner with the best product while reducing design cost and compressing schedules.

Why Use SUE?

SUE is no longer a novelty. SUE is now recognized by the American Society of Civil Engineers (ASCE) as a viable and necessary component for the practice of civil engineering. Their national standards activity, Standard Guidelines for the Collection and Depiction of Existing Subsurface Utility Data, will have major ramifications regarding the allocation of risk for utility owners, constructors, and engineers. SUE will be a necessary process for every project designed by a civil engineer. The result will be that the reliability of utility data on plans is better defined.

Last Thoughts on SUE

- Did you know that no one really knows how many people are actually killed or injured every year as a result of utility breakage's?
- Did you know that today, many new projects are burying new facilities without creating actual "as-builts"?
- Did you know that in India we do not have legislation requiring a person to use one-call systems prior to excavation? However, there are few departments that require the contractor to obtain both the horizontal and vertical location prior to excavation?
- Did you know that on many projects, a "surprise discovery" rate of twenty-five percent or more is found, i.e., utilities not found on research or contract documents?
- Did you know that many training programs for directional drilling equipment does not mention that on projects where there is ambiguity or uncertainty regarding the contract plans and "one-call markout' a SUE professional should be considered as a safety precaution to find utilities?
- Did you know that on many major construction projects a designer is required to investigate the Subsurface Soil Conditions (geotechnical investigations) but very few consider investigating utility condition and use the owner's specification and plans?
- Did you know that many utility breakage's and interruptions have happened while a driller is performing a "geotechnical investigation"?
- Did you know that many utility breakages's occur during test-pitting operations while "searching" for the utilities?
- Did you know that the scrapes and scratches left on a pipe by mechanical excavation equipment could lead to the pre-mature pipe corrosion and possible failure? In June 1994, in US, an apartment building was destroyed by a gas line explosion because of such marks on the gas pipe.
- Did you know that most existing utility compilation plans are based on a compilation from random search of records and survey location of surface structures? (You are at a loss if a quick paving project has superseded the project.)
- Did you know that many communication companies do not provide copies of plans to surveyors, designers, and construction managers for utility location plan preparation?
- Did you know that budgetary cutbacks by municipalities and utility owners result in old documents not being revised to reflect current utility location?
- Did you know that incorrect information often winds its way into GIS System Networks?
- Did you know that Sue reduces liability? Use SUE to avoid being sued.

SUBSURFACE INVESTIGATION

Ground Penetrating Radar Surveys

Ground Penetrating Radar, also known as Georadar or GPR, uses Radar technology to obtain a continuous profile of the subsurface. The basic principle of GPR is simple- an electromagnetic pulse is sent into the medium under investigations. Part of energy gets reflected from an interface across which there is a contrast in dielectric constant, and remaining energy travels further into the medium. The travel time and amplitude information of the returning signal are recorded. Almost continuous transmission of these pulses and recording of returning signal provides a real time continuous profile of the subsurface.

The Georadar is of immense application in areas requiring high-resolution information of relatively shallow subsurface. Depth of penetration of radar signal depends on the frequency used and material properties.

The application areas of GPR technology include:

- Detection of underground utilities- Pipes, cables (metallic and non-metallic)
- Soil-bedrock interface, shallow geological investigations
- Mining Development
- Mineral Exploration
- Water Table determination
- Glaciology
- Archaeology & Forensics
- Cavities & Voids (Structures- Dams, Bridges, Weirs, Barrages etc.)
- Ground Contaminants (Environment)
- Road Investigations (Layer thickness, Subsidence)

Advantages:

- Rapid ground coverage afforded by towing the antennae either by hand or from a vehicle.
- High lateral resolution of targets, even for larger surveys.
- The instant graphic display offered by most GPR systems allows on-site interpretation.

Limitations:

- Data acquisition may be slow over difficult terrain.
- Depth of penetration is limited in materials with high electrical conductivities like clays.
- Energy may be reflected and recorded from above-ground features, like walls, canopies, etc., unless antennae are well shielded.
- Artifacts in the near surface (reinforcing bars, boulders, components of made ground, etc.) may scatter the transmitted energy and complicate the received signal and/or reduce depth of penetration.

Seismic Surveys

Seismic technique is one of the most developed geophysical techniques, providing vital information on subsurface, crucial for most of the engineering projects. Seismic Refraction surveys are routinely carried out for assessment of subsurface conditions prior to engineering projects.

The seismic refraction method is based on the measurement of the travel time of seismic waves refracted at the interfaces between layers of different velocities. The seismic energy is generates at shot point using a source (hammer, weight drop, explosive). The energy radiates from shot point, and first arrivals are detected using geophones. The first arrivals can be direct arrivals or refracted arrivals, on different geophones, depending on velocities and thickness of subsurface layers. The time-distance curve is used to determine velocities and thickness of various subsurface layers.
The velocity depends on elasticity and density of material through which the energy is traveling, and hence provides information on the material strength, and helps in classification of the material.

The seismic refraction surveys are used to determine:

- Bedrock profile, rock quality and depth.
- Thickness of overburden
- Fractures and weak zones
- Topography of ground water
- Rippability assessment in mines
- Slope stability studies
- Pipeline route studies

Electrical Surveys

The electrical methods, used for measurement of subsurface resistivity, involve passing an electrical current into the ground using two electrodes, and measuring resultant potential using two potential electrodes. Resistivity sounding involves gradually increasing the spacing between the current and/or potential electrodes to obtain deeper penetration. Under profiling, the electrode spacing is kept constant and the entire arrangement is moved along profile lines, to obtain lateral variation in subsurface resistivity.

Electrical resistivity techniques are based on the principle that the resistivity varied depending on the material encountered. Resistivity can then be used to identify different geological units by their electrical properties. If a material's resistivity value drops it could mean that the rock is water saturated and one can expect to find fractured bedrock. The variation in resistivity will correspond to a geological variation along a investigated line. By calibrating the resistivity results with known geologic materials on site, valuable geotechnical information can be obtained for the site. This type of survey becomes interesting in determining the weathered bedrock layers and the presence of sand/ moraine under the clay. It also corroborates the information from the refraction results for better geological interpretation.

2D resistivity imaging uses an array of electrodes connected by multicore cable to provide a linear depth profile of the variation in resistivity both along the survey line and with depth. The acquisition system consists of two units connected to a laptop computer. One unit is a resistivity meter which injects the electrical current into the ground and measures the voltage between the electrodes. The other unit is a control switch box which selects both the injection electrode pair and the potential electrode pair for each data point.

The data are presented as pseudo-section in which the spatial distribution of the electric properties of the investigated material can be qualified. To qualify the data, a modeling routine is applied to the dataset according to the Zohdy method. This new section can be correlated to a depth section since the Zohdy method computes from the datapoint a series of continuous vertical electrical profiles.

The Electrical surveys of used in civil engineering, water resources, mining and environmental projects to:

- Determine the underground water resources
- Bedrock quality and depth measurements
- Mineral prospecting
- Dam structure analysis

- Landfill
- Contamination source detection

Seismic Tomography

Borehole seismic tomography is used to derive an image of seismic velocity between two or more boreholes by measuring travel time between source and receivers along various raypaths. The technique is used for detailed and targeted evaluation of material. One hole is used as source hole, and for wave generated at various depths in this hole; travel times are measured at number of receivers in the other hole, also known as receiver hole. This yields a network of overlapping ray paths, which are used in computations to create a velocity image, also known as tomogram. The tomogram helps identifying anomalous zones, which are visible as velocity contrasts. The technique allows determination of material property for each cell.

The application areas of seismic tomography are:

- Identification of features like fault zones and voids.
- Mapping of loose zones, sinkholes, anomalous zones in structures like dams.
- Detailed study of old foundations

Electromagnetic Ground Conductivity Mapping:

Electro-magnetic (EM) ground conductivity mapping has been in use since the early 1960s and is perhaps one of the most frequently used geophysical methods in environmental and engineering applications today.

An electro-magnetic field is transmitted in air using a coil of wire separated from a receiver coil by a fixed distance ranging between 1 m and 40 m. There is no requirement to couple the coils with the earth and it is usual for the operator(s) to carry them a set distance above the ground. The transmitted energy propagates into the sub-surface where a secondary magnetic field is generated due to the effect of soil moisture, conductive earth materials and buried objects. Both fields are detected at the receiver coil, but the instrument compensates for the primary field, enabling measurement of the secondary. The ratio of the field strengths is controlled by the apparent conductivity of the ground through which the EM radiation has passed. The depth of penetration depends on coil geometry and different system can have different effective depths of penetration ranging from 1.5 m to 60 m.

Micro-Gravity

All matter exerts a gravitational field in direct proportion to its mass. Dense earth materials will exert a stronger localized gravitational field than less dense ones and this can be measured using extremely sensitive gravity meters. These instruments are essentially highly sophisticated spring balances. A simplified gravimeter design consists of a precisely measured mass suspended by a spring. Locating the instrument above higher density material causes the downward component of the local gravitational field (g) to increase and the spring extends under the additional force. The relative increase in is determined through measurement of spring extension. In engineering and environmental applications, it is more usual to use the micro-gravity technique to locate the absence of material due to buried voids, mine shafts and wells. In these situations the mass deficiency results in shortening of the spring due to a relative and very localized decrease in 'g'. Data are acquired on a grid at intervals designed to ensure detection of targets at the desired resolution (0.5 m-1 m spacing for a 2 m buried mineshaft). It is vital that the position of every data point acquired is surveyed accurately and that short-term changes in the gravitational field of the Earth (known as *drift*) are monitored throughout the survey period.

Magnetic Surveys

The basic principles of operation are based upon detecting the disturbance to the Earth's magnetic field by buried magnetized materials. The method is entirely passive in that the instrumentation does not have to generate a field itself. The types of materials that affect the Earth's magnetic field include basic igneous rocks, certain forms of mineralization, and a wide variety of man-made materials and fabrications such as metal pipes, reinforcement bars, electric cables, types of furnace ash. Indeed any material that contains some form of iron oxide (a ferromagnetic substance) or other material that is susceptible to magnetization records the strength of the Earth's magnetic field at the location where the material acquires its magnetization. For example, a volcanic lava flow acquires its magnetization when the lava cools below the Curie temperature; this permanent magnetization is known as Thermal Remnant Magnetization. The same thing applies to bricks when they are fired in a kiln, or to metal pipes when they are extruded and then allowed to cool. Metal pipe segments represent individual bar magnets so that when a pipe line is constructed the magnetic response is akin to that arising from a line of bar magnets. Consequently, it is possible to determine the approximate length of individual segments of buried metal pipes from their magnetic signatures.

Applications:

The most common applications of geomagnetic mapping (including gradiometry) include:

- Locating pipes, cables and metallic objects, including metal drums and Unexploded Ordnance ('UXO');
- Locating concealed mineshafts, mine adits and Underground Storage Tanks (USTs);
- Mapping archaeological remains;
- Mapping geological features, concealed basic igneous dykes and metalliferous mineral lodes;
- Geological boundaries between magnetically contrasting lithologies, including faults.

INDIAN SCENARIO:

Use of Ground Penetrating Radar (GPR or Georadar) is not new in India. Author himself has been involved in various projects using GPR for utility mapping since 1996, in India. GPR services are being used extensively by many trenchless contractors for obtaining prior information on existing utilities, which is an encouraging trend. A larger segment, however, is still operating without such information, resulting in costly damages to utilities. It is therefore required to arrive at a consensus among various service providers about making use of available technology to avoid damages and risks.

Like any indirect technique, GPR has its own limitations, and should therefore not be seen in isolation. Gathering of background information, use of additional tools discussed in the present paper and an understanding of the utility infrastructure is therefore a pre-requisite for a successful project.

For other technologies discussed above, under SUE, an internationally reputed company GeoSpec has confirmed their willingness to provide these services in India, in a communication with the author.

Subsurface investigations using geophysical techniques is also gaining popularity and is an integral part of geotechnical investigations in most the major projects.

CONCLUSIONS

Various geophysical techniques exist to provide a continuous information of subsurface conditions in totally non-destructive manner to accurately plan activities in projects. This information make the operations safe eliminating and minimizing chances of damages to equipment and existing infrastructure. Different methods provide information on different physical properties, and a combination of techniques should ideally be used to get a unique result. For more information on any of these aspects author may be reached at sanjay@parsan.biz

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