Applications of Non-invasive Techniques for Site Investigations and Site Characterization of River Valley Projects

Khanna, Rajesh  
Assistant Research Officer  
e-mail: rajesh12khanna@yahoo.com

Varughese, Alex  
Senior Research Officer  
e-mail: alexvarughese@gmail.com

Central Soil and Materials Research Station, New Delhi

ABSTRACT

Non-invasive techniques are new and ideal techniques for site investigation to detect geological, engineering and hydraulic features for river valley projects. Ground Penetrating Radar (GPR), Seismic Refraction Survey and Electrical Resistively Survey are the main geophysical non-invasive techniques for site characterization. These non-invasive techniques can be used for site investigation of major river valley projects and also in congested urban areas for foundation investigations. These non-invasive techniques are quick and large area can be surveyed in short time. GPR survey was conducted at Aseana quarry site near Tehri Hydro Electric Project, Uttaranchal to find out the depth of overburden and also at Delhi high court and other major thickly populated areas in Delhi to detect the underground utilities like water supply line, sewer line and live electrical cables present at the construction site to have advance knowledge so that it may not present hindrance during excavation and construction. Electrical Resistively Survey was conducted at earth and rockfill, Kol Dam site (HP) to estimate the quantity of core, filter material present at the site. Seismic Refraction Survey was conducted at the Purulia Pumped storage scheme (WB) to know the underground profile at different locations of the project. The primary objective of this paper is to provide information about the different applications of non-invasive techniques for site investigation and site characterization.

1. INTRODUCTION

Puchkuian Road Crossing (New Delhi)
MTNL was to lay telephone cables at major crossing in Puchkuian road using trench less technology. Ground Penetrating Radar (GPR) survey was carried out to find out the underground utilities like sewer lines, man hole, electrical cables etc. for laying down the underground cables.

Purulia Pumped Storage Scheme (WB)
Purulia Pumped storage scheme in West Bengal consists of two dams forming upper and lower reservoirs and an underground power house for generation of 900 MW power. Seismic refraction survey was deployed at along the dam axis, spillway, water conductor system, underground power house, and various quarry sites to determine the depth of bed rock and overburden.

Kol Dam (HP)
Kol dam hydroelectric project is located across river Sutlej near Bilaspur Himachal Pradesh. The project envisages construction of earth and rockfill dam. It is estimated that about 2.0 million cubic meters of impervious clay core material and also filter material is required for the construction of core of an earth and rockfill dam. Since the total quantity of the materials available from a particular borrow area could not be assess from the borrow area investigations only, Electrical resistivity survey was carried out for assessing the nature of the overburden over the hard strata at various terraces.

2. GROUND PENETRATING RADAR (GPR)

GPR uses the principal of the reflection of electromagnetic waves to locate buried objects. The basic principal and theory of GPR are same as those used to detect the aircraft overhead but GPR uses a much broader band width and with transmitting and receiving antennas that are pointing downward towards the ground. Transmitting antenna transmits electromagnetic waves (25 MHz to 1GHz) into the ground. The wave spreads out and travels downwards until it hits an object that has different electrical properties from the surrounding ground. If the wave hits a buried object then part of the wave energy is reflected to the surface,
while part of the energy continues to travels downwards. The waves that are reflected back to the surface is captured and recorded on a digital storage device for interpretation.

In practice, GPR measurements are made by towing the antennas continuously over the ground. The antennas can be towed manually, or with a vehicle. A radar wave is transmitted and received each time that the antenna has been moved a fixed distance across the ground surface. The information that is recorded while the receiver is turned on is called trace. A trace contains the reflections that have bounced back from the buried objects. It takes a specific amount of time for electromagnetic waves to make the round trip from the surface down to the reflector, and back to the surface. Travel time for the electromagnetic waves is measured in nanoseconds. Two ways travel time is greater for deep objects than for shallow objects. If the velocity of the wave in the subsurface is known, the time of arrival for the reflected wave recorded on each trace can be used to determine the depth of buried objects. It can locate any object that has electrical properties in contrast with the surrounding ground and is within the detection range of the radar waves.

**GPR Survey at Puchkuian Road Crossing (New Delhi)**

At Puchkuian road crossing 20 numbers of profile lines were surveyed. Eleven profile lines were surveyed along the road and nine profile lines were surveyed across the road. The detailed layout plan of GPR profiles is shown in Figure 1.

![Fig. 1: Layout of Profile Lines for GPR Survey at Puchkuian Road Crossing](image)

**Interpretation of Data**

It was inferred from the GPR survey that the alignment along the profile line two, and sixteen that there is an anomaly (having strong reflections) starting at a depth of 2.5 m from the ground level. From the GPR prints of the profile lines three, eleven and seventeen it can be inferred that there is a clear zone at a depth of 2.0m from the ground level. The signature of the anomaly of pipe, metallic reverberation and line cables are shown in the Figure 2.

![Fig. 2: GPR Printout Showing Anomalies in the Subsurface](image)

**3. SEISMIC REFRACTION SURVEY**

In seismic refraction survey, elastic waves are generated artificially by explosive source or by mechanical hammer. The source should ideally provide a pulse of duration of not more than a few milliseconds with high amplitude. In an elastic homogeneous ground the source inducts instantaneous deformation, which causes deformation in the vicinity of the source point. By virtue of elastic behaviour of the rock, the elastic deformation propagates in all direction in spherical wave fronts. On critical refraction the refracted wave travels along the interface and sends out secondary waves to the surface. These returning waves are recorded in the seismic refraction survey.

A typical seismic profile consists of 24 numbers of vertical geophones uniformly spaced at a distance of 5 m. Explosive source/mechanical hammer is used for creation of waves. Five shots are used for recording the waves depending upon the topography and layout of the profile. The quantity of the charge range from 0.6kg to 6 kg depending upon the site conditions. The shots are fired with zero delay detonators. The seismic equipment is actuated automatically by make and breaks circuit or by a trigger geophone planted a distance of less than 0.5 m from the shot point.

The Terrolac Seismograph contains in one unit a set of seismic amplifiers to condition the week signals picked up by the geophones. There is a micro processor to control the operation of the equipments, a cathode ray tube (CRT) display for presentation of the data. The data is stored in the digital form on floppy disc with the help of build up system. The whole system is controlled via waterproof keyboard and powered by an internal sealed rechargeable power supply sufficient for 6-7 hours of continuous
operation. Record times from 24ms to 5sec with respective resolution from 24 microseconds to 5 mille seconds can be selected. During the record time the signal from the geophone is sampled 1000 times and these values are stored in the memory and the traces of these stored waves can be achieved by means of digital filtering. A final hard copy with help of printer is taken after satisfactory completion of the processing of the data by filters. The vertical sensitive geophones with a 10Hz cut-off frequency with a coil resistance of 375 ohms were used as detectors.

**Seismic Refraction Survey at Purulia Pumped Storage Scheme (WB)**

Seismic refraction survey has been conducted at Upper dam spillway area, seven profile lines 110001 to 110004 each of length 55.0m length were surveyed.

**Interpretation of Data**

The interpretation procedure consisted of picking up of the first arrival of P-wave from the field records. The Time distance graph was drawn from all the shot points.

**Table 1: Results at Upper Dam Spillway (PPSS, WB)**

<table>
<thead>
<tr>
<th>S.No</th>
<th>Profile No.</th>
<th>Depth of 1st layer (m)</th>
<th>Depth of 2nd layer (m)</th>
<th>Range of velocity (m/sec)</th>
<th>1st layer Bedrock</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>110001</td>
<td>11.10 to 14.75</td>
<td>–</td>
<td>600</td>
<td>4500</td>
</tr>
<tr>
<td>2</td>
<td>110002</td>
<td>10.10 to 11.30</td>
<td>–</td>
<td>650</td>
<td>5700</td>
</tr>
<tr>
<td>3</td>
<td>110003</td>
<td>11.30 to 13.40</td>
<td>–</td>
<td>550</td>
<td>5500</td>
</tr>
<tr>
<td>4</td>
<td>110004</td>
<td>11.30 to 13.40</td>
<td>–</td>
<td>550</td>
<td>5500</td>
</tr>
</tbody>
</table>

The interpretation of P wave velocity and depth of sub-surface layers was performed by using plus minus method. The depth of the refractor was determined at each geophone location. Results of the seismic refractions survey are shown in Table 1. Geo-seismic section of the profile is shown in Figure 3.

**4. ELECTRICAL RESISTIVITY SURVEY**

Electrical resistivity survey measures the apparent resistivity of the subsurface, including effects of any or all of the following: soil type, bedrock fractures, contaminants and ground water. Variation of electrical resistivity may indicate change in composition, layer thickness or contaminant levels. The resistivity method is useful for simultaneously detecting lateral and vertical changes in subsurface electrical properties.

It consists of injection of known amount of current in the subsurface and finding out the potential difference between the electrodes. This method of subsurface investigation based on the fact that the different materials offer different resistance to the flow of current through them. Thus by determining the vertical and lateral variation resistance it is possible with certain limitations to infer stratification and lateral extent of subsurface deposits. The common unit of apparent resistivity is ohm-meter. In soil the resistivity of the soil is particularly higher; similarly the resistance of ground water is higher. Therefore if there is passage of current through soil it would be exclusively through the electrolyte action due to the presence of dissolved salts in the ground water. Consequently the resistivity of the soil primarily dependent on the moisture content and the concentration of these dissolved salts. It is also influenced by the aning degree of void ratio, particle size, stratification and temperature.

In an electrical resistivity survey, electric current is applied to the ground surface through two electrodes. Two additional electrodes are placed in the ground to measure variation in the potential in the electrical field that is set up within the earth by the current electrodes. There are two basic field procedures which are commonly used in electrical resistivity survey: 1) electrical traversing in which the electrode spacing remains constant during the survey; 2) electrical sounding, in which the centre of the electrode spread is maintained at a fixed location and the electrode spacing is increased in increments.

Electrical traversing is normally employed when a rapid survey of an area is desired. It is particularly suited for prospecting for sand, gravel and old deposit and also for locating fault zones or contact between steeply dipping layers of earth material.

Electrical sounding is designed to provide information on the variation in subsurface conditions with depth. Sounding is typically used to help to determine the depth to water table, thickness of sand, gravel and rock layers.

**Electrical Resistivity Survey at Kian Terrace, Kol Dam (HP)**

Measurement of apparent resistivity is made in single location with systematically varying spacing of electrodes along the geoelectric line. This procedure is called Vertical Electrical Sounding (VES). Three profile lines were surveyed and 28 VES points were taken at the Kian terrace. Vertical Electrical Sounding of 28 points were carried out using
Schlumberger array at Kian Terrace. The VES points were taken at every 120m intervals along the profile lines due to the site conditions. The measurements were taken along the lines by keeping current electrodes separation from 1.50m to 60m. It was seen from the resistivity values that there was variation in resistivity with depth reflecting horizontal stratification of each material.

The data was interpreted using software Super VES. The weighted average apparent resistivity and thickness of each layer for Kian Terrace is shown in Table 2. The layout plan is shown in Figure 4. From the resistivity curve and model interpretation it was inferred that soil strata consists of three layers consisting of matrix materials in the second layer which could be used as a filter material in earth and rockfill dam.

### Table 2: Apparent Resistivity for Kian Terrace (Kol Dam)

<table>
<thead>
<tr>
<th>S. No</th>
<th>Profile No.</th>
<th>Layer (m)</th>
<th>Apparent Resistivity (Ohm-meter)</th>
<th>Thickness (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>EP-01-01</td>
<td>1</td>
<td>126.95</td>
<td>0.43</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>431.26</td>
<td>15.13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>8610.56</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>EP-01-02</td>
<td>1</td>
<td>63.39</td>
<td>0.77</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>875.28</td>
<td>20.43</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>54100.39</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>EP-01-03</td>
<td>1</td>
<td>88.03</td>
<td>1.60</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>236.81</td>
<td>23.95</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>18325.81</td>
<td></td>
</tr>
</tbody>
</table>

4. CONCLUSIONS

These non-invasive techniques can be used for site investigation of major river valley projects and also in urban areas for site investigations. These non-invasive techniques are quick and large area can be surveyed in small time. As these are the indirect methods of investigations, these investigations should be verified by direct methods or more than one indirect method should be used for the verification of the results.

ACKNOWLEDGMENTS

The author is really grateful to Director CSMRS for his cooperation and allowing using the data for publication. The author is also grateful to S/Sh. N N Singh, K S Bhandri and K C Dass for their hard work in completing field investigations.

REFERENCES


