3.4 ELECTRICAL AND SEISMIC METHODS FOR CIVIL ENGINEERING APPLICATIONS

Applications of Electrical and Seismic Refraction methods:

- ✓ For groundwater prospecting, required for various Govt. water supply schemes.
- ✓ For soil exploration studies, required for Foundation design of various civil engineering structures.
- ✓ Bed rock investigation, required for dam & reservoir projects, etc.

Electrical Resistivity method:

Principle:

All the materials (whether soil or rock) will conduct or resist current. If they conduct current, it will be in various proportions, based on their composition and moisture content present. The conductivity of any rock / soil is the reciprocal of its resistivity. Knowing the resistivity values, different rock strata present in earth's crust is inferred and their aquifer characteristics are studied. Ohm's law is the basis for the principle of this method.

Equipment used:

1. Resistivity meter
2. Two current electrodes & two potential electrodes
3. Power pack
4. Cables, hammers, etc

Types / methods of Resistivity survey:

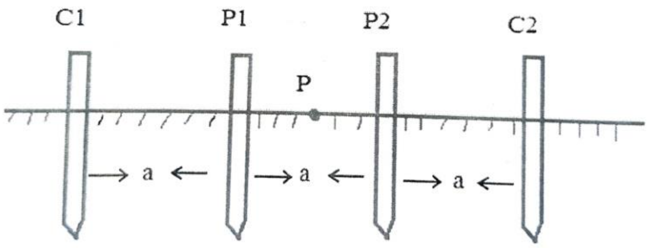
1. Wenner Electrode Array
2. Schlumburger Electrode Array

Procedure:

In both the methods, all the four electrodes are erected firmly into the ground and a known current (I) is sent into the ground through the two current electrodes (C1& C2) and the potential difference (V) between the two potential electrodes (P1 & P2) is measured.

In the case of Wenner configuration of electrodes, all the four electrodes are equally spaced where as in case of Schlumberger configuration, the potential electrodes are closely spaced and current electrodes are placed further apart.

Wenner Array:



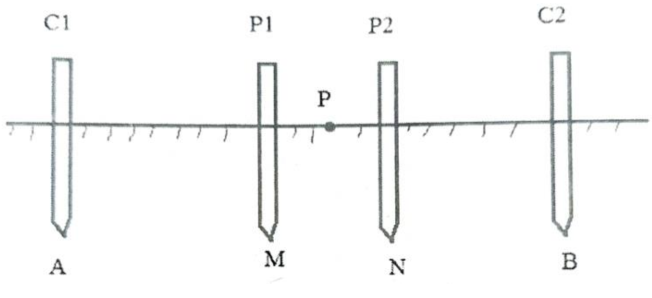
a = Electrode spacing

C1, C2 = Current electrodes

P1, P2 = potential electrodes

P = Point of exploration

Schlumberger Array:



Formula applied:

Wenner array:

$$\ell_a = 2\pi a (V / I) \text{ ohm m}$$

Where ℓ_a = apparent resistivity in ohm m a = electrode spacing

V = potential difference between 2 potential electrodes in millivolts / volts

I = current sent in Ampere / milli amps

Schlumberger array:

$$\ell_a = \frac{\left[\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2\right]}{MN} \times \left(\frac{V}{I}\right)\ ohm\ m$$

Where AB = spacing between current electrodes

MN = spacing between potential electrodes

All the four electrodes are moved laterally at a uniform spacing / span (in case of Wenner) and only the two current electrodes are shifted laterally (in case of Schlumberger), in order to increase the depth of exploration and at every shifting of electrodes, current is sent and potential difference between electrodes is measured. This process is repeated till the total depth of exploration is reached.

In case of Schlumberger, after reaching certain depth of exploration (say 50m), the potential electrodes are shifted to 1/5th distance of current electrodes (say 10m) and the procedure is repeated.

The linear expansion of electrodes denotes the depth of exploration at the point of investigation. Then applying the relevant formula, the apparent resistivity values (ℓ_a) are calculated.

Sedimentary strata	**Resistivity (in ohm m)**	**Hard rock terrain strain**	**Resistivity (in ohm m)**
Sand	8-15	Top soil	> weathered strata
Clay	Less than 5	Weathered strata	25-80
Sandy clay / clayey sand	5-8	Fractured rock	80-150
Kankar	25-40	Jointed rock	150-300

Sea water intrusion	Less than 1	Massive bed rock	> 300

Application civil engineering:

1. **For water supply schemes:**

   Depending upon the water table conditions of the study area and available favourable rock formations, the investigated location is recommended for open well or bore well or rejected, if unfavourable.

2. **For foundation studies in civil engineering:**

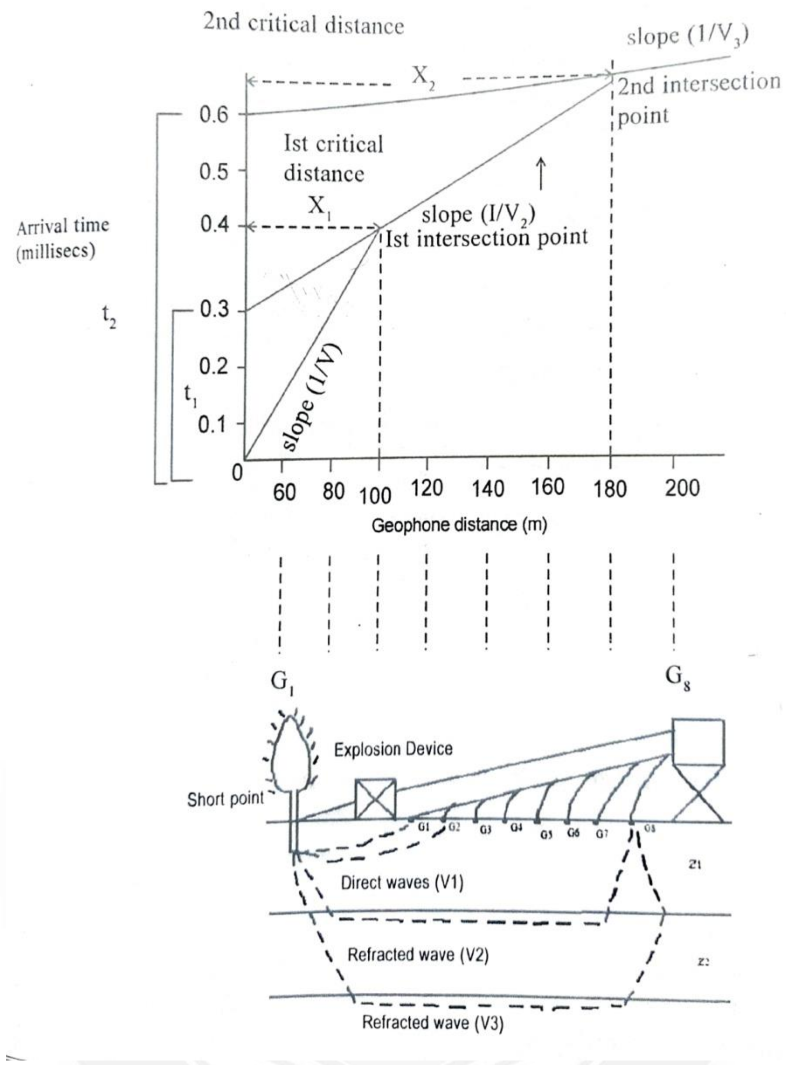
   The soil their nature type and depth to bed rock are inferred and based on the details of soil and rock types, foundation design is made for the civil engineering structures.

Seismic Refraction method:

Principle:

Seismic reflection methods are based on the principle that seismic or elastic waves travel with higher velocity through denser media and with lower velocity in denseless or rarer media.

Seismic refraction methods are for getting information on deep seated rock strata (say 750m or more) while the refraction methods cover only few hundred meters below the ground surface.



Procedure:

- An explosion pit is made (shot point) in the investigation site.
- A number of geophones (G1, G2, G3, etc.) or detectors are placed over the ground laterally. The number of geophones depends upon the depth of exploration required.
- All the geophones are connected to the recording device (seismograph), which is placed away from the shot point, as shown in the figure given above.
- The explosive is fired or detonated.
- The elastic waves generated, due to the detonation of explosives will start travelling in all direction.
- Some waves are directly reaching geophones travelling through the top soil. They are called direct waves.

- Some other waves get refracted in the 2nd and 3rd layers of strata and picked up by other geophones and recorded as electrical pulses.
- Arrival times of waves at different geophones are recorded and geophones distances from the energy source are known. So, the velocity of waves propagating through each rock stratum can be calculated.
- It is a known fact that the velocity of propagating waves in the underlying strata is higher than that in the overlying stratum.
- Critical time: The time taken by the wave, after denotation, to get refracted from its original path is called critical time. There are two critical times here (t_1 & t_2).
- Critical distance: The distance from the shot point, beyond which refraction of waves takes place is called critical distance. There are two critical distances here (X_1 & X_2).
- A travel time graph (time vs distance from geophone) is drawn as shown in figure and t_1, t_2, X_1 and X_2 values are obtained.
- For civil engineering applications in foundation design and or groundwater aquifer studies for water supply projects, the depth to bed rock should be known. So, the depth of the different layers of rock (say Z_1 & Z_2) is calculated as follows,

Depth I layer (Z_1):

$$Z_1 = \frac{X_1}{2}\sqrt{V_1V_2/(V_1+V_2)}$$

Where V_1 & V_2 are velocities of waves in I & II layers

X_1 = first critical distance

Or

$$Z_1 = \frac{t_1}{2} = \frac{V_1V_2}{\sqrt{V_2^2 - V_1^2}}$$

Where t_1 = first critical time

Depth to II layer:

$$Z_2 = \left[\frac{t_2}{2} - Z_1\left(\frac{\sqrt{V_3^2 - V_1^2}}{V_3 V_1}\right)\right]\frac{V_3 V_2}{\sqrt{\left(V_3^2 - V_3^2\right)}}$$

Where t_2 = second critical time

V_3 = velocity of wave in III layer

Average velocities of seismic waves in different soil and rock strata are listed below for interpretation & field applications.

Soil / rock strata	**Velocity range (m/sec)**
Dry sand / loose sand	150 - 400
Alluvium	500 - 1500
Wet sand	600 - 1800
Clays	900 - 3000
Sand stone	2000 - 4300
Shale	2100 - 4000
Lime stone	3000 - 6000
Deccan trap	4000 - 5000
Compact igneous & metamorphic rocks	4500 - 6500

Application in civil engineering:

1. **For foundation studies:** Soil and rock strata below the surface of the earth are inferred. Knowing the soil type and their characteristics, the type of foundation for buildings and other civil engineering structures may be decided.
2. **For dams & reservoir projects:** The depth to bed rock is inferred from seismic refraction studies, which help in selection of site for a dam & reservoir project.
3. **For water supply projects:** Aquifer and its characteristics can be inferred and studied, from the interpretation of seismic data.