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Variation of Moisture Content as a Parameter of Study by Induced Polarization Technique in Soil Sample of Coastal Andhra Pradesh

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Abstract By using non-destructive methods such as induced polarization (IP) based on indigenous equipment; experimental data has been collected to find relations of chargeability/resistivity and moisture content. The same techniques are applicable to other parameters such as CEC and grain size. Induced polarization technique based upon time domain methods can be used for studying the parameters of soil mechanics. Moisture content is a common quality which cannot be properly studied by electrical resistivity techniques. Chargeability of soil is directly related to moisture content. The chargeability is expressed as $m = \frac{V_s}{V_p}\left(\frac{mV}{v}\right)$ where V_p is ON-time measured voltage and V_s is the OFF-time measured voltage. Measurements are made of the decay of V_s over a short time period (0.1s) after some discreet intervals of time. The value of m is calculated from the integration techniques.
Keywords *Induced Polarization, Chargeability, Resistivity, Four Probe Method*

1. Introduction

Induced polarization is an electromagnetic method that uses electrodes with time-varying currents and voltages to map the variation of electrical permittivity (dielectric constant) in the Earth at low frequencies. Induced polarization is observed when a steady current through two electrodes in the Earth is shut off: the voltage does not return to zero instantaneously, but rather decays slowly, indicating that charge has been stored in the rocks, Figure 1. This charge, which accumulates mainly at interfaces between clay minerals, is responsible for the IP effect, Figure 2. This effect can be measured in either the time domain by observing the rate of decay of voltage, or in the frequency domain by measuring phase shifts between sinusoidal currents and voltages. The IP method can probe to subsurface depths of thousands of meters.

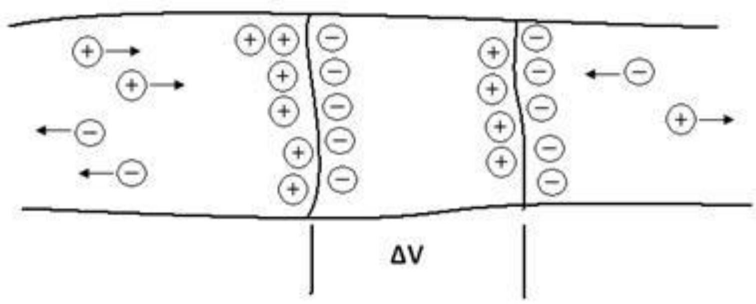

Figure 1: *Change in Voltage because of the Charged Particles in the Soil*

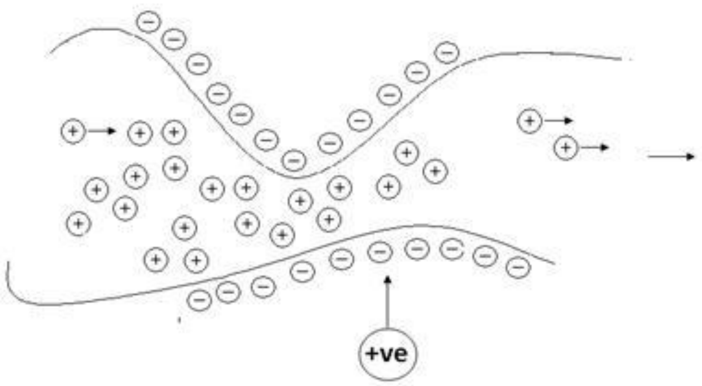

Figure 2: *Change in Voltage when the Rocks and Other Metallic Surfaces are Present*

In nature, the induced polarization (IP) effect is seen primarily with metallic sulfides, graphite, and clays. For this reason, IP surveys have been used extensively in mineral exploration. Recently, IP has been applied to hazardous waste landfill and groundwater investigations to identify clay zones. As with electrical resistivity surveys, vertical or horizontal profiles can be generated using IP. IP can also be used in borehole logging.

2. Instrumentation

The instrumentation for IP has been indigenously developed consists of a) transmitter b) receiver and c) display unit [1]. Using four probe methods, based on schlumberger, two electrodes are current electrodes and inner electrodes are used as voltage electrodes. With a timer, the applied voltage is given to the two current electrodes at intervals 2 or 4 or 8 seconds. The potential developed at the inner electrodes is measured by an accurate digital voltmeter. When the applied voltage is off, the induced voltage decays exponentially depending on the changeability of the soil. The decay is recorded and plotted in the electronic scope. The decay curve can be analyzed to give the exact value of m.

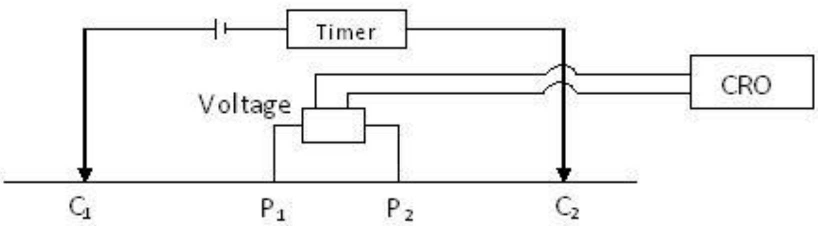

Figure 3: *Block Diagram of the IP Instrument*

When the current is forced through clay, the positive ions are displaced-the displacements in fact constitute the main part of the current. When the current is interrupted, positive charges redistribute themselves in their equilibrium pattern giving rise to decay in voltage.

Clay rich rock such as shall have comparatively less ability to polarize whereas siltstone has lower content of clay minerals have higher ability. This is because in rock having substantial current of clay, almost all the negative charges in exchange positions in the lattice so that no anion exists in the solution.

The transmitter generates a square pulse electric current a crystal controlled timer and relay drives have ON-OFF pulsing with 2-4-8 selection mechanism, Figure 4. Current rays are 30µA to 30mA. Receiver has log and arithmetic sampling modes of chargeability, Figure 5. The programmable mode has IP windows, Figure 3. It measures voltages between receiving electrodes and displays apparent resistivity and chargeability values.

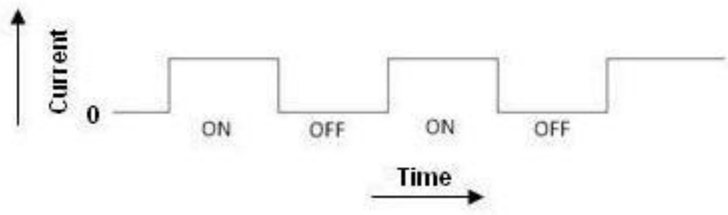

Figure 4: *Square Pulse Given to the IP Instrument*

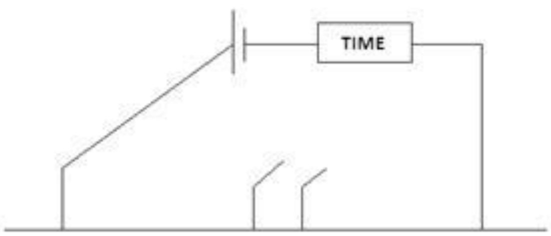

Figure 5: *Block Diagram of the Timer Circuit*

Main variable parameters of response obtained are chargeability and resistivity. These can be related to water content/clay content/grain size and CEC. Running readings displayed are average values of three last consecutive pulses, Figure 6. Cumulative readings shows values which are average of all pulses received from the beginning of measurement, Figure 7.

2.1. IP Effect

- Higher for disseminated than massive clay & metallic properties
- Depends on concentration of clay and metallic particles
- Increases if water in ground has a low conductivity
- Increases with decreasing porosity
- Varies with amount of water
- Depends on current input & current frequency

1. The presences of clay particles are filaments of fiber minerals both of these have negative charge. In the absence of conductive minerals IP over its origin to clay particles contain within pore structure of rock [3].
2. The surface of clay is negative and attracts positive ions from the electrolytes present in the capillaries of clay aggregate. Electrical double layers are formed, concentration of positive ions being greatest at the surface.

By constricting within a pore channel, the effects are:

- Net negative charge at the interface but most minerals and pore fluids
- Positive charges within pore fluid moving to rock surface for buildup positive charges (100μm)
- Pore channel diameter can be reduced by constriction which will block the flow of ions when charges are positive
- Negative charges will leave increasing the potential difference

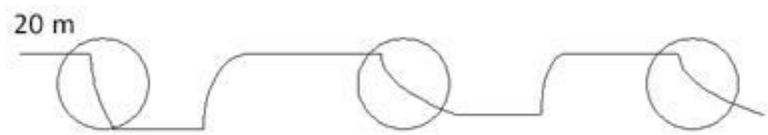

***Figure 6**: Change in the Chargeability from Pulse to Pulse*

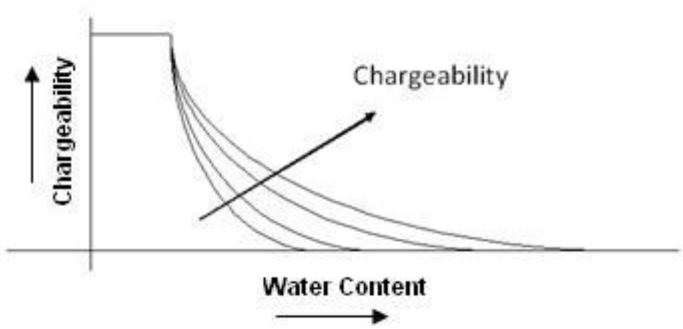

***Figure 7:** Variation in Chargeability with the Variation in Water Content*

3. Analysis of Experimental Results

A comparative analysis was made of chargeability and resistivity at different places. In the second phase, comparison of chargeability and water content was done. Generally it was found that chargeability values increases with water content up to a certain point [2]. After which there is decrease. For chargeability of 0-5 mv/v, resistivity variation was from 0-200 Ω-m. Table 1 records the comparison of water content and chargeability.

***Table 1:** Variations in Chargeability with Water Content and Type of Soil*

Chargeability	Water Content	Type of Soil
15 mV/V	Higher ≈ 30 %	Clay Silt Sand
8 mV/V	Lower ≈ 20 %	Clay Silt Sand
3 mV/V	Sandy ≈ 30 %	Sandy

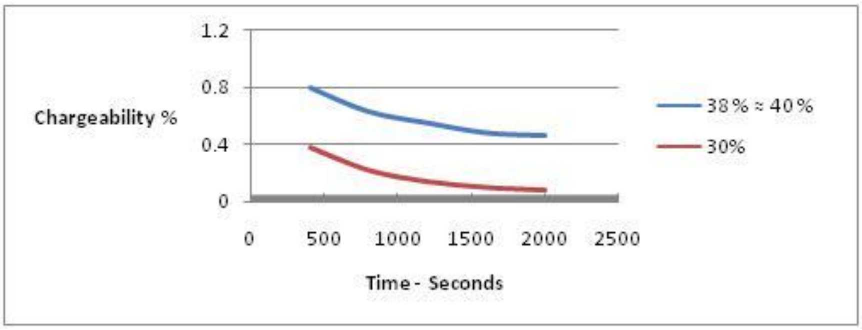

Figure 8: *Graph between the Chargeability and Time in Various Types of Soils*

Figure 8 gives the comparison of delay values for two types of soil.

4. Conclusion

Nondestructive methods such as IP can be used to correlate chargeability/resistivity and parameters such as water content. These techniques can be extended for CEC as well as grain size.

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