CORRELATING BOREHOLE DATA WITH RESISTIVITY TEST RESULTS

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SYNOPSIS - The results of electrical resistivity tests have been analysed using the "Inverse Slope Method" to interpret the electrical-litholog. This has been compared to borehole data so as to assess the stratigraphy. Correlating the resistivity data with the borehole data can be used as a quality check and also as a geotechnical investigation tool to assess stratigraphy, particularly where borehole data is insufficient. Case studies from two project sites are presented to illustrate the methodology for identifying the strata using resistivity information.

INTRODUCTION

On major projects, the geotechnical investigation activity usually involves a variety of different tests. To check the consistency of the results, it is essential that the data from different tests are comparable and lead to similar conclusions. This may be done using theoretical or empirical correlations that should be checked and calibrated using actual field data.

On most geotechnical investigation works in the industrial sector, particularly on power related projects, the resistivity test is usually conducted with the intention of providing the electrical engineer the data for design the electrical grounding system. The authors advocate use of the test as an investigation tool to supplement the borehole data.

The paper presents the field application of a simple correlation that helps to interpret the litholog from the electrical resistivity test. The interpretation is compared to the actual borehole data. The authors emphasize that good quality resistivity data can provide useful geotechnical information.

Such a comparison can also be used as a quality check on the resistivity data. Used in conjunction with boreholes, the resistivity test can confirm the continuity of the various strata and the depth of the layers (Ravi Sundaram and Sanjay Gupta, 2001).

ELECTRICAL RESISTIVITY TESTS

The Concept

When electricity passes through the earth, it encounters resistance to the flow from the soil/rock materials. The resistance offered to the current flow is dependent on the mineralogy, particle arrangement, water content and salinity of the underlying earth layers (Woods, 1994).

In soils or rocks, the flow of an electrical current occurs through

(i) the pore water which acts as a conductor, and
(ii) the soil or rock which may act as a conductor or an insulator/resistor depending upon the nature of the mineral.

Hence, the nature of the pore water as well as the mineral will affect the resistivity. Resistivity can therefore provide information about soil type. For example, a clay will conduct electricity through both the pore water and the clay itself, whereas a sand will transmit a current primarily through its pore water.

The Wenner configuration

Electrical resistivity tests for geotechnical works is usually performed using the four electrode Wenner configuration using different electrode spacing. A schematic of the test is shown on Fig. 1.

The apparent resistivity is computed using the equation :

$$\rho_a = 2 \pi a R$$

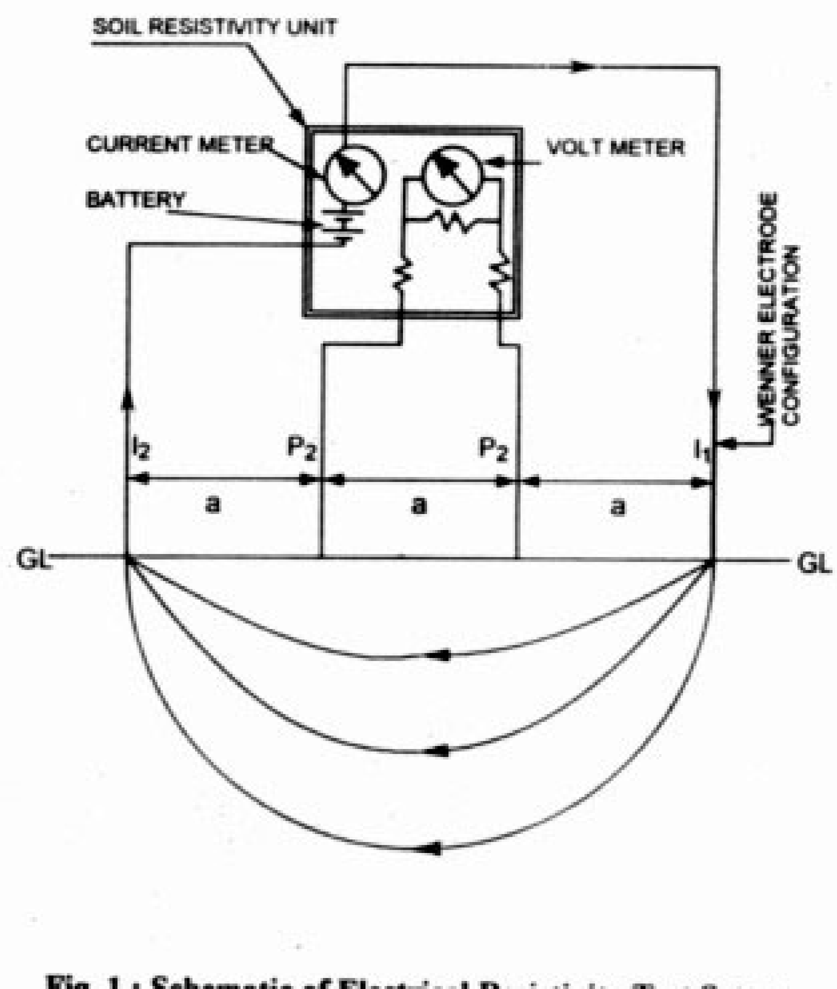

Fig. 1 : Schematic of Electrical Resistivity Test Set-up

where ρ_a = apparent resistivity
a = electrode resistivity
R = resistance

If the formation is homogeneous and isotropic in nature, the resistivity calculated from the above equation represents the true resistivity of the material. However, it represents only the apparent resistivity 'ρ_a' if the formation consists of two or more layers of different resistivities.

The apparent resistivity, depending on the geology, may be a crude weighted average of the true resistivities of the different layers. The effective depth of current penetration, and hence of the investigation, increases with increase in the electrode spacing.

INTERPRETING LITHOLOG FROM RESISTIVITY DATA

Based on an analysis of layered formations and empirical studies, Sanker Narayan & Ramanujachary (1967) have proposed a graphical procedure for computing the true resistivity of various layers. The analysis is called the "***Inverse Slope Method***". The procedure is as follows :

(1) Plot *electrode spacing* 'a' versus 'a/ρ_a' (*ratio of electrode spacing to apparent resistivity*).

(2) On drawing the best fitting straight line segments through the points, the intersections are read off for depths.

(3) The reciprocals of the corresponding slopes of the segments give the absolute resistivities of the layers directly.

A sketch showing the procedure is presented on Fig. 2.

The values of absolute resistivity are compared with published values of resistivity for different materials to interpret the electrical litholog. This litholog is compared with borehole data to confirm the stratigraphy.

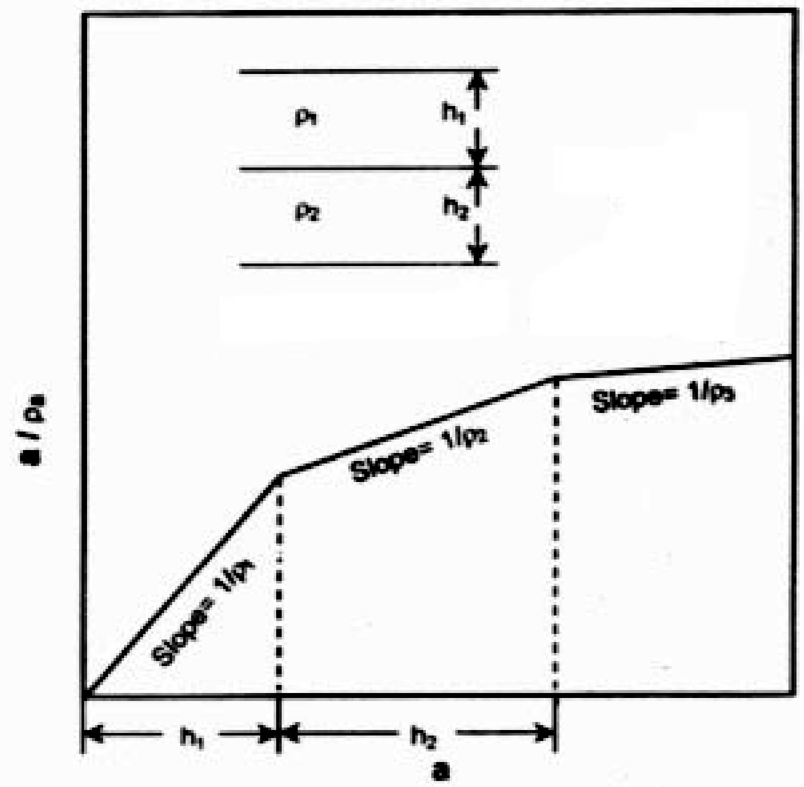

Fig. 2 : Identification of Geo-Electric Layers by Inverse Slope Method

CASE STUDIES

Raipur

A 32 MW Captive Power Plant was planned to be installed in the premises of a Sponge Iron Plant at Raipur (Chattisgarh). Seven boreholes were drilled at the site at various locations at the site to investigate the soil and rock stratigraphy.

As per the borehole data, the stratigraphy at the site consists of expansive hard silty clay (CH) formation to about 2 to 4 m depth. This is underlain by a deposit of calcareous gravel with sand infilling that extends to about 5 to 7.5 m depth. Below this, dark gray strong limestone of the Raipur Formation is encountered. The rock is jointed and has intermediate weathered zones. The core recoveries in

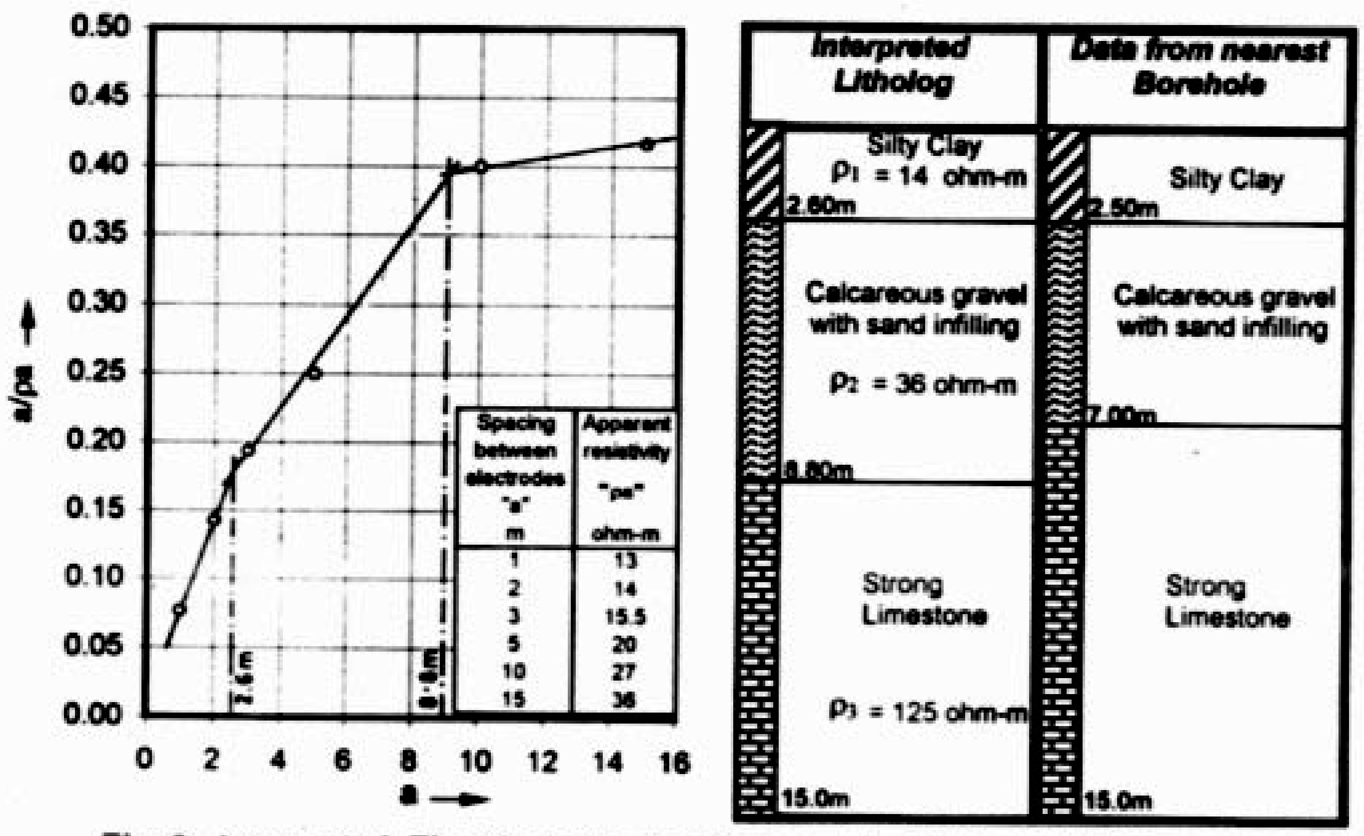

Fig. 3: Interpreted Electrical Litholog Compared with Borehole Data 32 MW Captive Power Project at Raipur

the rock generally range from 40 to 80 percent and the RQD values, range from 35 to 80 percent.

Three electrical resistivity tests were performed at the location the proposed switchyard to obtain data for the design of the grounding system. The results were analyzed to correlate the resistivity results with the borehole data.

Typical analysis of one test result is presented on Fig. 3. The analysis by the inverse slope method suggests the presence of three layers. The true resistivity values are consistent with the range of resistivity values for the three strata encountered at the borehole location, viz. silty clay, calcareous gravel with sand and limestone. The depth at which the strata change occurs as interpreted from the resistivity test analysis matches well with that the nearest borehole location.

Samalkot

A 500 MW Combined Cycle Power Plant is coming up at Samalkot, Distt. Rajamundhary (Andhra Pradesh). The scope of work included 19 boreholes through soil and rock and six electrical resistivity tests in addition to a host of other tests.

In general, all boreholes were drilled to 15 m depth except for 2 boreholes which were taken down to 30 m depth. The boreholes revealed the presence of lateritic formation. The surficial materials vary in gradation from silty sand to clayey silt with shale fragments. Refusal (N ≥ 100) was met between 4 to 7 m depth. Rotary drilling was done through the refusal strata which is also lateritic in nature and consists of severely to very severely weathered arenaceous shale with intermediate layers of feldspathic sandstone. The poor core recoveries and nil RQD values suggest the presence of highly disintegrated rock formation to 30 m depth.

Six electrical resistivity tests were conducted at site for generating data for electrical grounding design; however, the results were also analyzed to evaluate the electrical litholog and the true resistivity of the layers.

Analysis of the resistivity data obtained at one test location in the switchyard area is presented on Fig. 4 along with a comparison with nearest borehole data.

The electrical litholog establishes the presence of four layers. The top layer of laterite (clayey silt) extends to about 5.0 m depth and compares well with the borehole data. The second and third layers represent severely weathered arenaceous shale with feldspathic sandstone. As per the analysis, these layers extend to 34 m depth. The nearest borehole which was taken down to 15 m depth as well the 30 m deep boreholes at the TG location confirmed that the rock is severely to very severely weathered to 30 m depth.

The nearly flat or somewhat negative slope of the fourth line segment on Fig.4 (beyond "a" = 34 m) suggests that the resistivity of the formation below 34 m depth is very high. As per the assessment based on the test results, hard strong rock is likely to be encountered below 34 m depth.

CONCLUDING REMARKS

Resistivity testing is a useful geophysical tool that can be used to identify stratigraphy. Its application in geotechnical investigation works can help to correlate the electrical litholog with borehole data.

For preliminary and reconnaissance surveys, it can provide useful data for planning purposes. In strata containing rock or boulders, substantial savings can be achieved both in terms of costs and time by judicious inclusion of electrical resistivity tests in the geotechnical investigation program.

However, the interpretation has its limitations. It cannot be considered as an alternative to boreholes. Thorough knowledge of

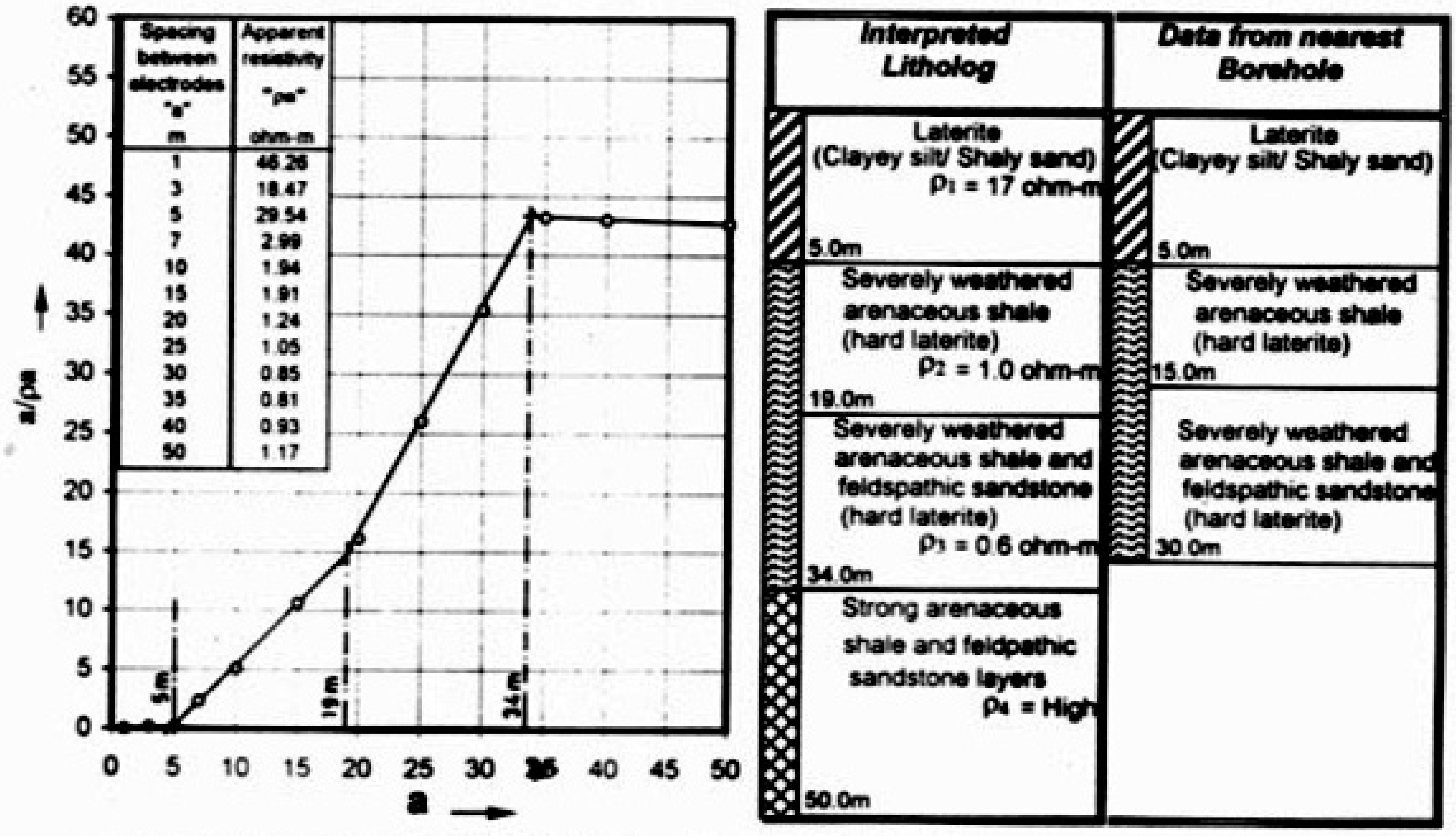

Fig. 4: Interpreted Electrical Litholog Compared with Borehole Data Combined Cycle Power Plant at Samalkot (Andhra Pradesh)

local conditions is essential for proper interpretations. Advance information on geology and geomorphology is essential. Also, the interpreted geo-electric litholog is, at best, an average profile over the area.

Where the strata dips steely and at site where the lateral variation in stratigraphy is substantial, the interpretations could be erratic. Also, if the ground is sloping, serious errors may be introduced.

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