Some Limitations of the Electrical Resistivity Apparatus

WYLSIE R. PLATTS
Chief Geologist, Idaho Department of Highways

Seven field conditions are discussed emphasizing limitations of the electrical resistivity test. In surveys to locate supplies of aggregate, the thickness of overburden, depth to underlying layer and relative cleanness of the aggregate can, singly and collectively, pose problems. Application of the test to landslide studies is limited to conditions where unlike materials exist above and below the failure zone. Some soil-rock mixtures resting on bedrock are not readily defined and soil overburden having higher resistivity than the underlying rock also produces poor test results.

The resistivity test should be limited to an expansion of subsurface data obtained by borings at structure sites. Its use in tracing aquifers may be adversely affected by the depth to the aquifer and its thickness. Natural ground currents can be so strong as to be very troublesome when using dc apparatus.

In spite of these limitations, however, it is concluded that the electrical test is a useful tool when used wisely.

•MANY WORDS have been written about electrical resistivity and its application to subsurface investigation. Most have been directed to the theory and mechanics of the operation. Some have discussed the conditions in which the apparatus has been successfully used. Few words have been written about those instances in which electrical resistivity has not produced good and reliable information. An instructor from a leading western university once asked the question, "Are there any failures in working with this type apparatus, or is it just that failures are never reported?" This paper partly answers this question and helps to fill in the apparent lack of written information on the limitations of electrical resistivity apparatus. To do this, seven situations are considered which, from experience, do not readily lend themselves to resistivity exploration.

CONSTANT DEPTH TRAVERSE IN AGGREGATE SOURCE AREAS

There are three apparent conditions that will affect the increase and/or decrease in resistance values when conducting a constant depth traverse to determine quantity and quality of granular material in an area. These conditions are: (a) thickness of overburden, (b) cleanness of the granular material, and (c) depth to a third layer underlying the granular material. The thickness of overburden will vary over a broad area. As the overburden is usually of less resistant material, an increase in thickness will result in relatively lower values of the constant depth reading, and a decrease in thickness will give the opposite results. The cleanness of the granular material likewise affects the resistance values; the more contamination, the smaller is the resistance.

The depth to a third layer can have a decided influence on resistance values. This third layer may or may not be within the depth of the constant traverse. If it is bedrock of high resistance and near enough to the surface at one test location to be included in the test depth, the resistance value will be relatively high. If the third layer is soil or other low-resistance material, the value will be relatively low.

Paper sponsored by Committee on Surveying, Mapping and Classification of Soils and presented at the 43rd Annual Meeting.

When these three conditions vary from test site to test site within the same area, they can result in many possible profiles and can be misleading to the unwary operator. A high relative resistance value does not guarantee a better aggregate area, nor does a low value necessarily denote a lesser quality aggregate area.

LANDSLIDES

Electrical resistivity has little value in locating a shear surface within homogeneous soil material. The failure that usually occurs is along an arc. The location of the failure surface has nothing to do with a changed material condition within the mass; the failure takes place along this surface because the shearing stress exceeds the shearing resistance more here than elsewhere. There is simply no condition within the material that lends itself to electrical resistivity interpretation. Failures in nonhomogeneous soils can occur along a plane of contact between two different soil layers. Often the layer on which failure occurs is itself too thin to be located by electrical resistivity methods.

Resistivity does have an application where failure occurs along a contact between two unlike materials if the difference in the resistance values of the materials is measurable and if each layer is thick enough to be evaluated.

CONTACT BETWEEN SOIL-ROCK MIXTURES AND BEDROCK

The mode of accumulation of fragmental rock and soil as a mixture on rock slopes will often result in a profile that does not offer itself readily to resistivity interpretation. Climatic and other conditions prevailing since the invasion of the Columbia basalt flows into Idaho seem to have resulted in an unusual sequence of debris accumulation on the slopes of hills and mountains. Apparently, as weathering proceeded and rockfall and rolling rock occurred on the slopes, there was little soil in the area to be incorporated with the fragmental rock as it came to rest. Therefore, the fragmental rock resting on solid rock was nearly free of soil. As time went on and the profile built up, more and more soil was available for deposit with the rock fragments. As the percentage of soil increased, the percentage of fragmental material decreased. The change was slow but constant, and there is no clear-cut change at any place in the profile. The change, as plotted from electrical resistivity reading, is so gradual that a curve results on which points of intersection are impossible to locate.

RESISTANCE OF SOIL OVERBURDEN TO ELECTRICAL CURRENT

It is unusual to find soil overburden with a resistance greater than underlying bedrock, and, therefore, it is easy to overlook this condition when interpreting the resisting values. The phenomenon was first observed on a project in northern Idaho during determination of a soils profile. The field crew had proceeded beyond the cut area and, in fact, had completed the project investigation. It was not until the overall picture was developed for the full length of the project that the discrepancy became apparent. A return trip was made to the cut and the geology of the immediate locality was studied. There seemed to be little question that the layer beneath the overburden had to be rock. A drill was brought to the site and a boring was made which verified rock as the second layer.

The most unusual feature was that tests made by electrical resistivity in adjacent cut areas involving the identical rock formation showed that the overburden was of lesser resistance, although it appeared to be of the same composition as the overburden which gave the higher values. We still have not accounted for the discrepancy to our satisfaction. This situation points out the need for study of local geological conditions along with electrical resistivity investigation.

FOUNDATION INVESTIGATION FOR STRUCTURES

Not much needs be written on this subject as the limitations inherent in use of the electrical resistivity method for this purpose are readily apparent. It is not enough to supply only a log of the profile to a structure designer; strength data must be obtained adequately to design the footings and substructure. Also, the changes in formation cannot be located closely enough by the resistivity method, and a few tenths of a foot can be very significant.

We do not wish to convey the impression that resistivity data should not be considered of value at structure sites. It is of value, but should be used only as a supplement to drill-hole logs.

TRACING AQUIFERS

The success in locating aquifers by this method depends on the thickness of the aquifer and on a measurable difference in the current resistance of the aquifer and the material above and below. Many aquifers are too thin to project a measurable change to the plotted curves. It is only when the aquifer is reasonably thick (i.e., two feet or more) that it can be located with any certainty, assuming that there must be two points at least on the plot to locate an aquifer. If an aquifer is only several feet thick, the electrode spacing must be shortened. If the resistance value of the material above the aquifer is close to that of the aquifer, it may be impossible to locate the contact. Likewise, if the same condition exists with the material below the aquifer, it may be impossible to locate the lower contact. As it is important to determine the thickness of the aquifer, as well as its surface position, these variable situations can result in a confusing picture.

GROUND CURRENTS

This phenomenon is not restricted to buried cables, substations, and high-voltage lines in the area investigated. Ground currents of appreciable magnitude may exist where there are no man-made electrical installations. Not only do unexplained ground currents exist, but also they do not express any directional pattern consistency.

We have experienced ground-current phenomena in which the direction of flow changes at depth. With one reading the currents are moving in one direction and perhaps two readings later, at only six-feet lower elevation, they are in an opposite direction. If there were any practical reason, I believe that their course could be plotted at different levels beneath the surface.

It has been possible on some, but not all, occasions to overcome this condition with the battery capacity we have. I suppose that resistivity equipment that can withstand a heavier current load theoretically could overcome these ground currents. Where the total battery supply has been able to overcome these currents and still be measurable, the results of the tests appear to be reliable. Change of traverse direction has also been somewhat successful.

SEISMIC APPLICATION

This paper would not be complete without a short discussion on the compatibility of seismic equipment with electrical resistivity. One can supplement the other rather neatly in some situations where each by itself would not produce reliable information.

A refraction seismic apparatus has the distinction of plotting the subsurface through changes in sound-wave velocity caused by variable densities of different materials. A plot of the profile, to be accurate, requires that the subsurface materials express these different velocities through an increase in their respective densities with increase in depth. That is, the second layer must have a greater velocity than the first to establish the contact and a third must have a greater velocity than the second. If the first layer has a greater velocity than the second, a contact cannot be established.

The use of one method to supplement the other can be readily seen. When the contact between soil and rock mixtures and bedrock could not be determined with resistivity, the refraction seismic method proved suitable for the task. A condition where high velocity cap rock overlies lower velocity soil material is not suitable to refraction seismic interpretation but may readily succumb to electrical resistivity.

CONCLUSIONS

Electrical resistivity can be a useful tool, but only if one realizes the limitations. When they are kept in mind, many of them can be coped with, or compensated for, by other aids.

One such aid has been discussed in this paper; others are available. There are six electrical resistivity systems currently in operation in Idaho. Their value has far exceeded any drawbacks they may have. I would judge that without them and their ease of transportation to an investigation site, there would be instances where no other investigation would have been made because of inaccessibility to other equipment.