DEEPHT AND EXTENSION OF THE BED ROCK DETERMINATION FOR ENGINEERING PURPOSES BY ELECTRICAL RESISTIVITY METHOD

Mohammed Sh. Zainal1 and Mohammed I. Abdul Razzak2

1 College of Ibn Al-Haitham Education, University of Baghdad. Baghdad, Iraq.

ABSTRACT

The aim of this research is to support the geophysical field survey results in a manner of vertical electrical sounding (VES) by the results of the engineering examination represented by the Standard Penetration Test (SPT) of some wells drilled in one selected sites near Baghdad province, namely (Al-Musayyib site), for the purpose of evaluating the geometric position of the foundation layer and thus the possibility of the application of electrical method in such Engineering investigations. Measurements of 25 VES's distributed in five parallel traverses were carried out by using Schlumberger array in which this results were correlated with SPT results and available geological information. The main outcomes in the study area revealed five continuous and homogeneous subsurface layers in which the fourth layer of very dense brown weakly cemented sand with little amount of gravel having SPT values of more than 50 represents the foundation where engineering construction can be set on it. Finally, encouraging results about the possibility of the application of electrical method in this situation were obtained.

Keywords: Iraq; Standard penetration test; Al-Musayyib; VES

INTRODUCTION

The electrical resistivity technique with which the present work is mainly concerned, is the most significant one because it gives information about the body location, thickness of the overburden, depth of layers, depth extension, thickness of the bed rock and the conductive zones layer and the resistivity variations within a definite depth from the surface, (Dobrin and Savit, 1988; Abdul-Razzak, 1990).

The electrical resistivity technique basically involves introducing a controlled D.C. or low frequency alternating current into the ground by means of two electrodes namely current electrodes and measuring the potential difference or resistance between two
points chosen with respect to the current electrodes. Any subsurface variation in conductivity alters the form of the current flow within the earth and this effects the electric potential distribution, the degree of effect depending on the size, shape, location and electrical resistivity of the subsurface layers. It is therefore possible to measure or obtain information about the subsurface from the measurement of potentials made at surface, (Dobrin and Savit, 1988; Abdul-Razzak, 1990).

The use of the electric method in determining the solid or bed layers that has been utilized as foundations for the engineering establishments and huge building structures is not a new approach, but the match of the electrical field results with results arising from the information of an engineering tests for the subsurface layers can be considered as a newly approach in Iraq. It is well known that rock density and thus rock layers increases with depth steadily as a cause of increasing compression and then consolidation relative to the above layers, but in fact the rock density and its hardness depends on the conditions of deposition and the fabric texture of such deposition even on the variables and other influences factors, (Keller and Frischknecht, 1966). So, accordingly, geophysical studies and investigations that supported by the geological and/or engineering information is an important process in which their practical results may be differed from one site to others relative to the environment and circumstances where there areas of research are tested. The most important of such engineering tests that has been used to determine the validity of the rocks and can therefore be relied upon as the basis for engineering states is called (Standard Penetration Test, SPT), (Rogers, 2006; Akintorinewa and Adesoji, 2009; Faleyey and Omosuyi, 2011; and Khatry and Shrivastava, 2011). It should be noted that, the available engineering survey as standard penetration test (SPT) in the studied area gave a good opportunity for matching and correlating it with the main electrical survey as resistivity data.

The area under study is located in the town of Musayyib, about (50 Km) south of Baghdad governorate. It is bounded by latitude (32° 47' 13.9" – 32° 47' 40.1") and longitude (44° 17' 54.4" – 44° 18' 13.6") (Fig. 1).

The main objective of the present work is made an attempt for matching the results of geophysical field survey represented as vertical electrical sounding with the results of the engineering investigation carried out by Consulting Engineering Bureau (CEB,
2007) represented by the standard penetration test (SPT) data of some wells drilled in the selected area near Baghdad province (Al-Musayyib site).

Fig. 1: location map of the study area

GEOLOGY OF THE AREA

The area under study is a part of the Mesopotamia plane. Therefore, the geological deposits existed in the area is belongs to the fluvial sediments, (i.e. river sediments), including gravel, sand, silt and clay. So, according to the depositional process, different layers will appear depending on the variation amount of these different materials, (Barwary and Slewa, 1995). However, the main geological information was given from five drilled wells available in the studied area as (BH1, BH2, BH3, BH4 and BH5) with depth not exceeded (25 m). Further useful geological information belongs to the borehole (BH0) with depth of (80 m), located at a distance of (400 m) away from the studied area has been even taken into consideration and shown in Figure (2). It should be noted that, the above boreholes involve their engineering test represented by Standard Penetration Test (SPT).
Fig. 2: Lithology of well (BH0) near the study area (CEB., 2007)

**METHODOLOGY**

a- Geophysical Electrical Survey Technique

Vertical Electrical Sounding (i.e. resistivity as a function of depth), Schlumberger array, is used to determine the thickness of the subsurface layers (depth of the subsurface rock boundaries), and their electrical resistivities. Resistivity values (\( \rho_a \)) were calculated by using the following equation:

\[
\rho_a = 2 \pi \left[ \left( \frac{a^2}{b} \right) \left( \frac{1}{b} \right) \right] \times R
\]

\[ \text{................................. (1)} \]

Where: 
- \( a = AB/2 \) (half the distance between the current electrodes). 
- \( b = MN \) (the distance between the potential electrodes). 
- \( R \) = measured resistance in the field.
b- Standard Penetration Test Technique

This technique has been stated and developed in United State. In which such development involves all Instruments and Test methods. The type of the test results depends on several factors where the most important one is the actual energy that transmitted on the column header, the dynamic properties of a drilling column, the drilling method and the stability of the drilling well. The measured (N) value is called a standard penetration test of the soil (SPT). Such (SPT) resistance values are affected by the stress conditions at testing depth (Massarsch, 1999). However, (Peck et al., 1974) find an equation to correct the confined pressure, depending on his observation about the column fall under knocking in which the measured value (N) will multiply by the factor correction (CN) in order to get the reference value (N1) that corresponds the affecting stress of the soil, as follows:

\[ N_1 = N \times C_N \]

and \( C_N \) is:

\[ C_N = 0.77 \times \log_{10} \left( \frac{20}{P'} \right) \]

Where: \( N \) = standard penetration resistance of the soil (SPT).
\( C_N \) = correction stress coefficient.
\( P' \) = affected vertical pressure on soil.

It should be noted that the resistant for the values of \( (N_{30}) \) has been correlated with a relative density of granular soils, composed of gravel and sand, which was given by the (Broms, 1986), as shown in the following:

<table>
<thead>
<tr>
<th>Soil type proportion to the relative density</th>
<th>SPT ( (N_{30}) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loose soil</td>
<td>( \leq 10 )</td>
</tr>
<tr>
<td>Medium dense</td>
<td>( 10 - 30 )</td>
</tr>
<tr>
<td>Solid dense</td>
<td>( \geq 30 )</td>
</tr>
</tbody>
</table>

FIELDWORK

The main aim of the present work in this site is to identify and assign the bed rock layer in which it will hopefully set up some economically important engineering structures. In the survey, the vertical electrical resistivity method represented by Schlumberger electrode array was carried out. Five parallel traverses were set out with interval of (100 m). Each one of these traverses was (800 m) in length, including (5) measuring points (VES’s) having distance interval of (200 m), whereas the maximum
distance for the spreading of current electrodes reached as (600 m). It is believed that such distance spreading can go down to depth of up to more than (100 m) (Fig. 3). The resistivity values for the VES’s points are measured by using the instrument of (ABEM Terrameter SAS 300B).

Fig. 3: show electrical traverses distribution in the study area

DATA INTERPRETATION OF RESISTIVITY SURVEY

All vertical field data is subjected to a qualitative and quantitative analysis process for the purpose of assistance and facilitate the process of interpretation even accessing the results to reach the objective of the study, as follows:

a- Qualitative Interpretation

Depending on the measured physical character ($\rho_a$), the field curves were analyzed and interpreted according to their shapes where all revealed a pattern (HAK) with five layers in which their physical property is ($\rho_1 > \rho_2 < \rho_3 < \rho_4 > \rho_5$). The similarity in the physical characters of these curves with each other and along the four measured traverses explain and demonstrate the homogeneity of the layers and the rock types that composed these layers indicates no interference or disturbance to it. Moreover, five space sections been constructed represented the five field traverse, described by
Figures (4, 5, 6, 7 and 8). In general, it can be seen from these figures that an identical in the shape, form and trend of the contour lines even response and more or less in their behavior. Further, all figures show closed contour exist and extent in the middle of these maps having maximum resistivity values relative to the values scattered in the area which indicate and gives an idea proofing a good hard layers. For more detail, one can analyzed quantitatively these sections by using the processing of composition rule method given by (Habberjam and Jackson, 1974).

b- Quantitative Interpretation

At the beginning and for the purpose of obtaining preliminary picture and thoroughly having reasonable results, the resistivity values drawn as curves on paper with a double logarithmic cycle of (62.5 mm) and subjected the process by using the standard curves for Schlumberger arrangement (interpretation by using partial curve matching approach) (Koefoed, 1979).

These obtained initial values as true resistivity and thickness of the multiple layers were subjected to the modeling technique using special computerized software called (Resist), which was developed by (Velpen, 1988). This program has a good specification of being fast, accurate, including the interpretation of several electrode arrangements, has iteration values up to 30, even calibration values was calculated as the percentage rate of the mean square root (RMS% error rate). This method represents the (Trial and Error curve matching approach). In this iteration technique, the observed data are compared with the data computed from a given layer model. If there is unsatisfactory agreement between the computed and observed data, the parameters of the layer model are changed and the procedure then repeated until a good fit between both sets of data is obtained, hence the parameters of the last model may represent the real earth with an assistance of available geological information. In general, all vertical field curves belongs the studied area been interpreted by modeling technique where (Fig. 9) revealed a typical sample of such interpretation with their result even percentage error. However and according to the identity in the behavior and response of the space section contour lines, the interpreted curve values (resistivity and thickness) for each traverse where jointed and correlated to each other and constructed as sections which led to the identification of five horizontal homogeneous layers with different vertical electrical zones.
Fig. 4: Apparent resistivity space section traverse (T1)
Fig. 5: Apparent resistivity space section traverse (T2)
Fig. 6: Apparent resistivity space section traverse (T3)
Fig. 7: Apparent resistivity space section traverse (T4)
Fig. 8: Apparent resistivity space section traverse (T5)
RESULTS AND DISCUSSION

By inspection all the obtainable electrical sections (Figs. 10, 11, 12, 13 and 14), layers with low resistivity have been shown in all in which this character may be come from the impact of groundwater level in the area where the water level does not exceed 2 meters.

It is observed that all space section figures revealed identical downward contour lines (beneath AB/2 =160 m) for the resistivity values. Despite conical shape appeared in the contour lines which are found under (VES 2), where it probably represents a limited clay pocket at depth of more than 25 m in which their affects not appeared when true resistivity values were calculated even for penetrating test as well and accordingly this effect was not appeared in the geo-electrical section (Fig. 10). Such not appearing effect may also attribute to the identical regression of the symmetric contour lines.

In order to convert such electrical sections into geo-electrical one, available geological information was taken from the drilled wells (BH1, BH2, BH3, BH4 and BH5). It should be noted that, each electric field traverse includes bore hole respectively in which such bore holes involves their engineering test represented by Standard Penetration Test (SPT). Since the depth of these boreholes is not exceeded the fourth
layer, thus, further useful geological information belongs to the borehole (BH0) as indicated in Figure (2) has been taken into consideration. However, the geoelectrical succession can be established as follow:

1- Top soil layer, represented as differentiated sediments, having resistivity values ranging from (2.4 – 2.9 ohm.m) with average thickness ranges between (1.3 – 2.2 m). It consists of stiff brown silty clay with loose fine sand with SPT values \((N_{30})\) range (10 – 12).

2- Second layer consists of loose fine sand deposits with electrical resistivity ranges from (1.8 – 2.7 ohm.m) and average thickness from (4.5 – 6.6 m). The SPT values \((N_{30})\) of this layer range between (17 – 23).

3- Third layer consists of medium dense to dense poorly graded gravelly sand having average resistivity values ranges between (7.4 – 8.3 ohm.m) and average thickness from (8.4 – 9.5 m). The SPT values \((N_{30})\) range between (25 – 35).

4- Forth layer, on the other hand, characterized by average resistivity values of more than previous layers, ranging from (10.7 – 12.2 ohm.m) and average thickness of (40.0 – 43.0 m). It consists of very dense brown weakly cemented sand with little amount of gravel. It should be noted that, the SPT values \((N_{30})\) of (> 50) is mainly correlated with this layer. Such characterization indicates a rigid layer which can be established as an engineering foundation.

5- Fifth layer, however, consists of loose sand with stiff brown clay having average resistivity values ranging between (3.0 – 3.4 ohm.m). Its STP value is not registered here because all bore holes depth are not exceeded 25 m.
Fig. 10: Interpreted geoelectrical cross section along traverse (T1)
Fig. 11: Interpreted geoelectrical cross section along traverse (T2)
Fig. 12: Interpreted geoelectrical cross section along traverse (T3)
Fig. 13: Interpreted geoelectrical cross section along traverse (14)
Fig. 14: Interpreted geoelectrical cross section along traverse (T5)
CONCLUSIONS

From all the figures shown above, conclusions can be given as:

- First, all geo-electrical sections include five continuous and homogeneous geological layers, their characters with engineering one are given as follows:
  1- Stiff brown silty clay with loose-fine sand with SPT value (N_{30}) range (10 – 12).
  2- Loose fine sand deposits with SPT values (N_{30}) range (17 – 23).
  3- Medium dense to dense poorly graded gravelly sand with SPT values (N_{30}) range (25 – 35).
  4- Very dense brown weakly cemented sand with little amount of gravel with SPT values (N_{30}) more than (50).
  5- Loose sand with stiff brown clay.

- Second, the study found that the depth of the bed rock (foundation layer) having range (16 – 20 m) with varied thickness range between (40 – 43 m).

- Third, one can be seen the agreement degree between the obtainable results belongs the fourth layer, class 4, (i.e Bed Rock) of brown heavy dense sand with little amount of gravel, which has a resistivity range between (10.7 – 12.2 ohm.m), with SPT having values more than (50) represented the rigid layer, in which engineering construction can be set out on the mentioned foundation layer.

- Forth, encouraging results about the possibility of the application of electrical method in this situation are obtained. Therefore and according to the stating above, it can carry out an engineering investigation in areas having a wide enough by digging only a single SPT well or two SPT wells, which then a matching between these engineering measurements and vertical electrical information can possibly be made.

REFERENCES


