APPLICATION OF 2D SURFACE ELECTRICAL RESISTIVITY TOMOGRAPHY TO DETECT THE UNDERGROUND CAVITIES A CASE SITE STUDY: TOLGA AREA (ALGERIA)

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ABSTRACT

Electrical resistivity tomography method is considered among the best non-destructive and non invasive geophysical techniques for detecting and characterizing the underground cavities and associated disorders. The detection of cavities in urban areas is important to prevent against different causes of accidents related to possible collapse and subsidence. This study focused on the application of electrical resistivity measurements to locate and identify cavities in the soil. The survey site is located in Biskra City, south-east of Algeria. This field contains cavities of natural origin and different sizes. The procedure using the electrical resistivity tomography of Wenner array permitted to detect the cavities in the range of depth 2 to 4m. These cavities were caused by the dissolution phenomena of carbonate materials. Also mechanical and dynamic penetrometer tests were performed in order to propose a solution for foundations building.

KEYWORDS: Cavity, Urban area, Resistivity, Borehole drilling, Electrical tomography.

1 INTRODUCTION

Geophysical methods are effective investigation at the phase of preliminary studies for construction projects that cover large areas. They enable fast, relatively low cost for assessing the subsurface soil. Practically, there is the electrical resistivity method, seismic, gravity, ground penetrating radar and other methods.

The electrical method is the most tools used to evaluate geological and geotechnical problems. Many research studies have been made by this technique to introduce applications for the detection and monitoring of under-ground cavities and sinkholes in a limestone area El Khammari et al [1], Emin and Irfan [2], Fehdi et al [3], Metwaly and Alfouzan [4], Oldenburg and Li [5], Van Schoor [6], for identifying the archaeological structures Muztaza et al [7], in environmental and hydrogeological studies, for mapping the detrital and sandy aquifers Martinez [8] and Šumanovac [9], analysis of karst aquifer structure Al-fares et al [10]. This study is involved to the search for instabilities represented by underground voids, using the electrical method, this method is not only used to detect underground cavities, gravimetric and electromagnetic methods are also used due to good resolution combined with the ERT Park et al [11], El Khammari et al [1], El Qady [12].

In the city of Tolga, south-eastern of Algeria, there are caverns of natural origin which are formed by the process of dissolution of limestone (Karst phenomena). The presence of these cavities affects the stability of constructions.

The aim objective of this paper is to apply the 2D ERT technique for analyze the shallow subsurface resistivity variation and characterize the possible cavernous zones in the study area of Tolga city.

the study area of Tolga city.

Figure 01: Illustration of an underground cavity

2 FIELD OF INVESTIGATION

The theory of the electrical method consists to inject an electric current of known intensity in to the ground, and to measure the potential difference (ΔV), in order to calculate the electrical resistivity value.

A 2D acquisition generally uses a large number of electrodes connected to a multi-conductor cable and placed in a profile.

For a good 2D image, it is necessary that the coverage of measurements is also 2D and uniform. For example, in a Wenner configuration with 19 electrodes, the distance between two electrodes is denoted “a”. In a Wenner configuration (Fig. 2), the first measure will be made using electrodes 1, 2, 3, and 4; the electrodes 1 and 4 will be used for current injection (A and B) 2 and 3 measuring the potential (M and N). The entire device will move a distance a. The electrodes 2 and 5 will be used then for current injection and 3 and 4 to the extent of potential. The process is repeated until the electrode 19. We obtained for the first level of acquisition 16 opportunities (19−3). As the characteristic of the Wenner configuration is to keep a constant distance between all electrodes, we take for the next level a distance equal to 2 * a.

The first step will involve the 2nd level, then the electrodes 1 and 7 for the current injection and 3 and 5 for measuring the potential. The process is repeated until the electrode 19. The second level will therefore include 13 possibilities (19−2 * 3). We conduct measures of each level of acquisition with 3 * a, 4 * a, etc…

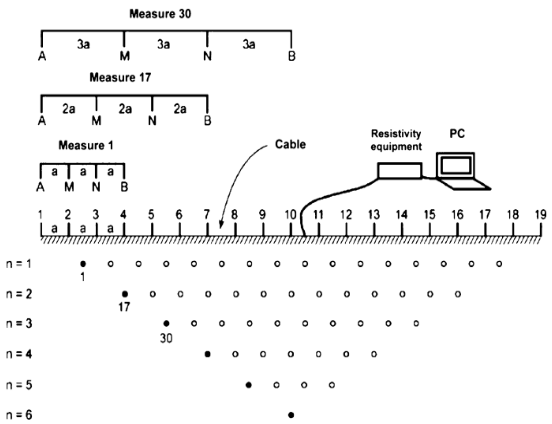

Figure 02: Arrangement of electrodes for a 2D acquisition and measurement sequence for the Wenner configuration

3 ERT MEASUREMENTS

The program of geophysical survey includes 10 profiles of electrical resistivity tomography has been planned along the study area for exploring the possibility to detect the subsurface extension of the surface cavities and dissolved areas.

Table 01: Characteristics of electric profiles

Number of profiles	Number of electrode	spacing (m)	Direction
1	30	2	W-E
2	29	2	S-N
3	30	2	W-E
4	25	1	W-E
5	25	1	W-E
6	25	1	W-E
7	25	0.5	S-N
8	24	0.5	S-N
9	28	1	N-S
10	28	1	W-E

The best arrangement of the profiles was controlled by the surface conditions and the possibility to extend the profiles along the study area (The aim of the current work is to build participatory social houses in Tolga city). The measure made with the SARIS (Scintrex Automated Resistivity Imaging System) manufactured by (Scintrex Ltd). The data were recorded using Wenner electrode array, considering a 2D acquisition Dahlin and Loke [13]. This array has a good horizontal sensitivity to detect lateral structures rather than the vertical variations Dahlin and Zhou [14]. The profiles have different lengths and electrode offsets (Table 1) ranging from 0.5m along the areas whereas there are surface evidences about cavernous features, to 2m for the normal ground (Fig. 3). To be sure that there is a good data quality in the field, the coupling performance with the ground was achieved using long stainless still electrodes (0.75m) inserted into the ground in a small hole filled with saline water. The injected current was (1 Am) and the voltage was ranging from. The data acquisition was performed during (April 2013) where the weather condition was relatively hot, and the subsurface soil is dry. Some electrodes were watered to ensure good contact with the ground.

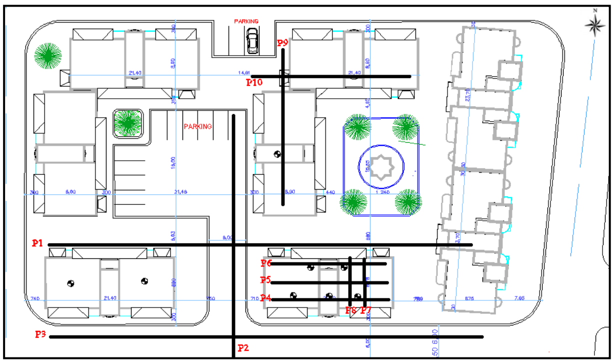

Figure 03: Disposition of all electrical panels

The apparent resistivity profiles of Wenner array were inverted using RES2Dinv software Loke and Barker [15], program that automatically determines in two-dimensional model of the resistivity and induced-polarization of the subsoil Griffiths and Barker [16]. This inversion code is capable of calculating the values of apparent resistivity, is based on the least-square method DeGrout and Constable [17], Loke and Barker [15], Sasaki [18]. For modeling, the RES2Dinv program distributes data by considering rectangular mesh throughout the depth of investigation Edwards [19].

4 RESULTS AND DISCUSSIONS

Geophysical recorded results are illustrated in figures (4, 5, 6 and 7), for electrical profiles P1 to P10, respectively. Geophysical measurements obtained show that the values of apparent resistivity of all electrical panels range from 10 to 500 ohm.m, and indicate that the site is very heterogeneous. The results are presented as pseudo-sections or electrical panels. The first panel represents the pseudosection of the measured apparent resistivity. The second pseudosection is the model calculated by the inversion program. The last panel is the inversion model section.

In this paper we present only the inversion model. Measurements of electrical tomography have identified three panels corresponding to the profiles P1, P2 and P3 (Fig. 3). The Figure 4 shows the electrical panel P1 that is composed of the ground clay of length 16m and a depth of 1.30 m, with a range of resistivity of from 35 to 40 Ohm.m; however, the panel P1 shows the existence of carbonate formations corresponding to limestone having very high values of resistivity of about 200 Ohm.m, are located at a depth of 3m. The first two panels have approximately similar characteristics (silty clay and carbonate clay). The electric panel P3 indicates a conductive layer near the (clay) surface resistivity lower than 15 ohm.m. Also, the panel contains a carbonated clay layer located at a depth of 3m, the apparent resistivity is around 30 to 50 ohm.m. Also we notice a very great contrast apparent resistivity of carbonate materials whose resistivity increases between 70-85 ohm.m.

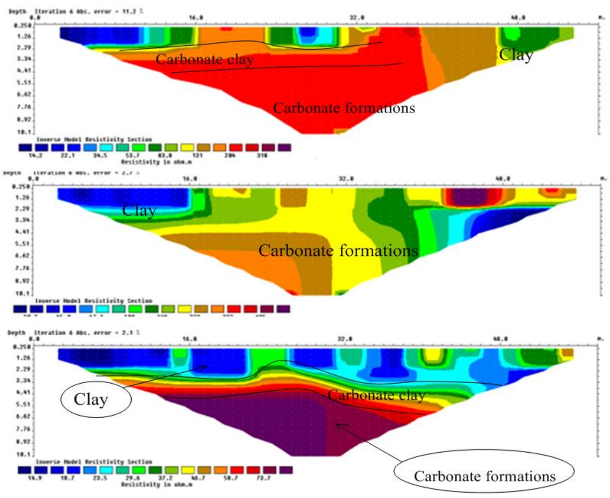

Figure 04: Results of geophysical measurements of profiles P1, P2 and P3

The panels P4, P5 and P6 were made parallel to the longitudinal direction, where as a spacing of about 3m, the results obtained are presented in Figure 5 shows a panel P4 carbonate formation covering the entire this profile is the resistivity of about 200 Ohm.m.

We notice the presence of a highly conductive clay zone has resistivity 20 Ohm.m. The electrical panel P5 shows the existence of a highly resistive zone of resistivity value over

200Ohm.m, this can be explained as a horizontally elongated cavity, the two profiles P4 and P5 have common characteristics (silty clay very highly carbonate and gravel). However, the electrical panel (P6) is characterized by carbonate formations, in addition there is a conductive area in the center of the panel represented by clay, a range resistivity of 20 Ohm.m.

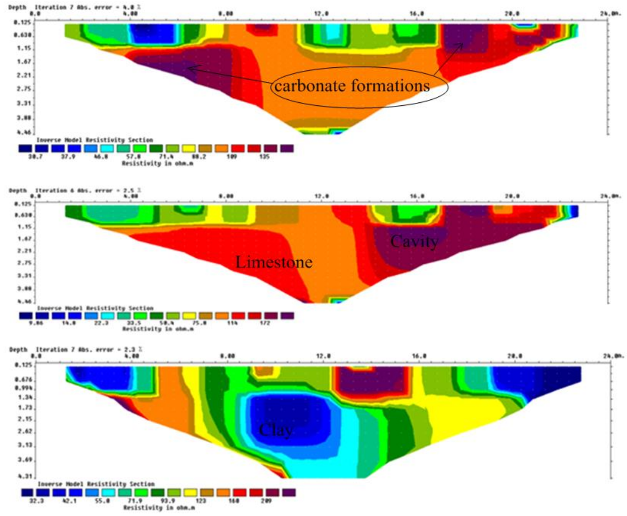

Figure 05: Electrical resistivity tomography profiles P4, P5 and P6

The P7 and P8 profiles were made at the base of the excavation has been excavated in the transversal direction, both, P7 and P8 electrical panels contain the carbonate formations (limestone) within range of resistivity from 120 to 170 Ohm.m. The results show subsoil clearly electrically resistant, however it can be said that the method of electrical tomography allows us to characterize existing formations in the site was tested.

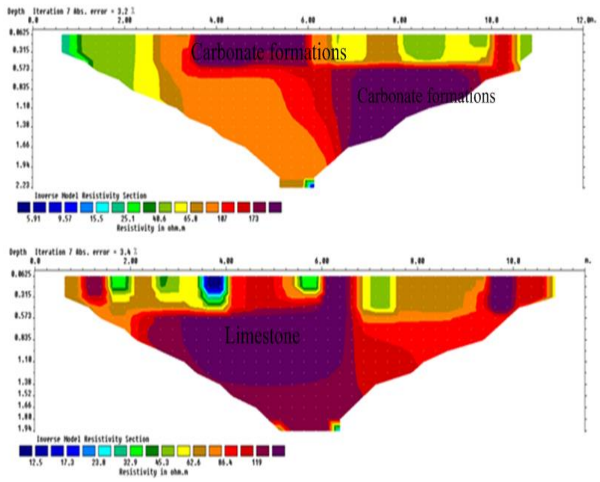

Figure 06: Electrical resistivity tomography profiles P7 and P8

Analysis of pseudo-section of the electrical profile P9, lets notice an area of very high resistivity (300 Ohm.m), it is massive and compact limestone, and a strong anomaly at the left, this may correspond to an anomaly value cavity 160 Ohm.m of resistivity, however, the characterization of which is unclear. Profile P10 shows that the subsoil consists of a clay layer located above a rock matrix; two highly resistive zones have been distinguished, the first located at a depth of 8m P10 left profile, while the other area is at the right end, the range of resistivity is more than 265 Ohm.m. It is noted, that variations in resistivity values measured in different classes in soil (Figure 3, 4, 5 and 6), it is because the resistivity of the soil depends mainly on a number of parameters such as; the porosity, the degree of saturation and the concentration of dissolved salt.

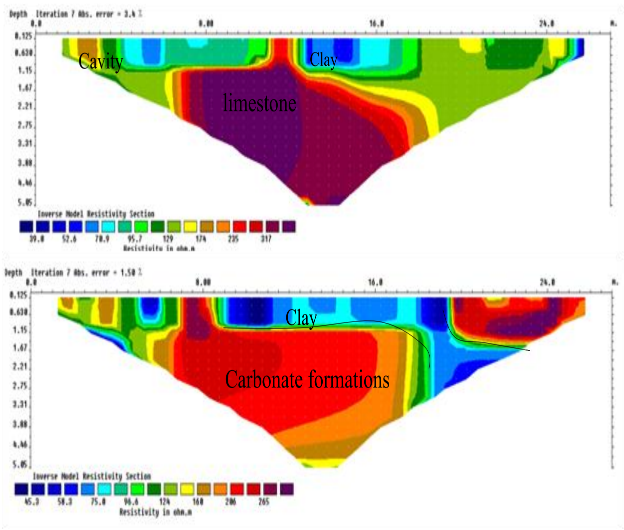

Figure 07: Electrical resistivity tomography profiles P9 and P10

5 CONCLUSION

The electrical geophysical prospecting method of electrical tomography is used to specify the location and extent of the cavities identified, the presence of underground cavities in the region of Tolga is mainly by the dissolution of limestone, electrical panels given vertical sections below profiles has been made, these panels contain information required for correct interpretations Comparing the results obtained by borehole drilling records is a very effective method.

The SPT tests have been executed give very satisfactory resistance of site. The proposed test infrastructure to achieve the total mass excavation and soil building (TVO) treated with a binder hydraulic, for example 15% of cement resistant, solution compacted layer by layer 20 to 30 cm. Cavities and voids located, according to size, can be filled with a concrete.

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