International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

Effect of Soil Cracking on 2D Electrical Resistivity Measurements

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Abstract: ***Soil cracks affect the engineering properties and behaviour of natural and engineered earth structures, and are known to contribute to slope failures. In practice, measurement of soil cracking has largely been limited to measuring crack geometries at the soil surface. In the current work, the non-invasive 2D electrical resistivity tomography method is adopted to identify the effect of cracking on soil resistivity. Horizontal resistivity profiles and 2D resistivity sections of Wenner array are used. As the resistivity of air filled cracks is significantly higher than the intact soil, cracks deviate the resistivity distribution of the soil. The high resistivity contrast between the cracks and the surrounding soil can be used to identify cracking in soil which is of a great importance in geoengineering studies, which has been hampered by the lack of non-invasive technique that can monitor cracking dynamics.***

Keywords: Soil, Cracks, Soil Cracking, Electrical Resistivity**.**

1. Introduction

Soil water content changes cause cyclic processes of swelling, shrinkage and cracking that adversely impacts the engineering properties and behaviour of soils. In particular, soil cracks alter the porosity, infiltration and runoff and create pathways for water that reduce soil strength and stability [1]. However, cracks have complex patterns that are difficult to measure. Although surface crack networks can directly be described by measuring crack geometries [2], or imaging crack morphology using surface imaging analysis [3], these methods are largely based on inadequate visual inspections. Field measurements of cracking dynamics are difficult and have largely been limited to soil pits [4], or pushing a probe wire or measuring tape into the crack [5]-[6]. Obviously, these techniques are destructive and prohibit repetitive measurements [7].

Clearly, an accurate understanding of cracking dynamics requires a non-invasive technique that can offer in-situ monitoring of cracking dynamics. The Electrical Resistivity Tomography method offers measurements that can be used at laboratory and field scales to identify the formation of soil cracks, as crack formation causes directional dependence of the electrical current flow [8]- [9]-[10]- [11]. In this paper, horizontal resistivity profiles and 2D resistivity section are used to identify the effect of soil cracking at a laboratory scale.

2. Electrical Resistivity Tomography

Electrical resistivity is a physical property that defines how a material resists the flow of electricity. The traditional four-electrode resistivity method is based on the principle that the potential drop across a pair of electrode (P1and P2) associated with DC or low-frequency current injected into the soil using another pair (C1 and C2), as shown in Figure (1), is proportional to the soil resistivity distribution [12], so that:

$$\rho = K\frac{\Delta V}{I} \quad (1)$$

Where, ρ is the soil resistivity (Ohm.m), ΔV is the voltage difference (Volts), I is the current (Amps), and K is a geometric factor (m) that accounts for the electrode arrangement.

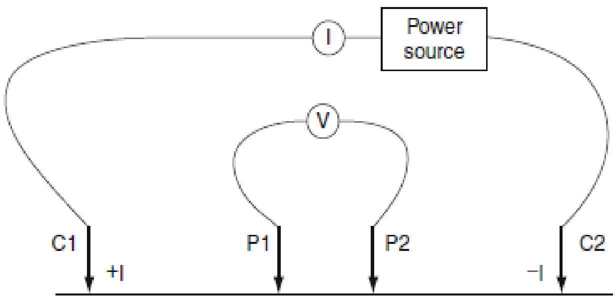

Figure 1: Four-electrode resistivity method [12]

In a modern multi-electrode resistivity method, commonly called Electrical Resistivity Tomography method [13], a number of electrode are used to collect resistivity measurements for different electrode spacing (a) and data acquisition (n) levels, see Figure (2). Figure (2) shows the schematic diagram of 2D resistivity data collection using Wenner array, adopted in this study. 2D/3D resistivity sections can be constructed using an appropriate inversion software [14].

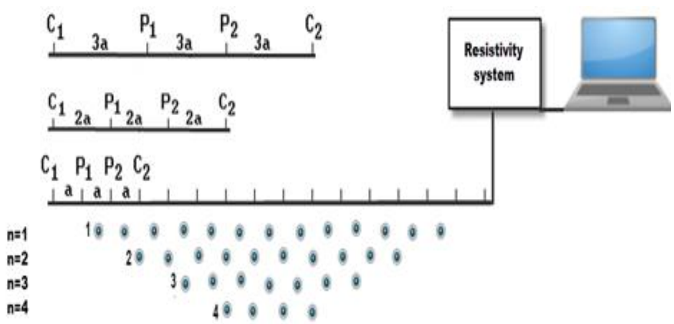

Figure 2: Schematic diagram of 2D resistivity data collection using Wenner array

3. Materials and method

Sandy soil sample compacted in a plastic container (80X60X40cm) was used in this study. The resistivity measurements were carried out using ABEM SAS 300C Terrameter along three lines (A, B, and C), as shown in Figure (3). Wenner array with a minimum electrode spacing (a) of 0.05m for four acquisition levels (i.e. n=4) was used (Figure 2). To consider the effect of cracks of a centimetric scale on resistivity measurements, a crack (6 cm depth, 0.5 cm width and 10 cm long) was introduced manually at 0.225m X distance using sheet of glass. The manually made crack represents an air-filled with high resistivity [15]. The crack does not intersect Line A, partially intersects line B and totally intersects line C (see Figure 3). Horizontal resistivity profiles were plotted to detect the lateral variation in soil resistivity. Finally, the collected apparent resistivity measurements were inverted using Ress2Dinv [14]. All the measurements were collected in a temperature-controlled laboratory. The temperature was maintained close to 20°C.

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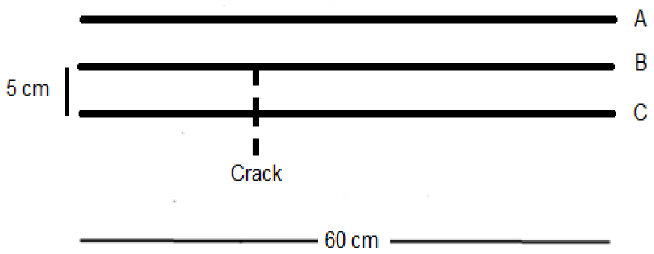

Figure 3: A sketch showing the resistivity lines A, B, and C

4. Results and discussion

4.1 Horizontal Profiling

In the resistivity method, horizontal profiling or Constant Separation Traversing CST can be performed by moving an array of electrodes with fixed electrode spacing along a profile to detect the lateral resistivity variations. As, three horizontal profiles (a=0.05m) were presented in this section. Figure (4) shows the horizontal profile of Line A. The profile shows that the resistivity does not change laterally which reflects the homogenous resistivity variations of the soil. However, a relatively high resistivity value was noticed at 0.225m where the crack is 0.05m away from the profile. Similarly, Figure (5) shows the horizontal profile of Line B. High resistivity values were measured at the position where the crack partially intersects the profile. Away from this position the resistivity changes homogenously. Figure (6) shows the horizontal profile of Line C. Clearly; the resistivity varies abruptly as the crack intersects the line completely. As the introduced air-filled crack has a high resistivity comparing to the intact soil and form barrier the disturb the electrical current [15], the crack increases the soil resistivity significantly. However, this effect is more important when the crack intersect the profile completely [11].

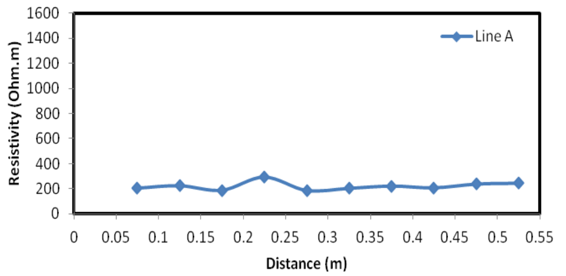

Figure 4: Horizontal profile of Line A (a=0.05 m)

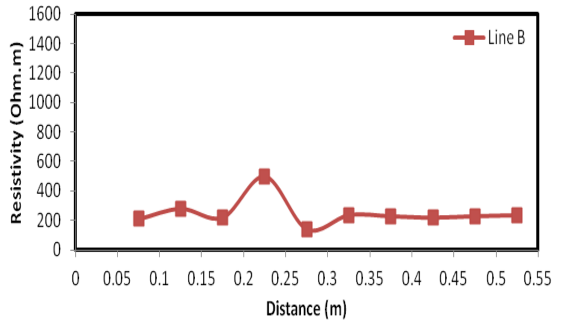

Figure 5: Horizontal profiles of Line B (a=0.05 m)

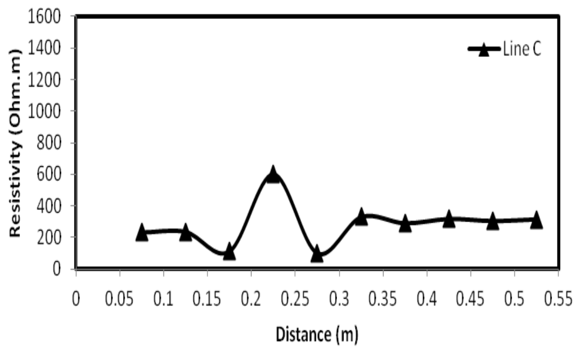

Figure 6: Horizontal profiles of Line C (a=0.05 m)

4.2 2D resistivity sections

Figure 7 shows the inverted 2D resistivity section of line A. As the crack does not intersect this line; no high resistivity changes were noticed close to the surface of the section. High resistivity values at the bottom reflect the effect of the plastic container. However, significant resistivity changes were noticed on the line B (Figure 8), where the crack partially intersects the line. For line C (Figure 9), where the crack intersects the resistivity line completely, high resistivity signature is clearly evident. Again, as the manually introduced crack is filled with air of high resistivity, the crack is reflected in high resistivity values in the 2D sections [16].

By theory, the resistivity method is based on the assumption that the subsurface is continuous, and measuring the voltage drop associated with the current injected into the soil provides information about the subsurface resistivity distribution. As the cracks form barriers that disturb the flow of current, the cracks cause a high voltage drop, and hence high resistivity, comparing to that measured for the surrounding intact soil. Therefore, cracks are expected to alter soil resistivity distribution significantly [17]. Although the actual resistivity of a dry crack can be assumed infinite [18], the measured resistivity of the clay soil containing cracks is far lower, as the resistivity measurement includes the intact soil as well [19]. However, in resistivity sections, the resistivity contrast between the crack and the surrounding soil is highly enough to be detected compared to the intact soil [16]-[19].

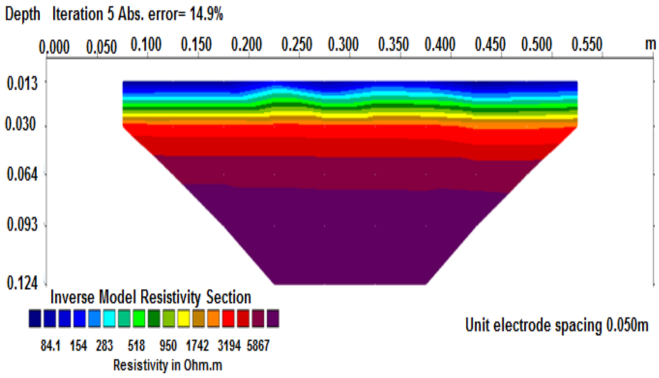

Figure 7: The inverted 2D resistivity section of line A

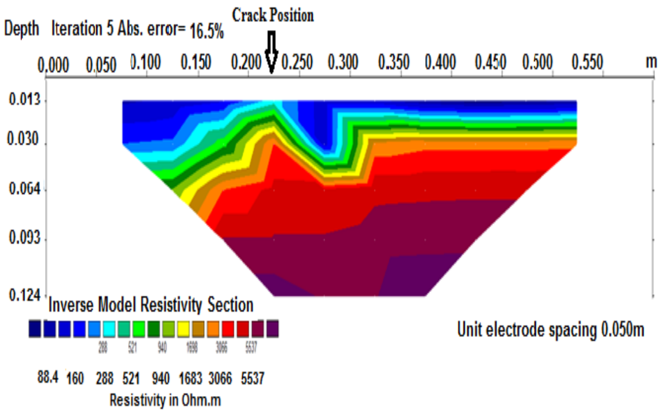

Figure 8: The inverted 2D resistivity section of line B

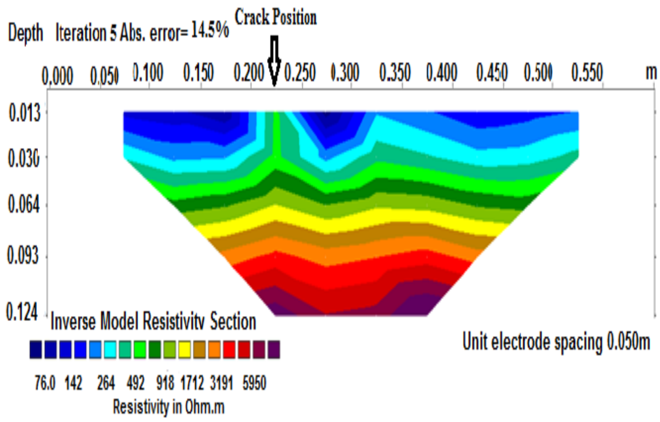

Figure 9: The inverted 2D resistivity section of line C

5. Conclusions

A non-invasive horizontal resistivity profiling and 2D resistivity sections were used to investigate the effect of cracking on soil resistivity. As the cracks are normally filled with air, the dielectric material that is infinitely resistive, cracks form barriers that alter the soil resistivity distribution significantly indicating the efficiency of the method to characterize cracking of soils which is of great importance in slope stability assessment. However, future work is needed to consider the influence of conductive water- filled cracks on soil resistivity distribution.

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Author Profile

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