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The use of Electrical Resistivity Tomography for Soil Sinking Investigation a case study in Satellite Town Langerpura Sub Himalaya Azad Jammu and Kashmir Pakistan

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Abstract: Soil sinking is a major engineering concern need to be addressed through proper planning and investigation. Usually Engineers depend on borehole data or soil tests for designing the solution for such problems. In view of cost, time and less destruction, geophysical methods are best to probe such engineering and environmental problems. Therefore, Electrical resistivity tomography (ERT) method used to investigate soil sinking in Satellite town Langerpura, Sub Himalayas Azad Jammu and Kashmir Muzaffarabad Pakistan. Two profiles acquired overlap the zone under study with electrode spacing 5m and average depth of 40-50m. Three different geological zones are identified on the base of resistivity data. Low resistivity zone having resistivity 3.0 – 15Ωm is water saturated friable sandstone. Intermediate resistivity zone with resistivity range 100-1000 Ωm consists of alternate layers of sand, clay and river deposits. High resistivity zone with resistivity range 1000-4000 Ωm show cavities in subsurface. The room size cavity detected which cause the soil sinking at surface. Muck filling or compaction grouting recommended as engineering solution for stabilization of sink soil.

Keywords: Electrical Resistivity Tomography, Soil sinking, Cavity detection

1. INTRODUCTION

The Geophysical methods assist the engineers to solve the problem through the exposure of different physical properties of the soil, by using different Geophysical methods. Electrical Resistivity Tomographic (ERT) procedure based on electric current is used to discriminate the differences of resistivity between various layers. Electrical Resistivity Tomography (ERT) is one of the most popular techniques for the shallow subsurface investigation and is applied for hydrogeological, engineering, and environmental problems (Telford *et al.*, 1990). The technique has been worked out in imaging structures from only a few millimeters to several kilometers scale (Linderholm *et al.*, 2008; Storz *et al.*, 2000). Instruments have been rapidly developing in the past decades. In most cases fully automated instruments with multiple receiver channels are used, but in large-scale applications independent dipoles for current injection and potential difference registration are used. ERT provides relatively inexpensive, noninvasive and fast means of describing spatial models of the sub surface. It is markedly propitious for polluted land, soil creep and soil sinking related engineering and environmental issues (Hemeda, 2013 and Chukwunonso 2012).

The engineering problem addressed in the current study is soil sinking that occurs as a result of water logging or percolation of water through the surface. In general, soil sinking/erosion refers to a kind of soil destabilization besides soil compaction, low fertility of soil, reduction in soil structure, poor abysmal drainage, salinization, and low pH problems. The changes in intrinsic properties the soil can regulate constructional operations as well as performance of erected structures. In this respect, ERT was appropriate in measuring the resistivity variations that is a very important physical property of soil. The cavities development creates a great focus of interest in present work as it is an important factor of water percolation beneath the surface and could trigger landslides and erosion. The current study was carried out in the newly planned satellite town Langerpura Muzaffarabad Azad Jammu & Kashmir (AJK), Pakistan **(Fig. 1).** The Government has planned to construct housing society for 2005 earthquake affecties. The area is sector wise divided by installing network of roads, power supply and sanitation **(Fig. 2).** In the next phase buildings are being constructed according to seismic building codes. The soil sinking was reported in the south western portion of the site. The current study is carried out for the preliminary subsurface investigation for addressing the problem of soil sinking in the area. Hence, the ERT was carried out to find the cause of soil sinking.

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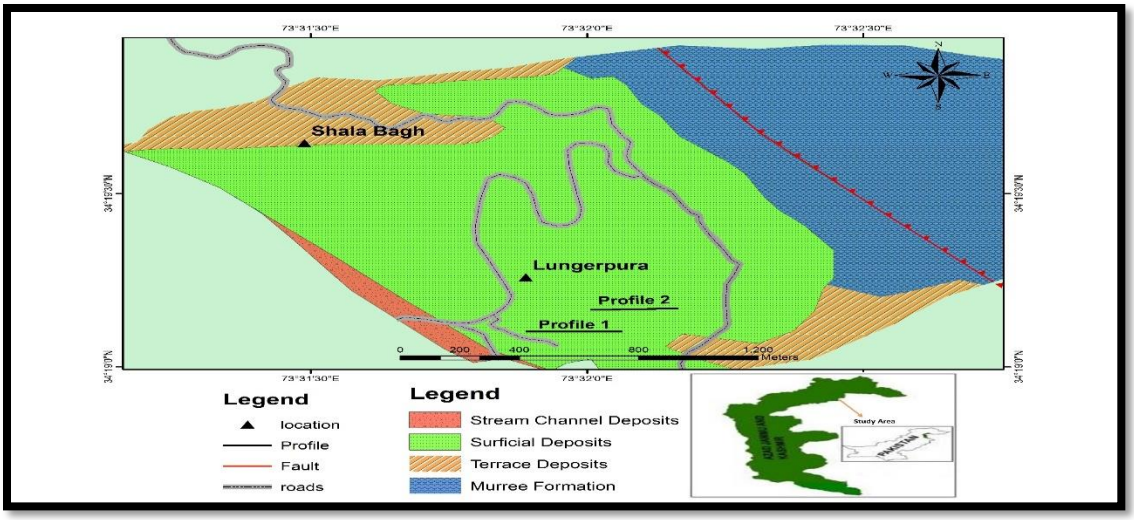

Fig. 1: Location map of study area.

Fig. 2: Google image of newly planned site for construction of Satellite Town.

1.1 Geology of the Area

The study area lies at the right bank of river Jhelum. Topographically, it consists of plain river terraces and low to high mountainous areas in Jhelum valley. The area lacks sustainable irrigation system and rain water is the main source of agriculture and the small waterways are connected to perennial hydrological sources.

The area under consideration is very close to two confronting active faults, the Muzaffarabad Thrust and the Jhelum Fault. The former has convulsed the whole region during catastrophic earthquake of Magnitude 7.6 on October 08, 2005; whereas the latter is relatively inactive. Stratigrapically study area is consisting of Miocene Murree Formation (consist of siltstone, sandstone and mudstone) and Quaternary Alluvium(river deposits consist of boulders, clay and sand.(Ibrahim 2009).

2. MATERIALS AND METHODS

Electrical resistivity tomography (2D) is a comparatively fast method allows combination of horizontal profiling and vertical sounding for data to be collected simultaneously. On other hand electrical resistivity survey (1D) has the greatest limitation that it cannot account the horizontal change in ground resistivity. Usually 1D resistivity survey acquire 10-25 subsurface resistivity reading, while 2D ERT involves 100-1000. In comparison 3D survey acquires many thousands of resistivity points (Loke, 2000; Meying *et al.*, 2018)

The multi-electrode resistivity procedure is operated by means of a multi-layered cable holding

numerous conductors (24, 48, 72, 96) as the electrodes are exerted in the ground at a definite spacing of 5m at all occasions. The electrode switching according to the pattern of predefined reading and stored inner memory of apparatus is relayed using resistivity meter. By combining different relays (transmitted (A, B) and received (M, N) pairs) of electrodes, the maximum depth of investigation (depending on the ultimate extent of cable) can be approached by constructing the mixed sounding / profiling section.

The 2D resistivity images derived through multi-electrode procedure were used to investigate subsurface structures from tens to few hundred meters, the information obtained through these images becomes complementary when used with traditional Vertical Electrical Sounding (VES) technique, determining the depth of 1D horizontal structures from near surface to the extent of few hundred meters.

2.1: Data Acquisition

Geophysical investigation done by using Sweden made instrument ABEM Terrameter SAS 4000, multichannel adopter, and cables with 48 electrodes, spaced at 5m distance acquiring total traverse length about 320m**(Fig.3).** Two resistivity profiles acquired parallel to each other with overlap the zone of soil sinking **(Fig. 4)** in each profile. The Schlumberger array configuration used for collection of resistivity data. This type of configuration is very sensitive to vertical changes in resistivity, which means that it performs well in mapping vertical structures such as vertically oriented solution-widened joints and cavities (Zhou, 2003). The investigation depth is generally the 25% of the length of profile line.The data was acquired in the month of June 2018 and the moisture contents were less in the soil during acquisition.

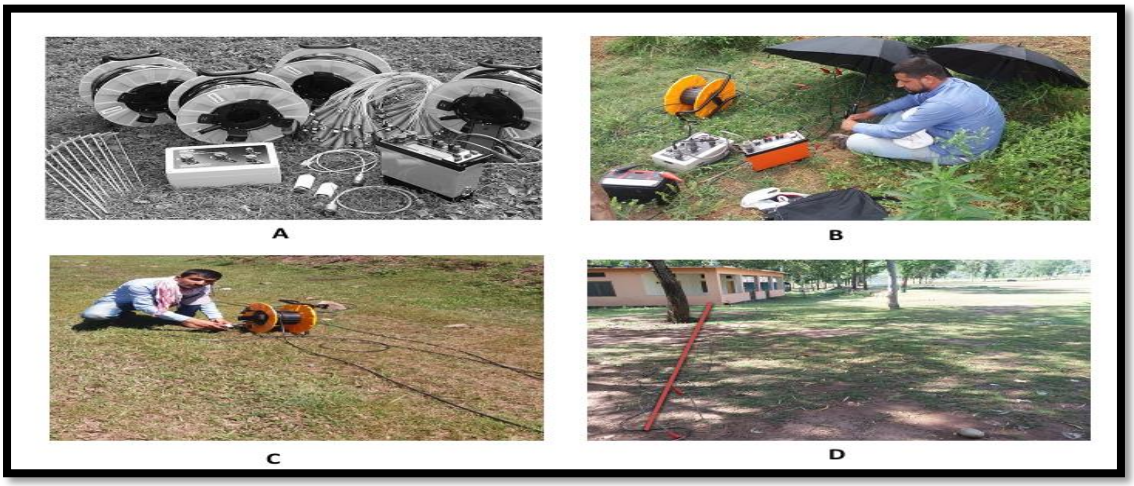

Fig.3: A Instruments use in (ERT) survey. B Field data acquisition system. C Field cables spread. DFielddata acquisition line

Fig.4: Surface indication of soil sinking.

2.2: Data processing and Modeling

The 2D resistivity framework is automatically generated using RES2DINV computer software (Griffiths and Barker 1993). The various steps have been taken in the processing and modeling of the data. These steps include removal of noisy data from each profile, checking and fixing of bad data points, A trial base inversion of data is made and initial modeling, calculation of RMS inaccuracy between the observed and calculated apparent resistivity, bad data points having huge RMS inaccuracy is cut-off from original data and Final inversion framework having least RMS errors is accepted geologically and portrayed. Otherwise these steps are repeatedly carried out to attain a final validated model.

3. RESULTS AND DISCUSSION

An ERT survey conducted to map out the lateral and vertical extent of soil sinking zone and to locate expanse of cavities/voids cause soil sinking **(Fig. 4).** With this study, it is possible to design an appropriate engineering solution to address such soil related problems. Acquired electrical profiles with 5m electrode spacing **(Fig. 5)** show a general increase in resistivity 4000-8000 Ωm (Mohamed and Fouzan, 2013)from surrounding to show the cavity in both resistivity profiles. The room size cavity is detected in both profiles at location of soil sinking. Void was encountered on profiles, and according to studies (Anderson *et al.*, 2006), air-filled cavities usually show very high resistivity values, usually more than 1000 ohm-m, but again, are variable, relying on the geo-electric conductivity of surrounding beddings and void's morphology.

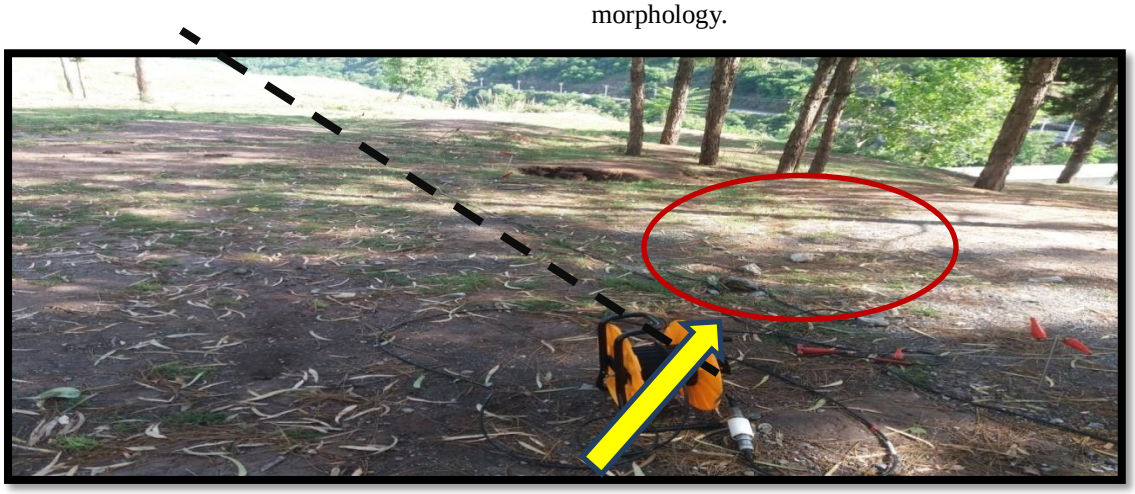

Fig. 5: Resistivity profile line over sinking area.

3.1. ERT Profile-1

Three different zone marked from resistivity data in profile 1 **(Fig. 6);** (i)Alternate layers of alluvium, sand and silt with resistivity range 40-350 Ωm (ii)Friable sandstone with water traces resistivity range 1-15 Ωm and (iii) Cavity zone having very high resistivity up to 4000 Ωm. Similar results obtained in Laclede County in South-Central Missouri by (Obi, *et al.*, 2012) "The use of electrical resistivity tomography (ERT) to delineate water-Filled vugs near a bridge foundation".". The average depth of bed rock in surrounding area is 30m consist of sandstone, Siltstone and clays of Murree formation

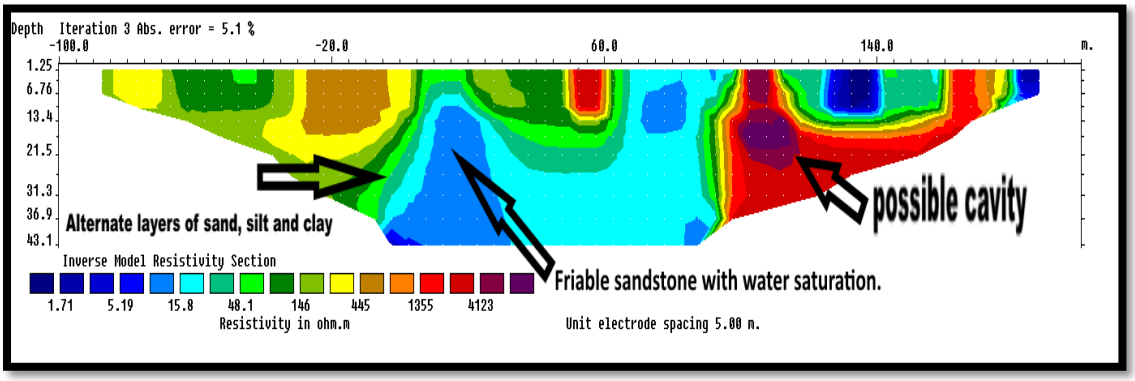

Fig. 6: Inversed section of Profile-1

3.2: ERT Profile-2

The size and location of cavity conformed in second profile at location of overlap. Similar soil and rock identifies, and good water indication seen in profile 2 **(Fig. 7).** The rock is highly saturated because friable sandstone has good porosity. The comparison of both profiles indicated the limited extend and size of the cavities at same locations **(Fig. 8)**

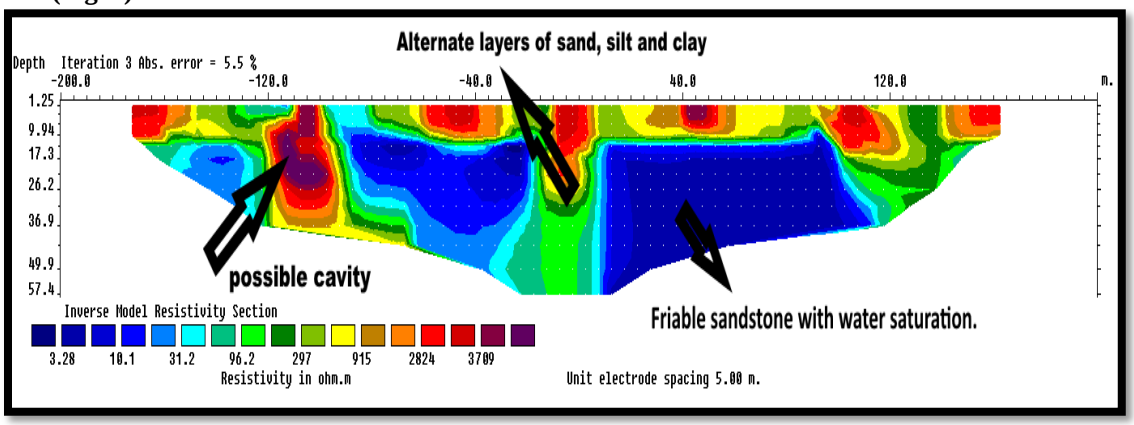

Fig.7: Inversed section of Profile 2

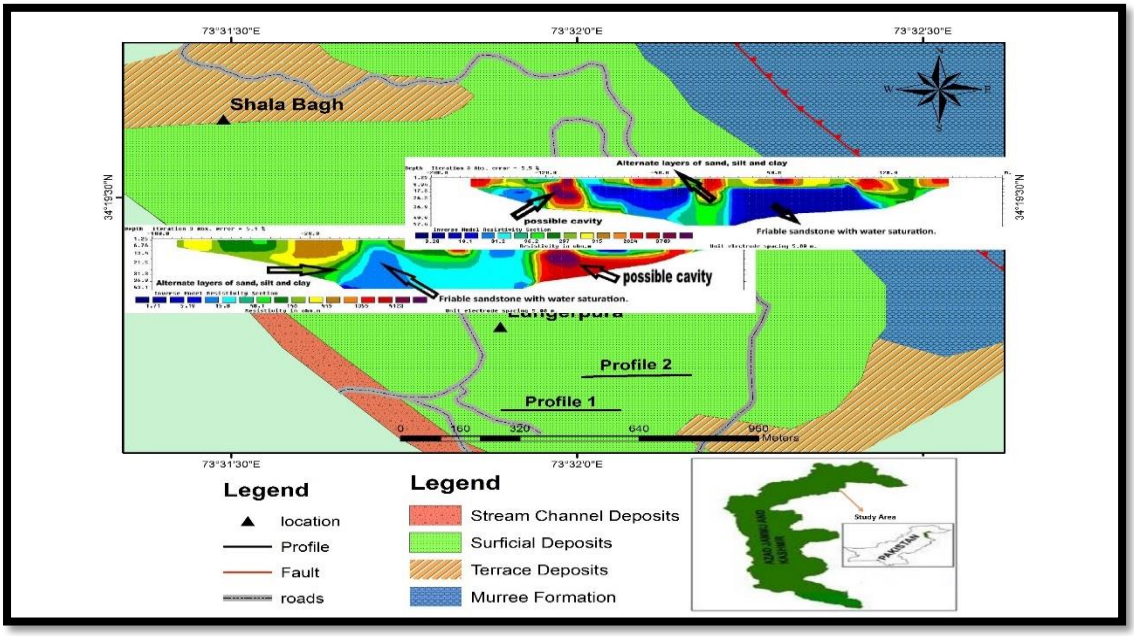

Fig. 8: Comparison of both inversed resistivity sections with overlap.

4. CONCLUSION

In order to map out the reason behind soil sinking in Satellite town Langerpura ERT survey deemed the appropriate geophysical tool to be used for site characterization. The result of this survey was used to determine the proper engineering solution to be employed to achieve this purpose. Cavities encountered with resistivity range 1000-4000 Ωm beneath the sinked soil are limited in size and extent. These cavities can cause landslides if not addressed through proper engineering solution. They developed most probably along horizontal bedding planes and are likely to be partially filled air and water. The drainage either internal or external starts cavities development and soil erosion. The low resistivity in the area is showing the saturated rock with good porosity. Based on the result of ERT, voids/cavities were detected along resistivity traverses close to the sinked soil in study area. The voids/cavities backfilled by muck material and drainage system channelize properly. Relatively expensive solution is backfilling by using compaction grouting technique. Compaction grouting is a grouting technique in which the low slurry slump is injected by means of an injection pipe in the voids and sinkholes of the soils or rocks to enhance their strength and elastic properties. This technique artificially increases density and stability of loose soils. Government authorities should consider this study for future city development plan.

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