HIGH-RESOLUTION GEOELECTRICAL CHARACTERIZATION OF THE CONDITIONS OF THE COVERAGE OVERLYING A TUNNEL BEING EXCAVATED BY A NEW 3D DATA ACQUISITION TECHNIQUE

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Abstract. The electrical resistivity tomography (ERT) is a method designed to measure the distribution of apparent electrical resistivities in the subsoil by means of a great number of observations, with the aim of determining an image of the underground geological/anthropic structures in terms of true resistivity values retrieved by the inversion of the acquired data. Such technique can be carried out to define 2D, 2.5D or 3D models of the subsurface (e.g., Drahor *et al.,* 2007; Chambers *et al*., 2011; Di Maio and Piegari, 2012; Di Maio *et al*., 2016). However, dense electrode arrays are required to assure high-resolution (HR) 3D images easily readable by users. For a 3D ERT, usually, the electrodes are placed in a square or rectangular grid keeping the distance between adjacent electrodes constant in the *x* and *y* directions. Another common electrode configuration consists of a series of parallel lines whose inter-space must be smaller or equal to two times the electrode separation. These electrode dispositions are difficult to

realize in complex contexts, such as strong topographic variations, dense vegetation, rough terrain around landslide areas. To overcome such problems and to reduce costs, HR 3D ERT data acquisitions with *non-conventional* geometries of electrodes have been proposed. In this work, the results of a 3D ERT survey carried out by a new layout of electrodes that makes use of cross-cable quadrupoles (i.e., all possible combinations of transmitting and receiving dipoles that are not on the same line) is shown. The proposed technique is particularly suitable in presence of strongly three-dimensional features that necessarily require 3D surveys, limited availability of space for electrode disposition, limited budget for surveys, logistical difficulties.

In this work, a non-conventional 3D electrode configuration is proposed for a high-resolution characterization of the conditions of the coverage overlying a tunnel being excavated (Fig.1). The adopted scheme has been able to provide a very detailed image of the investigated survey area allowing to discriminate of the phenomena of instability in place on the site in question.

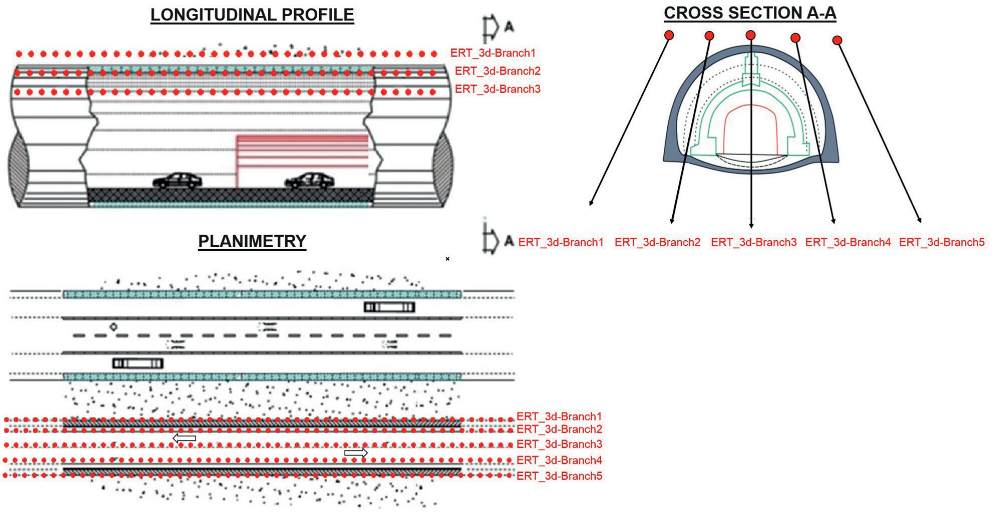

Fig. 1 - Acquisition geometry.

Method. Conventional design for a 3D ERT survey requires data acquisitions along parallel profiles (2.5D modeling) or along a grid of electrodes (3D modeling). The latter has usually small size being limited by the number of electrodes that can be managed by the modern georesistivimeters, generally 48, 72 or 96, which, therefore, allow high-resolution investigations only for the shallowest portions of the subsoil.

To obtain both HR resistivity distribution and greater investigation depth, in this work an unconventional 3D electrode geometry is proposed for the electrical characterization of the subsoil, whose complex topography prevented the use of conventional electrode arrays. The adopted 3D acquisition scheme is based on a sequence of measures designed ad hoc, which allows to use the electrodes of each cable both as transmission and as measuring devices. This means that the position of the transmitting (TX) and receiving (RX) dipoles is continuously modified to obtain a uniform coverage along the measurement profiles and along all three spatial directions. Specifically, the ERT-Lab Sequencer software (distributed by Geostudi Astier S.r.l.) has been used that allows to set complex acquisition geometries by choosing cross-cable sequence generation according to the specific requirements for the survey area. Such a procedure is thus able to provide a real volumetric distribution of apparent resistivity values and not an interpolated one, like that obtained from a pseudo-3D (or 2.5D) ERT technique. Finally, the successive processing of the acquired data by suitable inversion software provides the exact nature of the subsoil 3D model.

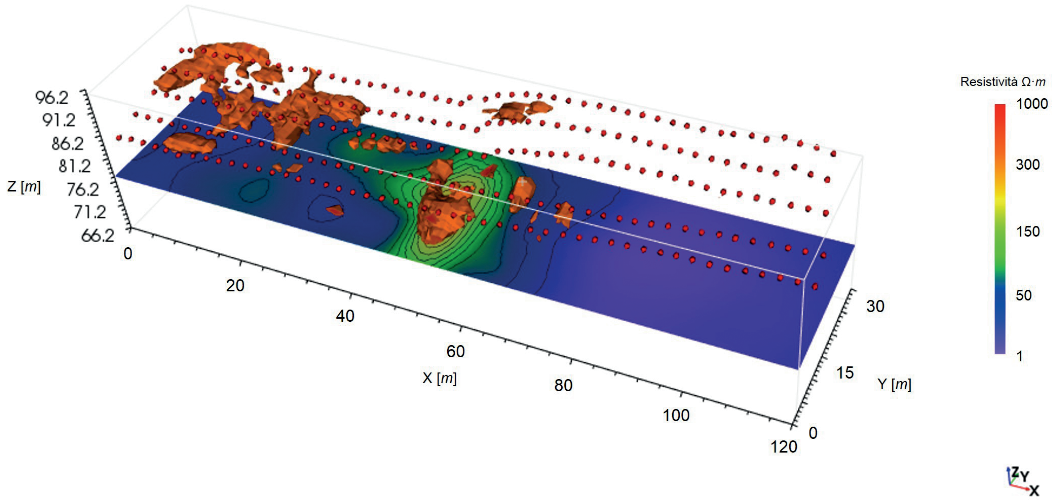

Fig. 2 - View of subsoil portions corresponding to the most resistive ρ value ranges.

Site investigations. The area of investigation is located it is located near the variant of *Palizzi SS 106 Jonica*.

The survey area is characterized of quaternary deposits, the studied succession was alternation of sand and silt. These deposits are moregravelly at the base (sand with metamorphic clasts).

The presence of these scant cohesive deposits can generate detachments during the excavation of a tunnel.

3D ERT survey. The non-conventional 3D electrode geometry in the survey area consisted of five profiles of length 24 m and distant 6 m each other (Fig.1). Thus, the three-dimensional ERT data were collected on a rectangular grid of 117.5 × 24.0 m^2.

A total of 240 electrode stations (red dots in Fig.1) along five lines, plus two infinite electrodes, were arranged in the field, and 14873 data points were collected using the pole-dipole array with an inter-electrode space of 2.5 m.

The latter has been chosen as it is able to give: exploration depth and 3D coverage greater than that provided by symmetric electrode configurations; good signal to noise ratio; multi-channel receiver optimization. The IRIS Syscal Pro multi-channel georesistivimeter with 96

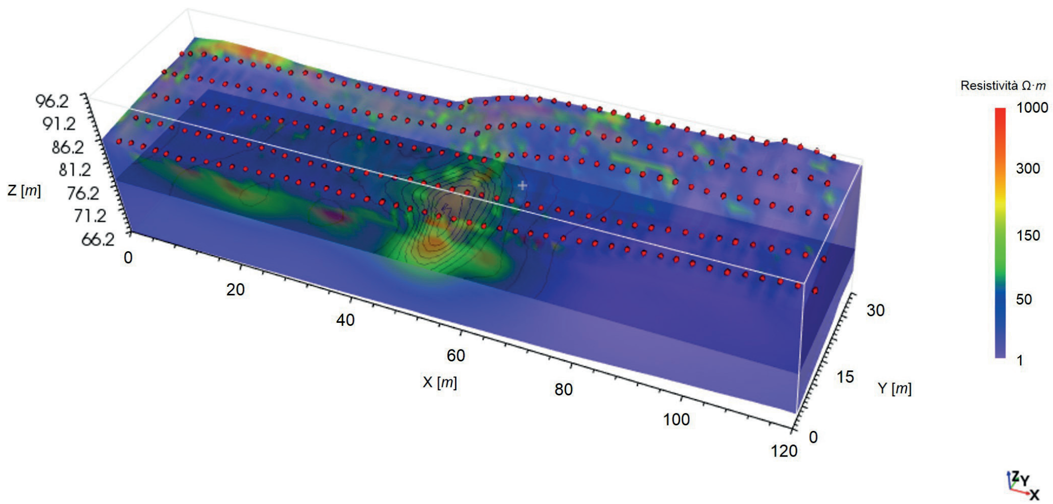

Fig. 3 - 3D resistivity model of the investigated area.

electrodes was used. The set of acquired apparent resistivity data has been implemented in a single 3D model, which takes into account the elevation of the measure electrodes, and then appropriately processed, filtered and inverted using the ERT-Lab_64 software (Geostudi Astier S.r.l.). The 3D electrical resistivity model of the investigated subsoil has been obtained by using a three-dimensional finite element method with a tetrahedral mesh with a resolution of 50 cm. A rapid convergence of the model response to the field data was reached, with a RMS error lower than 5%. Finally, by using the ViewLab3D software (Geostudi Astier S.r.l.), a three-dimensional visualization of the investigated slope in terms of electrical resistivity.

Conclusions. The data processing shows a clear contrast between the sedimentary cover and the void created during the tunnel excavation, subsequently verified with direct investigations.

Indeed, high-resistivity values, more than 800 Ωm they are characteristic (Fig. 2), in this case, the presence of cavities. While values between in the range 150 Ωm $\leq \varrho \leq$ 700 Ωm they are representative of unconsolidated material (Fig. 3). Conversely, low-resistivity values, in the range 1 Ωm $\leq \varrho \leq$ 150 Ωm (Fig. 3), values associated with the lithology rich in silts and clay which are present in the examined area.

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