# Evaluation of determining the electrical resistance of soil over a wide range to measure the corrosivity of soils - Case study: Kermanshah urban train

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**ABSTRACT**

**This research presents the results of field studies of large-scale underground geoelectrical explorations. The study area is the 14-km route of the first line of the Kermanshah urban train project. Studying the electrical resistivity of soils at the depth of boreholes can provide useful information about their corrosion susceptibility to designers of reinforced concrete and steel structures. The four-electrode Wenner method is the basis for the field measurements of this study and the presentation of its findings. To conduct electrical resistivity tests at different depths of urban train track boreholes, the precise findings of the Megger DET5/4D device were used. Electrical resistance tests have been conducted in 15 boreholes at 12 different stations of the project for at least three depths of 3, 5, and 7 meters. According to the comparison of the results of these tests and the tolerance table, the soil corrosion level, based on the Romanoff quantitative soil corrosion criterion, was moderate to severe at stations 4, 6, and 9 at the time of the tests, and moderate at the remaining stations. The field results of this study, along with the findings of other research studies, show that the presence of the Qarehsu and Abshuran rivers within Kermanshah city and the leakage of wastewater into these rivers, as well as the presence of extensive clay and calcareous soil beds, are the main factors in identifying moderate to severe corrosion potential in most parts of the city, especially in areas adjacent to these rivers.**

**KEYWORDS**

**Geophysical study, soil electrical resistivity, soil corrosion, 4-electrode method, Kermanshah urban train.**

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## 1. Introduction

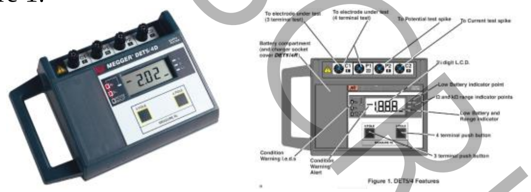
Before constructing engineering structures, it is of great importance to conduct studies related to the corrosivity of soils. Steel and reinforced concrete structures are each affected in some way by damage from corrosive soil environments. Damage to steel and concrete has irreparable consequences on the serviceability and lifespan of structures. Therefore, to determine the degree of soil corrosion, the geo-*electrical resistivity tomography (ERT)* method is one of the most widely used and important geophysical methods for indirectly and non-destructively determining the subsurface conditions of soil and rock beds at the construction site of structures. In addition to general subsurface identifications, the presence of any problems, cavities, subsurface irregularities, the status of groundwater aquifers, and other issues can be well detected using this method. In this research field, valuable studies have been presented in the last decade in different climatic conditions, in order to exploit the results of different methods of measuring subsurface electrical resistivity.

For example, in the study by Mendoza et al. [1], a two-dimensional joint inversion of data with dipole-dipole, Schlumberger and Wenner configurations was applied to real and synthetic data. Their results show that the application of joint inversion is better than using separate inversions because joint inversion uses higher data density and different electric current distribution in the subsoil. In the study of Constantin et al. [2], 2.5-dimensional ERT measurements performed with an inverted Wenner-Schlumberger array complemented the microgravity and seismic results of their previous research program and contributed significantly to the identification of *karst voids* in a highly heterogeneous karst environment in Germany. In the work of Aizebeokhai and Oyeyemi [3], the potential of using a multi-gradient array, an unconventional electrode configuration, for cost-effective and rapid subsurface resistance measurement and inductive polarization mapping has been evaluated. This array has been used for two-dimensional electrical resistivity measurements and time-domain induced polarization imaging at a study site in Ota, southwestern Nigeria. In the article by AL-Hameedawi et al. [4], three types of ground heterogeneity and their effect on apparent electrical resistivity were measured and inverse electrical resistivity tomography models were investigated. According to their results, the dipole-dipole array provides better resolution and can identify subsurface layers with greater accuracy.

The study by Bellmunt and Marcuello [5] also deals with ERT data and uses linear combinations of the data to obtain other subsurface identification data sets that have not been directly measured. According to the method presented in their research, quasi-polar-dipolar datasets can be acquired with common equipment, using standard polar-dipolar recording sequences. However, according to detailed comprehensive studies, as an important innovation, the results and precise details of the geoelectric method of measuring electrical resistivity on a large scale (especially in domestic research) to investigate the corrosion potential of soils have not been examined so far. Determining soil corrosion zones in a large urban area can prevent damage caused by it and the imposition of large unwanted costs in the construction of steel-concrete structures. Therefore, in this study, this important issue has been carefully examined and evaluated in a technical format, relying on actual field findings in a large case study project including the Kermanshah urban train [6].

## 2. Methodology

In this research study, the precise findings of the Megger DET5/4D device were used to prepare field data and conduct electrical resistivity tests at different depths of urban train track boreholes [7]. The Megger DET5/4D is fully automatic, four terminal instrument, housed in a rugged, water-resistant case, protecting the instrument for outdoor use. This instrument is suitable for testing earth electrodes and measuring the electrical resistance of the earth [7]. The present instrument has the ability to measure electrical resistance from 0.01Ω to 19.99 kΩ with an accuracy of 0.01. Measurements can be performed with this device in two general methods, including the Fall-of-Potential test and the slope method. Soil resistivity measurement through three or four-terminal measurement and high tolerance to spike resistance helps in testing it in urban areas. It also has the ability to suppress noise up to 40 V. This device complies with international standards IEC364, VDE 0413, BS7671 [7]. The following is a picture of the device and an introduction to its various parts in Figure 1.



(a) (b)

**Figure 1. The four-electrode device used to measure apparent electrical resistivity of earth layers, including: (a) 3D view and appearance, (b) introduction of the various components and parts of the device [7]**

## 3. Results and Discussion

Figure 2 shows sample images of geoelectric tests conducted at stations M4, M5, and M7 at depths of 3, 5, and 7 meters, along the Kermanshah urban train route [6].

Station M7 stations M4 and M5

**Figure 2. Sample images of geoelectric tests conducted at stations M4, M5, and M7 at depths of 3, 5, and 7m [6]**

The apparent electrical resistivity of the soil measured in terms of ohm-centimeter units at three different depths of 3, 5, and 7m in boreholes of 12 stations along the route of the Kermanshah urban train project (which completely covers all 8 urban areas of Kermanshah) is presented [6]. According to the comparison of the results of this test and the tolerance table, the soil corrosion level at stations 4, 6, and 9 at the time of the tests, based on the Romanoff criterion, is moderate to severe, and at the remaining stations it is moderate [6]. According to the graphs in Figure 3, the lower the specific electrical resistivity of the soil environment, the greater its corrosion potential will be.

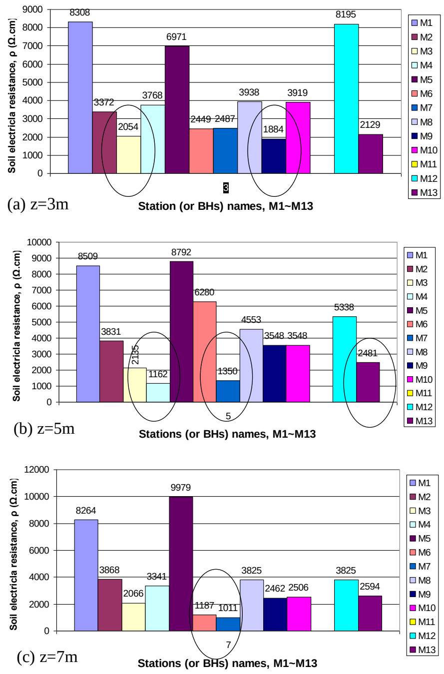



**Figure 3. Results of electrical resistivity measurements in the boreholes of the 13 urban train stations, including depths: (a) 3m, (b) 5m, and (c) 7m**

## 4. Conclusions

In this study, the subsurface specific electrical resistivity of soil layers in the urban area of Kermanshah along the excavations of the Kermanshah urban train 14km route has been studied and evaluated using a field method. Some main results are as follows:

1. Based on existing scientific documentation and research measurements, the presence of permanent rivers within the city and the leakage and infiltration of sewage and leachate into them at different sections and locations can lead to the leakage of various chemicals into the soil and changes in its conductivity and specific electrical resistance at different depths.
2. The presence of extensive subsurface clay-limestone beds, as well as the infiltration of leachate and sewage into the soil at the leakage points of rivers within the city and its sewage network in some parts of the city, has caused the soil corrosion potential threshold to be moderate to high in most of the boreholes dug on the Kermanshah urban train route.

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