Iranian Journal of Engineering Geology
Winter 2020, Vol.12, No.4

Case study on the effect of physical parameters in electrical resistivity of fine grained soils

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Abstract

Soil electrical resistivity is an easy indicator of soil corrosion potential assessment. In order to investigate the soil corrosion in an industrial zone on the margin of the Meyghan salt lake (Kheyr-Abad industrial town), the electrical resistivity was measured by Miller box in laboratory considering different conditions in terms of moisture content. Soils in the region are generally fine-grained and typically are from clay type (CL/CH) according to USCS. In the minimum considered moisture content for the test, which correspond to the dry season, the soils of the study area have the moderate to the severe corrosive potential that increases to the Meyghan lake side. The corrosion potential pattern in superficial soils (0 to 5 m) follows northeastern to southwest waterway channels and is more homogeneous in the deeper parts (5 to 10 m). With increasing moisture content, the electrical resistivity is strongly reduced and in the moisture content of 25%, the corrosion potential of the soils of the study area increases to severe and very severe. Analysis of covariance and correlation coefficient of resistivity decreasing ratio due to increased moisture content with the basic physical properties of soil indicates that the fine grained material content (passing #200) has the most effect on the decreasing of resistivity. The plasticity index, liquid limit and dry density have minor effects in comparison to fine grained material content.

Keywords: *Electrical resistivity, soil corrosivity, soil physical properties, Miller box*

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Extended Abstract:

1. Introduction

Soil corrosivity potential could be investigated by soil electrical resistivity measurement. It is known that soil physical properties affect the electrical resistivity and corrosivity potential. Yahaya et al. (2011) studied the effects of water content and amount of clay minerals on soil corrosivity and showed that water content had more effect on soil corrosivity than clay minerals. Tahir et al. (2015) investigated various parameters affecting soil corrosivity and stated that electrical resistivity and soil chloride ion content are the main parameters affecting the corrosivity. Taghipour et al. (2016) examined the physical and chemical properties of soil samples from the one-meter depth of sediments near the coast of Bushehr province and proposed an algorithm to classify the soil corrosivity. The effect of water content on electrical resistivity has also been addressed by other researchers such as Murad (2012) and Hazreek et al. (2015). In some studies, the effects of density, soil type, and water salinity have been mentioned as other important factors, but the effects of known physical parameters such as the fine particles content and the Atterberg limits as well as their priority effect on electrical resistivity changes have not been investigated. The purpose of this study is to investigate the corrosivity potential of soils in an industrial area and also to compare the effects of soil physical parameters, including dry density, liquid limit, plasticity index and fine particles content to determine their preference for decreasing electrical resistivity due to the increased soil water content.

2. Site Location and Soil Samples

The soil samples are gathered from the Arak Anode Manufacturing Project of Iran Aluminum Company site at the west of the Kheir-Abad Industrial City. The site is located a short distance from the Mighan salt lake and according to the preliminary geological studies, surface soils have corrosivity potential, where it is important to study their electrical resistivity in different conditions. The surface geological units of the site are from Quaternary age and are formed by floods on Mighan salt Lake. Surficial soils are mainly fine-grained and are saline in the areas near the margin of the lake. Groundwater levels vary within the study area and reach a maximum of 10 m depth in the dry season (Pazhoohesh Omran Rahvar, 2015)

41 samples were used in this study, all of which are composed of fine-grained soils. As the main purpose of the study was to evaluate the soil corrosivity, the depths of the samples were limited to the less than 10 m, corresponding to the buried structures. All samples are clay-type except for 2 cases. Four parameters of soil physical properties have been selected, to investigate the effect of geotechnical properties and parameters on changes in soil electrical properties. Selected parameters are simple and basic soil identification parameters that are available in most site identification studies. The parameters are density, #200 passing, liquid limit, and plasticity index. Although the samples were randomly selected from boreholes, their distribution throughout the area was taken into consideration and it was attempted to sample the whole study area as far as possible. Also, it was attempted that the four selected basic physical characteristics have acceptable dispersion.

3. Electrical Resistivity Tests

Soil electrical resistivity has been measured by laboratory Miller soil box based on the ASTM G57-95a (2001) standard method. To study the effect of water content changes on the soil electrical resistivity and the relative effect of soil physical parameters on the rate of electrical resistivity change, four different soil water contents were performed for all soil samples. The lower limit was 10%, which corresponds to the natural water content of the soils up to a depth of 10 m in dry seasons, also the electrical resistivity of soil at water contents of 15%, 20% and 25%were measured for all soil samples.

4. Results and Discussion

Samples were divided into two groups: depth less than 5 m and depth more than 5 m to investigate the soil resistivity in the dry season. Fig. 1 shows the zoning of the electrical resistivity values at depths of 0 to 5 m and 5 to 10 m for 10% soil water content. As can be seen, in both maps the electrical resistivity decreases from northeast to southwest. Besides, the comparison of the two maps shows that the resistivity values increased with increasing depth. According to BS 7361 (1991), the studied soils are in the category of corrosive to moderately corrosive soils.

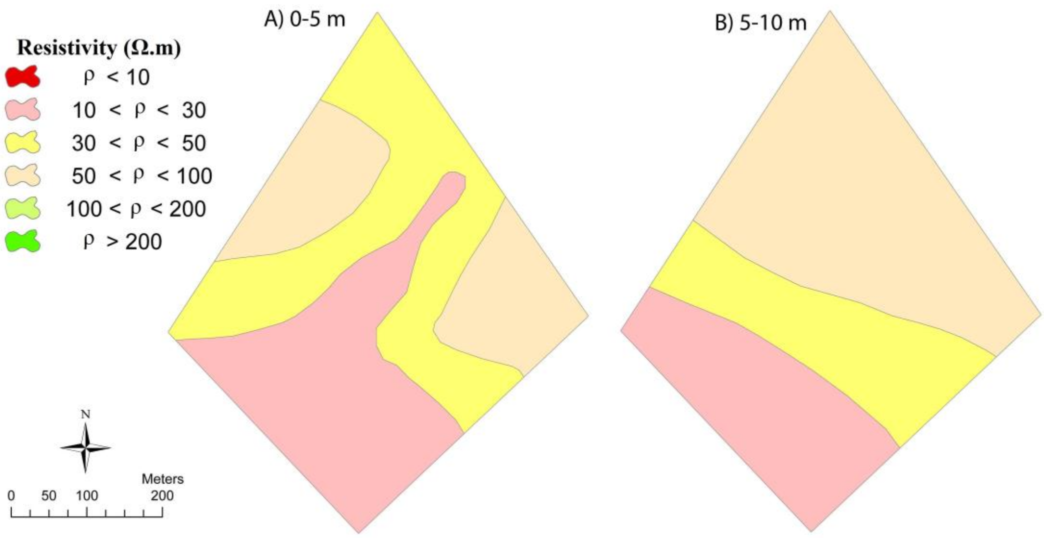

Fig. 1. Electrical resistivity of samples with 10% water content at A) depth of 0 to 5 m and B) depth of 5 to 10 m.

It is important to note that the low water content values for the samples correspond to the soil water content in the dry season, and if the water content increases, the resistivity values will change. Fig. 2 shows the variation of the mean values of soil electrical resistivity in terms of different amounts of soil water content. The range of the standard deviation around the mean is also shown in this figure. It is observed that by increasing the soil water content from 10% to 15%, the amount of electrical resistivity decreases sharply. This reduction is approximately 70% of the electrical resistivity at initial water content. By increasing the water content to 20% and 25%, the electrical resistivity decreases once again, however, the amount of reduction is lower in the later stages compared to the first-order reduction.

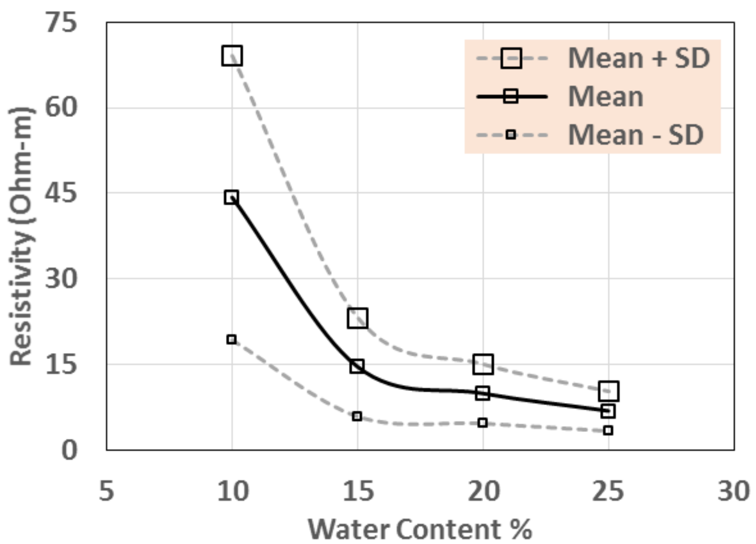

Fig. 2. Variations of electrical resistivity of soil samples with water content

Considering the electrical resistivity values in soil samples with 25% water content, almost all studied areas fall into the category of corrosive and highly corrosive soils. To investigate the relative influence of the physical properties of the fine-grained soils on the rate of decrease in resistivity due to increased water content, the Resistivity Decreasing Ratio (RDR) is defined as follows:

$$RDR = \frac{R_\omega - R_i}{R_i} \quad (1)$$

Where R_i is the initial resistivity of the soil sample and R_ω is the modified electrical resistivity of the soil at ω water content. In this study, the initial resistivity value is equal to the soil sample resistivity at 10% water content which corresponding to the natural state of soil in the dry season. The modified electrical resistivity is taken to account as the soil electrical resistivity at 15%, 20% and 25% water content. Covariance and correlation coefficients were calculated and used to investigate the relationship between the RDR and soil physical properties.

Table 1 shows the covariance values and the correlation coefficient between the RDR and the basic soil physical characteristics including dry density, passing #200, liquid limit, and plasticity index. The correlation coefficient of all parameters is positive, which means that the RDR increases with all four parameters. According to the correlation coefficients, it can be concluded that all four parameters are effective on the RDR. Among the four physical properties, the passing #200, especially at high water contents, was most correlated with the RDR and the plasticity index and liquid limit are the second and third ranks. The correlation coefficient of the RDR to dry density is also the lowest.

Table 1. Covariance and correlation coefficient of RDR with soil physical properties

Statistical Parameter	ρ_d	Passing #200%	Liquid Limit	Plasticity Index
COV ($\omega = 15$)	0.19	59.66	43.98	39.82
COV ($\omega = 20$)	0.14	54.10	28.75	24.78
COV ($\omega = 25$)	0.07	41.54	20.65	15.43
R_{xy} ($\omega = 15$)	0.19	0.25	0.23	0.27
R_{xy} ($\omega = 20$)	0.25	0.41	0.26	0.30
R_{xy} ($\omega = 25$)	0.18	0.43	0.26	0.26

5. Conclusion

Soil electrical resistivity was evaluated using in laboratory measurements on 41 samples of fine-grained soils of the Arak Anode Manufacturing Project of Iran Aluminum Company site. The samples were prepared at different values of density and water content and soil electrical resistivity were measured. Based on the criteria for soil corrosivity assessment, the results show moderate to severe corrosivity potential in natural minimum water content in the soils of the region that increase toward the Mighan salt Lake. As the soil water content increased, the amount of resistivity decreased sharply and it was expected that at a water content of 25%, the corrosivity potential of the soils would increase to a very severe degree. The relationship between the ratio of decrease in electrical resistivity due to increased water content and soil physical properties with covariance and correlation coefficient indicated a major effect of the passing #200. The reduction of soil electrical resistivity in the next step is affected by the plasticity index, liquid limit, and dry density.

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