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Compaction Control of Clayey Soils Using Electrical Resistivity Charts

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Abstract
Traditionally, electrical resistivity tests are being used for geophysical characterization but the electrical properties of soils can also be explored for compaction control of geotechnical works. Theoretical relations for estimating the electrical resistivity can be derived based on the degree of saturation and can be plotted in a chart relating water content with dry volumetric weight. The curves for specific values of electrical resistivity considering different degrees of saturation and porosities define an electrical resistivity chart, which can be used for compaction control of clayey soils. However the contribution of the water adsorbed in the electrically charged clay minerals surfaces must be considered, as they increase electrical conductivity. This paper presents the results of an experimental study in which the electrical resistivity was measured in different specimens of white kaolin compacted with different voids ratio and molding water contents. Discussion is made over the influence on electrical resistivity of the structure induced by the compaction process. Experimental data allowed defining the resistivity chart for this clay, which differs from the theoretical chart defined based only in the degree of saturation. Considerations are done about how this information can be used in compaction control considering the definition of resistivity charts and different clayey soils.

Keywords: compaction control; clayey soils; electrical resistivity; degree of saturation.

1 Introduction

The use of electrical resistivity for soil geophysical prospection tests is well defined in standard tests (Holyoake *et al.* 2014). The measurement of electrical resistivity for this purpose can be used as an alternative to traditional methods and was investigated in this paper. The use of this technique for *in situ* prospection allows characterizing wide open areas and large depths, while for compaction

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control the measurements are localized. However both cases are ruled by the same principles.

Electrical resistivity of Geomaterials is affected by the presence of water filling their pores and is influenced by the structure of these materials because pores geometry affects the liquid phase and therefore the path followed by the electrons. Compacted soils are unsaturated soils and it is well known that the degree of saturation must also be considered because electrical current through the porous media depends on the continuity of the liquid phase due to the fact that the electrical conductivity of water is much larger than that of the solids. Adding to that, the nature of the pore fluid is also important.

Soil physical properties relevant for studying electrical conductivity may be controlled by the compaction process because soil structure and degree of saturation in compacted clays depend on the choice of the compaction interval. Based on this, an extensive set of experimental tests was performed in which several samples were prepared with different water contents and void ratio, for which the electrical resistivity was measured for the water content at compaction and after full saturation. Data collected allowed to draw resistivity charts, which are curves connecting the points where equal resistivity was found in plots of water content versus dry volumetric weight. Such curves can be used for compaction control if compaction curve is known.

Various relations for the electrical resistivity (or the inverse, which is electrical conductivity) have been proposed for specific types of soils based on their degree of saturation, porosity, pore fluid conductivity and cation exchange capacity. The simplest are based only on the degree of saturation. These theoretical relations were used to draw resistivity charts and were compared with the experimental charts. The differences found are commented in the paper based on how they are affected by soil structure and on the simplifications taken for defining these charts. The paper ends discussing the practical use of such charts and how this information can be extrapolated for other kinds of compacted soils.

2 Electrical Conductivity in Clayey Soils

In coarse granular soils, electrical resistivity is affected by the soil porosity/tortuosity and also by the nature of the pore fluid. Soil structure can influence electrical flow because the arrangement of the pores can provide different paths for the current. In fine grained soils, however, it depends also on the minerals present because electrical current may flow through the charged surfaces of the clay minerals. According to recent studies, the flow in the clays due to electrical potential considers the pore water conductance as well as the surface conductivity of the particles; however it can be affected by the tortuosity created by the structure of the soil after compaction. There are various models which explain the conductivity in clayey soils (Mitchell and Soga 2005, for example). The Cation Exchange Capacity (CEC) of a particular mineral may play an important role in the conductivity in the solid phase of the soil. The CEC of Kaolinite is around 3-15 meq/100 g and can be taken into consideration for the conductance in the solid phase.

The structure of compacted clays usually can be arranged into flocculated and dispersed depending on the compaction interval chosen. The compaction on the dry side contain less water and hence the attraction forces between the edges and faces of clay particles makes the structure flocculated. When done on the wet side, the water reduces the repulsion between the faces of the clay particles and results in a dispersed structure. In both cases clay particles are arranged into aggregates and therefore two kinds of pores may be identified: the macropores, which are the pores between the aggregates, and the micropores, which are the pores of the aggregates (Romero *et al* 1999; Alonso and Cardoso, 2010). Water exists in the two kinds of pores and has different contributions to soil electro-hydro-mechanical behavior. The water in the macropores is the free water and its amount depends on the degree of saturation of the soil. The water in the micropores is the microstructural water and part is adsorbed on the clay minerals. The adsorbed water can also be named as immobile water and does not contribute to