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An In-expensive and Tabletop Measurement Apparatus for Soil Electrical Resistivity

Zeminlerin Elektriksel Direncini Ölçen Ucuz ve Masaüstü Bir Aparat

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ABSTRACT

Compaction quality test methods are essential to determine the quality of fills, compression ratio and dry unit weight of fill materials. These methods are separated into destructive and non-destructive. Destructive methods are time-consuming and generally provide point-by-point information, while non-destructive methods are time-saving, inexpensive and give large-scale results. In the present study, an apparatus was constructed to specify the compaction state of soils by determining the electrical resistance. For that purpose, a mixture consists of 20% bentonite and 80% sand was prepared to test the apparatus. Electrical resistivity (ER) was measured in two ways; while water content increases at constant compactive effort and while compactive effort increases at the optimum water content. As a result, these measurements indicate that the electrical resistance decreases while the water content increases at constant compactive effort. Likewise, the electrical resistance decreases while the compactive effort increases at optimum water content.

Keywords: *Compactive Effort, Compaction Quality, Electrical Resistivity, Water Content.*

ÖZET

Kompaksiyon kalitesini kontrol etme deneyleri, dolguların kalitesini, sıkıştırma oranını ve kuru birim hacim ağırlıklarını belirlemede önemli rol oynar. Bu deneyler tahribatlı ve tahribatsız olacak şekilde ikiye ayrılır. Tahribatlı deneyler, zaman alıcı ve genellikle noktasal olarak bilgi sağlarken tahribatsız deneyler pahalı değildir, zaman tasarrufu ve geniş alanlar için bilgi sağlarlar. Bu çalışmada, zeminlerin sıkılığını belirlemek için elektriksel direnç ölçen basit bir aparat yapılmıştır. Aparatı test etmek için %20 oranında bentonit ve %80 oranında kumdan oluşan bir karışım hazırlanmıştır. Elektriksel direnç iki farklı şekilde ölçülmüştür; sabit sıkıştırma enerjisi altında su içeriği yükseltilerek ve en uygun su içeriğinde sıkıştırma enerjisi artırılarak. Sabit sıkıştırma enerjisi altında su içeriği artarken elektriksel direncin düştüğü gözlemlenmiştir. Benzer biçimde en uygun su içeriğinde kompaksiyon enerjisi artırıldıkça elektriksel direncin belirli seviyelere kadar düştüğü bulunmuştur.

Anahtar Kelimeler: Elektriksel Direnç, Kompaksiyon Kalitesi, Sıkıştırma Enerjisi, Su İçeriği.

1. INTRODUCTION

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Non-destructive tests in geotechnical engineering have become increasingly common because they are fast, time-saving, and cheaper. The electrical resistance method, one of the non-destructive tests, helps to determine some of the soil's physical properties, such as water content and initial degree of saturation (Rooposhti et al.,

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2019). Abu-Hassanein et al. (1996) identified distinct relationships between electrical resistivity and soil properties for compacted clays.

Minor changes in soil components can widely affect the electrical resistivity of the soil. (Swileam and Shahin, 2019). For example, Seladji et al. (2010) found that electrical resistivity is over-sensitive to density changes for specific water content values. The electrical resistance decreases exponential as the temperature increase at temperatures above 0 degrees. However, the temperature reaches the freezing point (0°C), electrical resistivity drops abruptly due to pore fluid changes into the solid state. (Keller and Frischknecht, 1966; Abu-Hassanein et al., 1996).

Conventionally, four-electrodes are used to determine the resistivity, which current and potential difference are separated. Nevertheless, depending on the purpose two probe is also used which current and potential difference readings are taken same electrodes (Zhou et al., 2015). In this paper, an apparatus is constructed to determine soil resistivity. The apparatus components are easily purchased from the internet and relatively cheap compared to equipment purchased from commercial vendors. It has been observed that how the water content and compaction effort changes affect the electrical resistivity by using the apparatus.

2. MATERIALS AND METHODS

2.1. Materials

Soil

The soil, evaluated in this study, consists of 20% bentonite and 80% sand. Bentonite and sand were chosen for their known electrical resistivity values. The index properties of the bentonite-sand mixture are summarized in Table 1. A wet sieve analysis test was carried out on the sand bentonite mixture, the size grain distribution of the mixture is shown in Fig. 1a. According to standard proctor results, the compaction properties of the soil are shown in Fig. 1b.

Table 1. Index Properties of the Mixture

Soil	Liquid Limit	Plastic Limit	Plasticity Index	Activity	Sand (%)	Clay (%)	USCS
Bentonite-Sand	65.6	22.2	43.4	2.11	79.4	20.6	SC

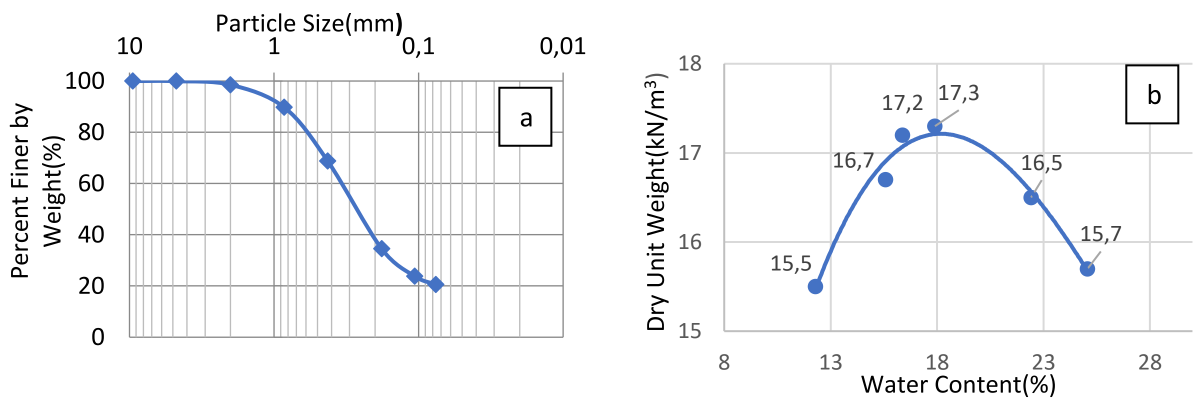

Figure 1. (a) Grain Distribution of the Mixture; (b) Compaction Curve of the Mixture.

Apparatus

The components of the apparatus can be purchased from any electronic store and easily constructed with basic physics knowledge. The battery, which is the source of the apparatus, generates 12V direct current (DC). 12V DC convert to 220 alternative current (AC) by power inverter due to DC can change the soil propeties such as water content (Hamed et al., 1990; Abu-Hassanein et al., 1996). The reason why we use batteries instead of wall plugs as electrical source is the mobility of the apparatus and safety concerns. A multimeter which connected to the source was used to measure the current between the electrodes. Another multimeter separate from the source measures the potential difference between the electrodes. All probes are made of copper and covered with PVC for safety. The ends of the probes is sharpened for better penetration into the soil. The illustration of the general configuration of the apparatus and the components of the apparatus are shown in Fig. 2 and Fig. 3 respectively.

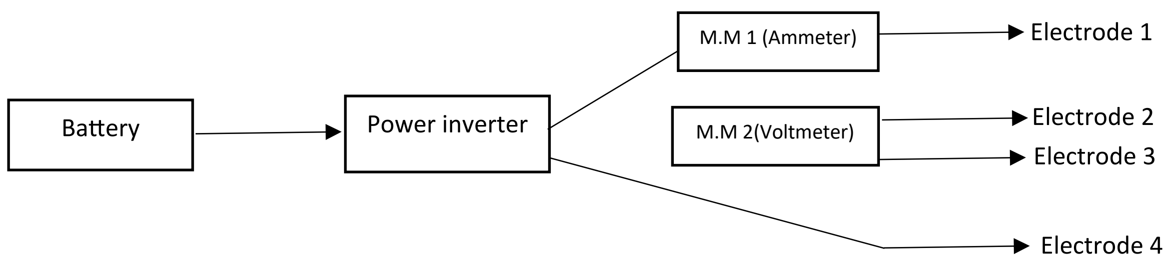

Figure 2. General Configuration of Setup of The Apparatus

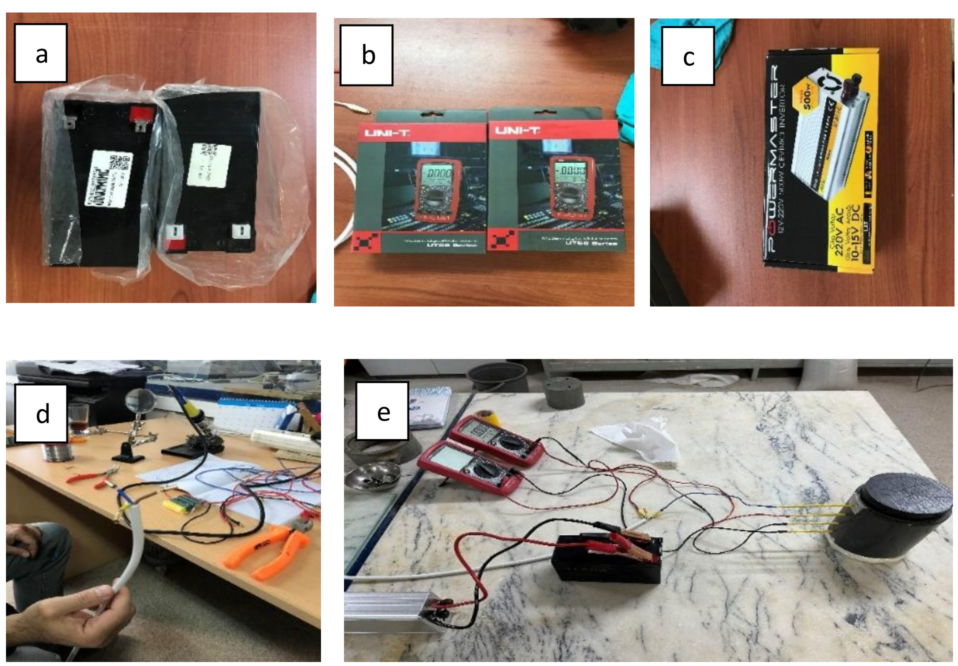

Figure 3. The components of the apparatus: (a) 12V Dry Accumulators; (b) Digital Multimeters; (c) Power Invertor (12V DC to 220V AC); (d) Copper Connection Wires; (e) The Apparatus After Completing Setup

2.2. Method

Electrode Configuration

There are several different configurations for measuring the electrical resistivity of soils such as Wenner, Schlumberger, Dipole-Dipole. In this study, Wenner Configuration was used which the equal distance between each electrode. Current flow and equipotential lines are easier to understand in the Wenner configuration and it gives the results for midpoint of the configuration (Herman, 2001). These two main reasons led us to use the Wenner configuration.

Sample Preparation and Compaction

The samples were adjusted for certain water content, in this case the optimum water content. To prevent the high electrical conductivity of tap water, distilled water was used instead. The soil mixtures were kept in a sealed bag for 24 hours in order to disperse the water in the soil thoroughly.

The specimens were compacted in two different ways. Firstly, the compactions applied with increasing water contents at constant compactive effort in standard proctor compaction mold. Afterwards, the specimen is removed from the mold by lifting jack and covered with foil which is an electrical insulator. This part of the test helps us to understand that correlation between electrical resistivity and water content. The second part of the tests was carried out in a specially designed PVC mold. Four holes were drilled reciprocally in the mold so that electrodes could pass through easily. The compactions are made for different compactive effort at optimum water content of the specimen. The compaction tests were performed according to ASTM D-698 (2012) standard.

3. RESULTS AND DISCUSSION

3.1. Electrical Resistivity-Water Content

Due to high conductivity of water, there is a negative correlation between electrical resistivity and water content in Figure 4. Moreover, it was observed that as the water content increased at the same rate, the change in electrical resistance slowed down. Measurements could not be taken at high water contents due to increased current, which resulted as heat and alter the water content of the specimens.

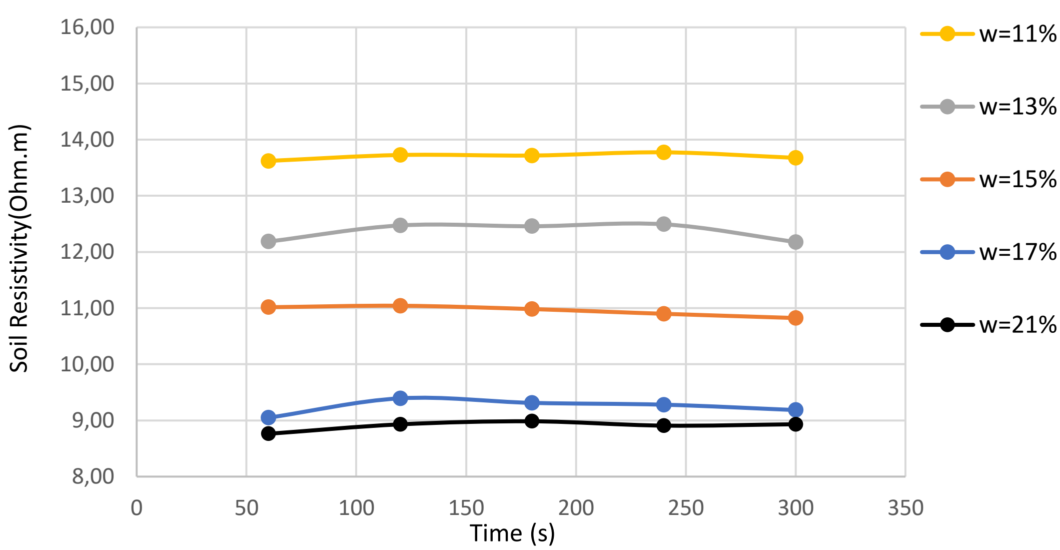

Figure 4. Electrical Resistivity Readings for Different Water Contents

3.2. Electrical Resistivity-Compactive Effort

A distinct relationship exists between compactive effort and soil resistivity, as shown in Table 2. And Fig 5. respectively. The electrical resistivity decreases with increasing compactive effort until the soil reaches the maximum dry unit weight. After a certain compactive effort, there was minimal changes in electrical resistivity since the soil could not be compressed anymore.

Table 2. Relationship Between Number of Blows, Avg. Mean Resistivity and Dry Unit Weight

Number of Blows (N)	Avg. Mean Resistivity (ohm.m)	Dry Unit Weight(t/m^3)
5	15.89	1.36
10	12.15	1.52
15	11.22	1.61
20	10	1.69
25	9.82	1.72
30	9.99	1.72
35	9.68	1.73

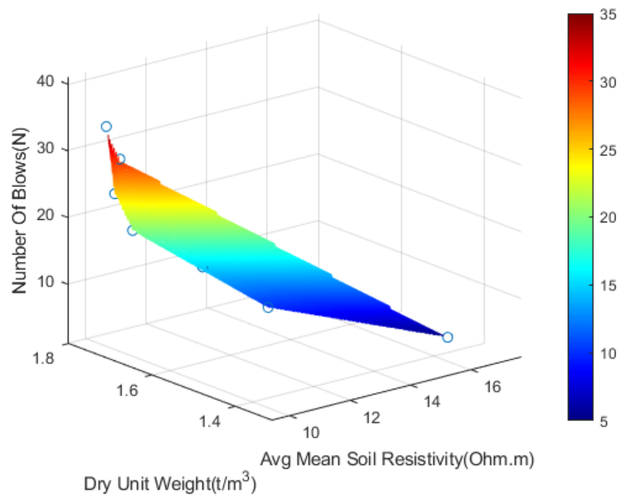

Figure 5. Relationship Between Number of Blows, Avg. Mean Resistivity and Dry Unit Weight

4. CONCLUSIONS

In the present study, an apparatus was established for the electrical measurements of soils and the relationships between electrical resistivity, water content and compaction energy were investigated using this apparatus. It has been observed that minor changes in the soil can easily affect the electrical resistance. The following results were drawn from the study:

- The electrical resistivity of the mixture decreases as the water content increases.
- The electrical resistivity of the mixture decreases as the compactive effort increases. However, the reduction in electrical resistivity almost stops once the mixture reaches maximum compression.

The study is still in progress with different type of soils to investigate the relationship between electrical resistivity, water content and compactive effort.

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