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The Effect of Compaction Towards Resistivity Value

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Abstract: Electrical resistivity tomography is a non-destructive method of site investigation that involves injecting electricity into the sample and measuring subsurface resistance. This study looked at the effects of compaction on resistivity values as well as the relationship between different degrees of compaction. The material used in this experiment was laterite soil. The sample was tested into a standard proctor mould. The model has 10.20cm diameter and 11.6 cm for height of the mould. Each sample's resistivity was measured entirely compacted.The resistivity testing in this study were conducted using the Miller 400A. ASTM D 422 Standards were used, and for electrical resistivity testing, ASTM G57 is used. This research emphasises the impact of moisture content on resistivity value, as soil reduces resistivity value when the soil has higher moisture content which is 120 Ωm at 37%, and 190 Ωm at 25%. By comparing the results of different moisture content of soil samples under varied degrees of compaction, better resistivity interpretation tables may be generated.

Keywords: Resistivity, compaction, soil, porosity, water saturation

1. Introduction

Civil Engineering structures are commonly constructed on or below the surface of the earth. It is important as an engineer to determine and predict whether the surface and the subsurface of a proposed construction site are safe and suitable to yield the total designated weight of a structure over a prolonged period. To estimate the strength and safety of the site, geotechnical properties are important parameters to be investigated in civil construction and design, monitoring, maintenance or rehabilitation purposes during the pre and post construction (Al-Heety et al., 2021; Ungureanu et al., 2017)

. It is important to investigate and predict the condition of the subsurface that may affect the long-term safety of the structures such as salt-water intrusions, underground voids, and groundwater movements to avoid accidents and major losses to the structures (Helaly, 2017; Xiao et al., 2021; Zhao & Konietzky, 2020). Multiple methods are often used to collect the geotechnical data for both disturbed and undisturbed samples for the purpose of site safety design and often times the method to obtain such data are tedious and extra efforts are required for the sample to be transported into the laboratory for further testing. Some examples on the important geotechnical parameters that are investigated on site are soil bearing capacity, ground water table and SPT (N) value (Gonçalves et al., 2021; Mirzanejad et al., 2020)

Geophysical methods have been utilized in recent years to explore the subsurface of the earth and has since been a popular option in profiling the subsurface without having to conduct extra tests on the subsoil. Geophysical methods utilized the physical processes and physical properties of the earth and its surrounding environment to predict the condition of the earth without having to disturb the soil from the earth. It is noted that different physical parameters may give different perception of the subsurface and hence different geophysical methods are more suitable to be used in certain site conditions according to the needs of the exploration. In this study, electrical resistivity method is applied. Electrical resistivity method is a non-destructive method of site investigation that involves injecting electricity into the

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subsurface and measuring the sample's resistance (Mepaiyeda et al., 2020; Liu et al., 2021). Electrical resistivity of a geomaterials is closely related to the geochemical and geotechnical properties of the soil. Hence, this study was performed to establish the effect of compaction towards the electrical resistivity value of soil. The nature of laboratory testing may produce significant results of the electrical resistivity behavior due to the controlled environment of the testing.

2. Electrical Resistivity Equipment and Testing Method

The purpose of this study is to find the resistivity value of soil with different degree of compaction and moisture content by using direct current methods. The physical properties of soil were initially tested before the compaction and electrical resistivity testing was conducted. After the compaction of soil was established, the electrical resistivity testing was then done on the compacted soil The soil used in this study was lateritic soil and several testings was conducted in term of soil physical properties such as particle size distribution, Atterberg's limit, specific gravity and moisture content before the soil compaction and electrical resistivity testing was conducted. Table 1 shows the physical properties of the lateritic soil after being tested in accordance with the BS 1377: Part 2: 1990.

Table 1 - Soil sample after compaction

Soil properties	Value
Particle size distribution:	
Gravel, %	7
Sand, %	58
Silt & Clay, %	35
Atterberg limit:	
Liquid limit, %	45
Plastic limit, %	21
Specific gravity, Gs	2.7

After the physical testing of the soils was conducted, the soil was then compacted by using standard proctor compaction test in accordance with BS 1377: Part 4: 1990. The mould used has an internal diameter of 101.6 mm and height of 116.4 mm. The soil sample was sieved using sieve no 4, 4.75 mm until 3 kg of laterite soil was obtained. After being sieve, the sample was mixed with water before being placed in the proctor mould and compacted using proctor rammer for 25 times per layer for 3 layers of uniform thickness until the soil filled the mould. The weight of mould and soil was calculated before and after the compaction was conducted to obtain the dry density and dry unit weight of the lateritic soil. The soil moisture is collected from the compacted soil and more water was added into the soil before the soil was being compacted again. The amount of moisture content collected after 24 hours inside the soil for the first compaction until the last compaction was 25 %, 29%, 33% and 37% respectively. Figure 1 shows the lateritic soil and proctor mould being measured after the soil was compacted and trimmed.

Fig. 1 - Soil sample after compaction

The electrical resistance of the soil is measured using Miller 400A Analog Resistance Meter as shown in figure 3. In order to evaluate the resistivity value, four electrodes were used to inject current into the soil and to measure the differences in electrical voltage in between the sample. The currents are injected through C1 and C2 and the differences in between the voltages are measured in between P1 and P2 as illustrated in Figure 2. The testing follows the ASTM G57 Standard and ASTM G187/AASHTO T-288 Standard respectively. With this arrangement, the MILLER 400A determines the resistance of the soil sample that fills the electrolyte box. There are seven steps to take a resistance reading. First, put the connector to the soil in the middle of the proctor mould. Set the “Ohm Multiple By “range selector switch to 100k and the “Balance Dial “knob to “10 “. With the "Null Sensitivity" switch set to "Low," step down through the resistance ranges, for example, 10k, 1k, 100k, until the needle moves to the left of the null position, and then step back up one range. Adjust the position of the "Balance Dial" until the needle was positioned at the null (center) location on the meter. Multiple the "Balance Dial" setting with the range setting on the switch labelled "Ohms Multiple By" to obtain the resistance value. Apply the resistance value to the calculation of resistivity using appropriate formula. Ohm's law was used to determine the observed voltage (V) and resistance (R) from the known current (I).

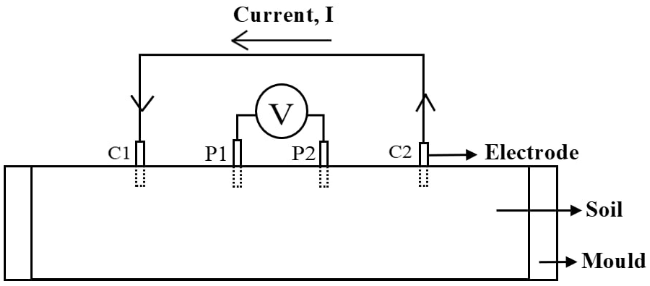

Fig. 2 - Schematic diagram of the electrode placement inside the mould

Fig. 3 - The current flow of proctor mould

3. Results and Discussions

This study intent to determine the resistivity value of soil from different degree of compaction and moisture content. Throughout the process of resistivity testing the water used for every sample were different as it were the variable changes in this test. By referring to table 2, the resistivity value was obtained at 190 Ωm, 160 Ωm, 140 Ωm and 120 Ωm which was obtained at different moisture content of the soil at 25%, 29%, 33% and 37% respectively. The overall results from the compaction testing on the laterite samples are illustrated in Table 2. The highest resistivity value for the experiment is 190 Ωm which has the lowest moisture content 25%, and dry density value of 1.399 kN/m^3. The lowest resistivity value is 120 Ωm which has the highest moisture content which is 37%, and dry density value of 1.237 kN/m^3. The change in density indicates that the resistivity value reduces as the density of the soil increases as shown in figure 5.

The water was used for this testing is from the same source throughout the resistivity test. There is a positive relationship in between the resistivity and moisture content throughout the whole sample during the experiment. The value of the resistivity obtained from the testing indicates that the resistivity is directly influence by the addition of the moisture content. The compaction imposed on the soil reduces the air void inside the soil which will reduces the resistivity value of the soil. The air void within the soil sample is the area in which electrical current may not passed through (Abidin et al., 2017). The more air void available inside the soil, the higher the resistance of the soil became. As shown in figure 5 the denser the soil, the less resistance the soil may impose. The measured resistivity is affected by the porosity, degree of saturation, and water resistivity factors, according to Archie's law. Table 2 displays the resistivity with varying moisture content, as well as other parameters such as void ratio and porosity. The moisture content is controlled in these study parameters. This study demonstrates that changing the moisture content and the degree of compaction of the soil sample changes the void ratio and porosity value as shown in figure 4.

Table 2 - Soil properties condition after compaction

Soil condition	*A*	*B*	*C*	*D*
Dry density ρd (g/cm3)	1.499	1.453	1.419	1.351
Dry unit weight, Yd (kN/m3)	14.7	14.3	13.9	13.3
Specific gravity, Gs	2.7	2.7	2.7	2.7
Moisture content, Mc (%)	25	29	33	37
Void ratio, e	0.80	0.86	0.90	1.00
Porosity, n	0.44	0.46	0.47	0.50
Saturation, Sr (%)	84	91	99	100
Resistivity Ωm	190	160	140	120

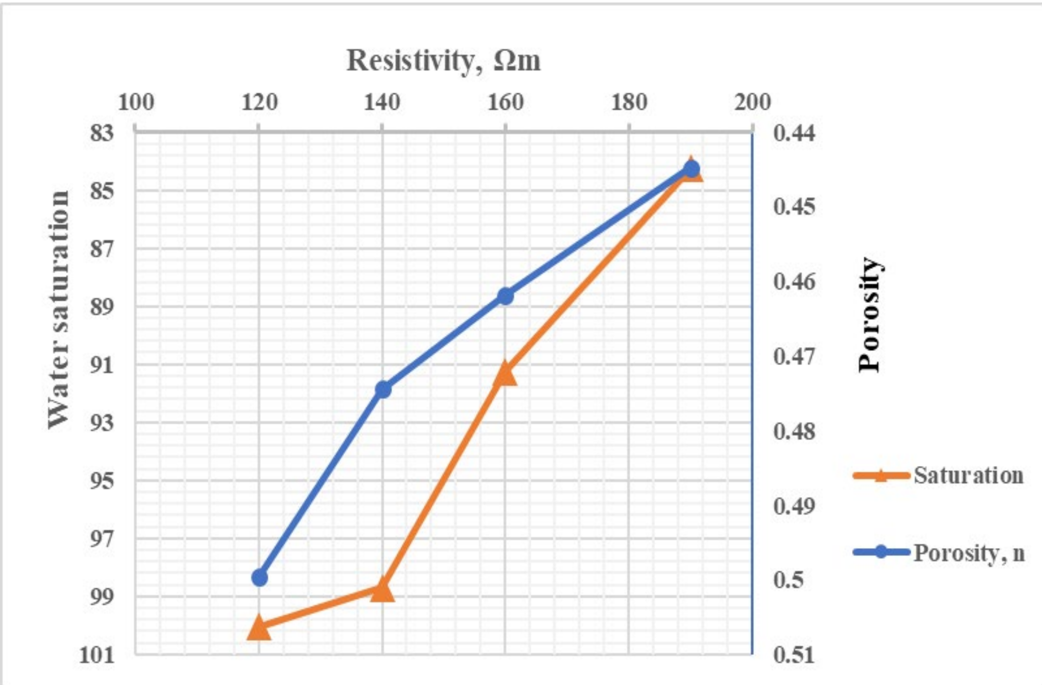

Fig. 4 - Soil sample after compaction

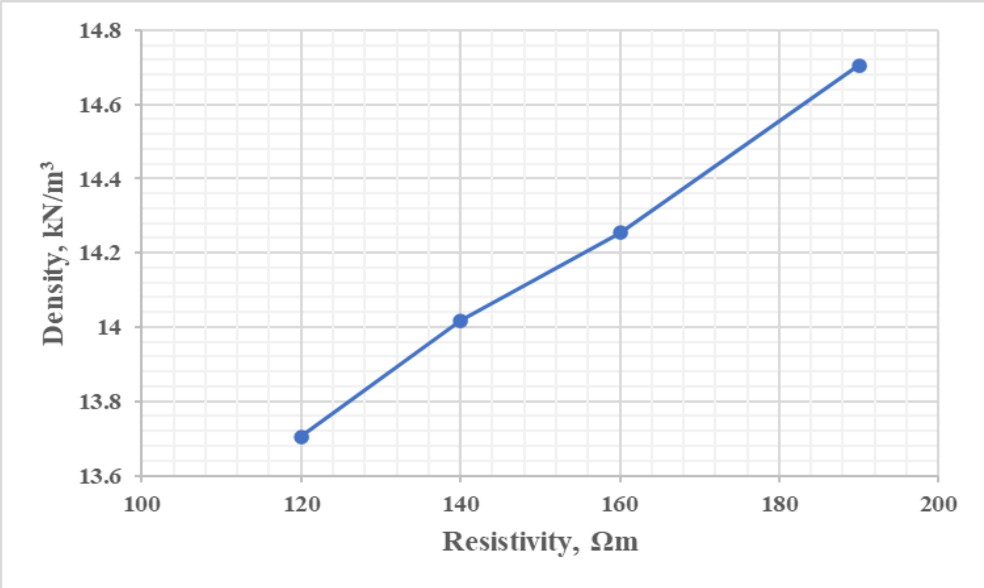

Fig. 5 - Resistivity value changes with density

4. Conclusion

The effect of soil compaction towards the resistivity value was assessed in this study. This study shows that, the resistivity value is affected by the degree of compaction. The denser soil has less resistivity value compared to the less dense soil. It is also shown that the change in the resistivity value is directly caused by the change in moisture content and porosity of the soil. The more porous soil causes more water to be present within the soil and causes the resistivity value to decrease.

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