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The Effect of Saturation of Towards Resistivity Value for Groundwater Investigation Interpretation

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Abstract: Identifying the position of the aquifer is essential the groundwater exploration. The method for detecting the groundwater is utilizing of electrical properties of the subsurface. The aquifer layer is known via its electrical properties of low resistivity and chargeability, represented by saturated and highly permeable subsurface layer. Then electric charge injects into the subsurface and the results of the resistivity and chargeability will be obtained. The previous studies produced a lack of resistivity and chargeability value for the samples based on their saturation. In order to obtain a new table of resistivity values based on saturation for the sample, this study was conducted in a laboratory setting by using sand box testing for sand and clay. The testing is conducted using the 4-electrode principle for the sandbox used for the sand, silt, and clay samples. A new set of resistivity values according to saturation range from the gravel and sand will be produced by conducting a resistivity laboratory test. The significance of this study was to identify the effect of saturation on electrical resistivity for groundwater representation. As an outcome of this study, it will produce the earth material-resistivity interpretation table for groundwater representation and enhance the information about the flow of groundwater and the effect of saturation toward resistivity for groundwater aims.

Keywords: Resistivity, Saturation, Sand, Clay

1. Introduction

The selection of geophysical investigation is the Electrical Resistivity Method (ERM). The method is preferable in investigating groundwater because it is a non-destructive method. In this method, the resistivity value is essential for the interpretation data of possibility groundwater aquifer. The previous studies produced a lack of resistivity and chargeability value for the samples based on their saturation. In order to obtain a new table of resistivity values based on saturation for the sample, this study was conducted in a laboratory setting by using sand box testing for sand and clay. A new set of resistivity values according to saturation range from the gravel and sand will be produced by conducting a

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resistivity laboratory test. By doing a controlled study, an understanding of the factors that can affect resistivity values and providing a more comprehensive interpretation of tomography concerning the lithological component can be concluded.

The study aims are to determine the consequences of sand and clay saturation towards resistivity value for groundwater investigation. The objective of the study is to conduct the soil index test for soil mixture proportion raging from gravel to sand. Identifying the effect of saturation of samples towards the resistivity and chargeability values. From the laboratory setting, it can establish the interpretation values for the resistivity and chargeability due to the moisture content.

In these methods, the electrical properties are applied to the intended subsurface, and an electric charge will pass through the area. The device used to measure resistivity is the Miller 400A resistivity meter. The testing uses a 4-electrode principle for the sand box used for the sand, silt, and clay samples. For this study, the applications are focusing on utilizing of direct current or very-low-frequency rotating current methods. The samples are filled with distilled water until all the samples are fully submerged to emulate the aquifer layer. Then, the resistivity testing is conducted.

2. Literature Review

In general, the geophysical method is related to the archaeological, engineering studies and environment where they use the mapping and detection method to obtain the data. According to (Hazreek et al., 2015), the geophysical method as the other method in the geophysical investigation are useful which it can give excellent performance on consuming of time, cost and data availability. The Electrical Resistivity Method is a good way to assess soil properties because it is a non-destructive method and has no harmful impact on the environment. It also can be used at different depths. Electrical Resistivity Method has a great capability of detecting geotechnical parameters like as water content at a low cost, do not give negative effect and efficient on resulting the data. Furthermore, the Electrical Resistivity Method does not need large equipment, unlike the destructive method which is the traditional method.

The resistivity value is a measurement that shows how effectively a material can resist current flow. Material with low resistivity is a good conductor, whereas a material with a high resistivity is act as a good insulator. Variations in basic geotechnical parameters connected to the soil such as moisture content can give a significant impact on electrical resistivity values in the subsurface. The presence of non-conductive fluid in the pore space and the wettability of the rock affects the saturation exponent (Liu & Moysey, 2012). When compared to the driest location condition of the experiment, the wettest location has a considerably lower resistivity value.

3. Materials and Methods

This study has explained the methods used in this study to figure out the resistivity value of samples based on their saturation.

3.1 Materials

The materials were utilized in this study include gravel, sand, and distilled water. The type of soil that used in this study are gravel and sand. Both materials were obtained from a manufacturer in Batu Pahat. The purpose of this study is to determine the resistivity values of materials based on their saturation. On top of that, the water content of materials will be decided based on the amount of distilled water used.

3.2 Methods

The tests were proposed and performed in the laboratory: sieve analysis, moisture content, specific gravity test, hydrometer test and resistivity test.

3.2.1 Sieve Analysis Test

The samples will undergo a sieve analysis test before performing the resistivity test. For this test, clay and sand used will be tested by referring to BS 1377: Part2:1990 as the standard of sample preparation

Figure 1: Sieve Set

3.2.2 Hydrometer Test

A hydrometer was an instrument for determining the relative density of liquids. The hydrometer test was used to measure the particle size distribution of soil particles smaller than 75 m in diameter.

Figure 2: Hydrometer bulb

3.2.3 Moisture Content

The presence of groundwater in the soil, which produces its own electrolyte, frequently causes the resistance of sediments beneath the water table. This demonstrates that the presence of water affects electrical resistance significantly. Moisture content was taken into consideration while determining the resistivity value of altered material. The formula given is used to identify the moisture content of altered materials:

$$Moisture\ Content\ (\%) = \frac{w_2 - w_3}{w_3 - w_1} x100\% \quad Eq.1$$

Where:

w_1 = container weight (g)

w_2 = weight of moist sample + container (g)

w_3 = weight of dried sample + container (g)

3.2.4 Specific Gravity Test

The Specific Gravity is calculated by comparing the weight in air of a certain volume of soil particles to the weight in air of an identical volume of distilled water at the same temperature. In this setting, water bathing was used to get the constant temperature for the samples.

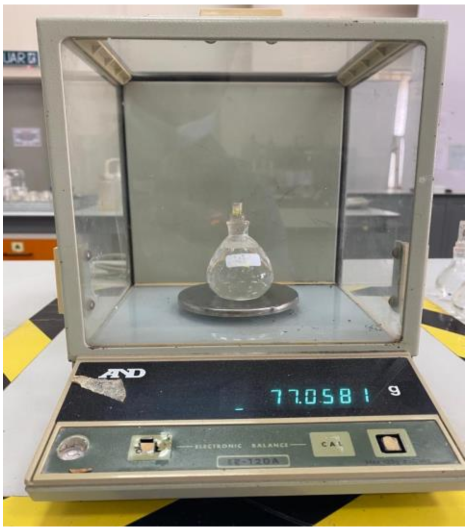

Figure 3: Pycnometer

3.2.5 Resistivity Test

In this study, resistivity values were obtained from Miller 400A resistivity meter. The meter is connected to the soil box and soil cylinder to determine the resistivity value for gravel and sand.

Figure 4: Miller 400A resistivity meter

The types of resistivity methods that be used in this study which is 4-electrodes for soil box.

The following formula is used to obtain the resistance value by theoretical calculation:

$$\rho = R\frac{A}{L} \qquad Eq.2$$

Where:

ρ = resistivity (ohm.cm)

R = resistance (ohm)

A = current electrode's cross-sectional area (cm^2)

L = distance between potential electrodes (cm)

The formation factor, F also need to be determined as the tortuosity, water saturation and porosity of the sample will affect to it. The value of the formation factor can be found as shown below:

$$F = a \ x \ S_w{}^{-n} \ x \ Ø^{-m} \ Eq.3$$

Where:

a = tortuosity

$S_w{}^{-n}$ = water saturation

$Ø^{-m}$ = porosity

4. Results and Discussion

This study provided the parameters of resistivity towards sand and kaolin clay.

4.1 Atterberg Limit Test

For all samples, it was shown that the Liquid Limit result was greater in percentages than the Plastic Limit result. From those parameters, the Plastic Index can be defined for each sample. As the **Table 1** shows below, 100% Kaolin Clay has the highest value of Plastic Index which is 23.96%, meanwhile the lowest value of Plastic Index is 100% Sand. These results show that the physical properties of minerals were achieved and suitable for the next following laboratory testing.

Table 1: Atterberg Limit Parameters

Samples	Liquid Limit (LL) %	Plastic Limit (PL) %	Plastic Index (LL-PL) %
100% Kaolin Clay	70.80	46.84	23.96
80% Kaolin Clay + 20% Sand	51.00	34.53	16.47
60% Kaolin Clay + 40% Sand	43.62	28.11	15.51
50% Kaolin Clay + 50% Sand	38.90	30.06	8.84
40% Kaolin Clay + 60% Sand	32.20	17.56	14.64
20% Kaolin Clay + 80% Sand	29.30	17.49	11.81

4.2 Specific Gravity

In this analysis, the results of specific gravity for samples were obtained using a pycnometer. The results were collected by repeating the process three times to find the average specific gravity values. As refer to **Table 2**, it showed the results of the average specific gravity for each sample.

Table 2: Average Specific Gravity

Type of Samples	Average Specific Gravity (s.g.)
100% Kaolin Clay	2.52
80% Kaolin Clay + 20% Sand	2.54
60% Kaolin Clay + 40% Sand	2.57
50% Kaolin Clay + 50% Sand	2.59
40% Kaolin Clay + 60% Sand	2.63
20% Kaolin Clay + 80% Sand	2.648
100% Sand	2.68

4.3 Sieve Analysis

In this setting, a Sieve Analysis test was held to classify the particles size for Sand and Kaolin Clay referring to BS 1377: Part 2: 1990. In **Figure 5**, it shows that the classification of particles size for Sand. The graph shows in good grading curves which is the samples are suitable for the resistivity testing in soil box

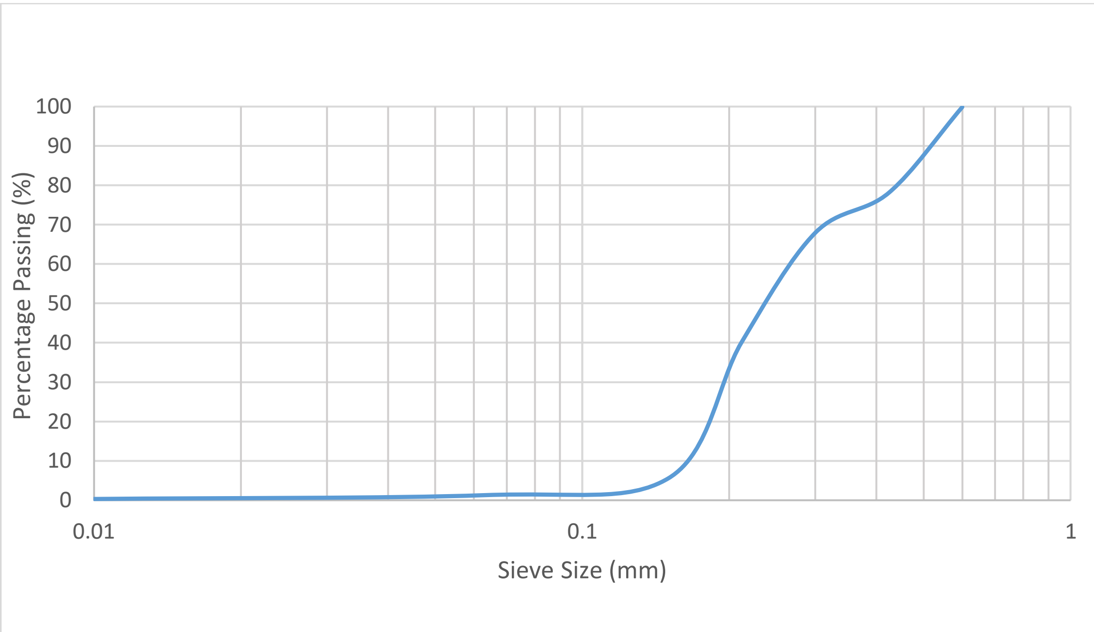

Figure 5: Particle Size Distribution for Sand

4.4 Resistivity

In order to get the results of resistivity of samples, Miller 400A Resistivity Meter with soil box was applied towards Sand and Kaolin Clay. Moreover, the distilled water also blended with the samples with constant increment until they reached saturated condition. The samples were undergo full compaction, which is 25 blows in three layers. In **Figure 6**, it shows the combination of results of resistivity values for all samples as the saturation increases until they were fully saturated. Again, they have a similarity in the trend of resistivity where they decreased as the percentage of saturation increases.

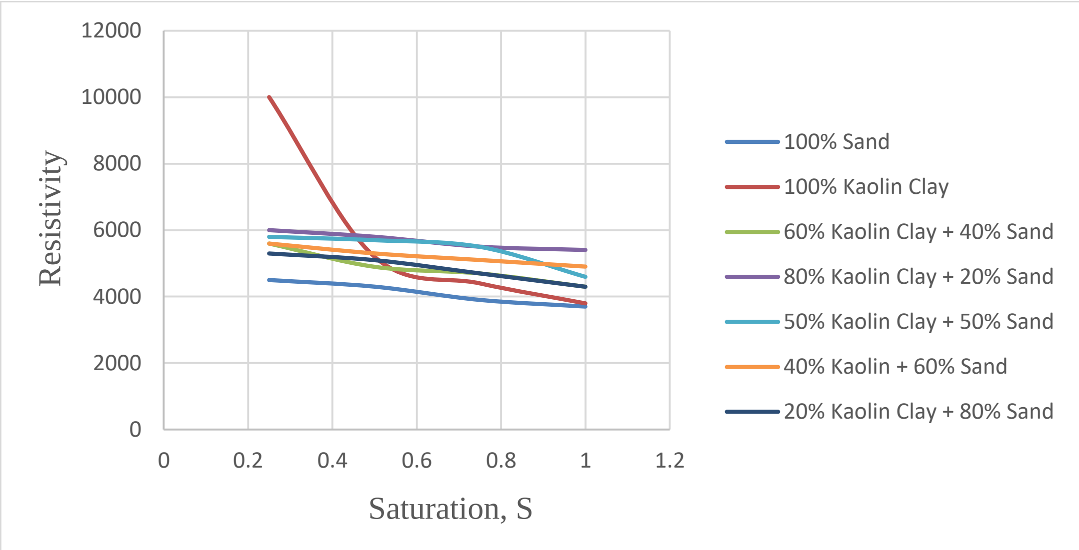

Figure 6: Comparison of resistivity vs saturation

5. Conclusion

Moisture content have given the effects on resistivity values, as has been shown. In addition, a new table was constructed for resistivity interpretation tables for sand and clay minerals in different proportions as example 80% of Kaolin Clay with 20% Sand, 60% of Kaolin Clay with 40% Sand, 50% of Kaolin Clay with 50% Sand, 40% of Kaolin Clay with 60% Sand, and 20% of Kaolin Clay with 80% Sand.

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