Correlation of Electrical Resistivity with Different Condition of the Soil

by

Mior Khairul Azmil Bin Mior Fazali

Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Civil Engineering)

JUNE 2010

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CERTIFICATION OF APPROVAL

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(CIVIL ENGINEERING)

Approved by,

Syed Baharom
____
(Dr Syed Baharom)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
JUNE 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MIOR KHAIRUL AZMIL BIN MIOR RAZALI

ABSTRACT

Assessments of slope stability using electrical parameters have least been research by many scholars. The method is non destructive and very sensitive. It offers a very attractive tool for describing the subsurface properties of the slope without disturbing the physical characteristic of the soil. The method has been applied in various contexts like groundwater exploration; landfill and solute transfer delineation, agronomical management by identifying areas of excessive or soil horizon thickness and bedrock depth.

The ranges of benefit of this method have attracted the author to do research on the correlation between electrical parameter with some soil parameter. The experiments were conducted in the laboratory using sand boxes specially designed using Perspex material. Then to get the physical parameters of the soil, conventional Shear Box Test has been used. Results and values obtained from both experiments were then analyzed in order to establish some possible correlation.

From this research, the author sees a unique relationship exists between electrical resistivity with percentage of moisture content for each variable of the soil parameter. In general, Soils with higher percentage of moisture content and salt content will have lower electrical resistivity. In addition soil with higher value of pH (alkaline) will have lower electrical resistivity than lower value of pH (acidic).

II

ACKNOWLEDGEMENTS

First and foremost, I am expressing my greatest praise and gratitude to Allah for His guidance and blessings throughout the duration of my final year project (FYP).

The completion of this FYP would not have been possible without the support, hard work and endless efforts from those who are involved directly or indirectly in this report. I would like to thank to Dr. Syed Baharom as project supervisor for delivering many precious lessons on both technical and non-technical matters from my very first days assigned for this research. His dedication and enthusiasm inspires me a lot and working under his supervision was a great pleasure and valuable experience for me.

Loads of thanks to the UTP respective technicians such as Ms. Ema for providing me sufficient and useful guidelines and lending an effortless compassionate help, support and guidance so that I can complete my project on time towards the success of FYP.

Besides, my deepest appreciation goes to my family and friends who offered helps whenever I faced obstacles within the completion of this FYP. Their support possibly makes me ongoing for my project progress. I hope that the outcome of this report will bring beneficial output to others as well.

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CHAPTER 1
INTRODUCTION

1.1 Problem Statement

The conventional method of doing the soil investigation (SI) is by borehole sampling and involves laboratory testing of samples collected. The time required to do the experiment on every sample at the lab is very long. The problem of time requirement, field size and the field area that involved has lead to geophysical method practice. One of the geophysical methods is electrical resistivity survey, which can be conducted rapidly in the field.

The electrical resistivity survey that is being used today provides limited information to be use for estimating the characteristics of the soil. The survey cannot determine some of the important variable such as the strength parameters, mineralogy, particle size, fabric, texture, salt content and percentage of organic content.

The general approach behind this quick assessment system is to eliminate the usage of physical soil parameters such as cohesion (c), internal frictional angle (Φ), and unit weight (γ) as is currently being practice for the calculation of FOS and replace these physical parameters with their correlated electrical parameters such as resistivity, conductivity, voltage etc.

1.2 Objectives.

The primary objective of this study was to find possible correlation between resistivity & some soil parameter with variation in different soil conditions. The experiment will be focused on doing the laboratory test.

1.3 Scope of Study

Using electrical resistivity for slope stability study, authors must know electrical resistivity depends on many factors such as porosity, electrical resistivity of the pore fluid, composition of the solids, degree of saturation, particle shape and orientation, and pore structure.

The study of correlation between electrical resistivity and soil investigation is divided by many portions. Because the research areas are really wide, this research has been divide to several group. Authors have been more focused on doing the experiment by determine on the three important variable that are:

a) Correlation against kaolin soil with different percentage of moisture content.
b) Correlation against kaolin soil with different percentage of salt content.
c) Correlation against kaolin soil with different pH value of the soil.

CHAPTER 2
LITERATURE REVIEW

2.1. Conventional Soil Properties Test and Electrical Resistivity Method

Engineering properties of geomaterial are very important for civil engineers because almost everything they build; tunnels, bridges, dams and others are in, on or with soils or rocks. For geotechnical engineers, the strength, the stress-deformation behavior and the fluid flow properties of earth materials are of primary concern and form the conventional framework of the geotechnical discipline. Conventional techniques for the determination of these engineering properties can be generally divided into three categories; laboratory tests, in-situ tests and geophysical methods. Of these, geophysical methods have been least developed as regards to their suitability for specific quantification of soil properties.

Laboratory tests have the advantages of directly measuring the specified engineering properties under controlled boundary conditions and different environmental conditions. However, soil samples are usually disturbed during the drilling and sampling processes, which may make the measured engineering properties, deviate from their actual values.

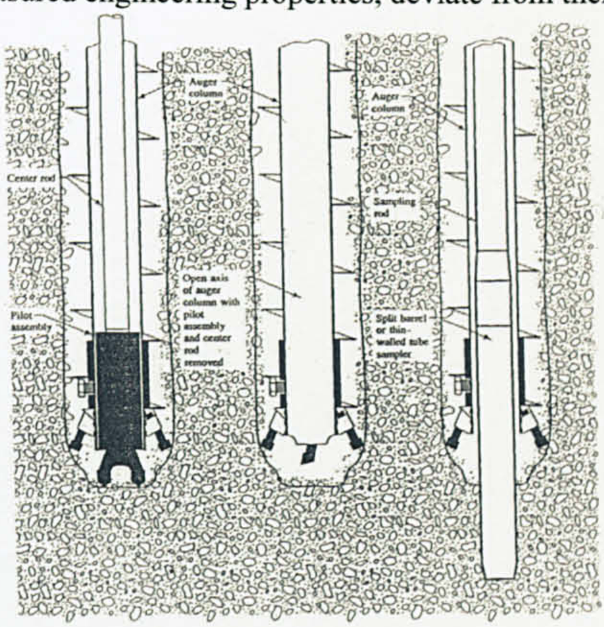

Figure 2.1a: Borehole Sampling Method

The electrical resistivity method is one of the most useful techniques in Soil investigation because the resistivity of a rock and soil is very sensitive to its water content. In turn, the resistivity of water is very sensitive to its ionic content.

In general, it is able to determine the soil properties at the site and determine the mineralogy without need to wait for the sample to be sent to the lab for experiment and research.

Applications:

1. Water table depth.
2. Groundwater quality
3. Brine plumes.
4. Seawater intrusion
5. Well sitting.
6. Aquifer exploration
7. General stratigraphic mapping

Advantages:

1. Less costly than drilling.
2. Non disturbing.

Disadvantages:

1. Cultural problems because interference, e.g., power lines, pipelines, buried casings, fences.
2. Resolution.

2.2. Soil Properties and Electrical Resistivity

Electrical conductivity and resistivity of soils have been investigated in a large number of studies, which can be divided into three groups.

The first group includes laboratory studies of electrical conductivity and dielectric constant of different dispersed media (including soils) with electromagnetic waves. These studies help to develop relationship between electrical parameters, quantitative and qualitative compositions of electrolytic solutions. The relationships were enhanced by the studies of soil electrical parameters with constant electrical field. For some diluted soil solutions and groundwater, the methods are developed to calculate electrical conductivity from the solution compositions.

The second group of studies is devoted to laboratory measurements of surface electrical conductivity. The surface electrical conductivity is a major parameter describing structure of electrical double layer and its ion composition. There is only limited special research with experimental measurements of surface electrical conductivity in soils.

The third group of studies includes measurements of electrical conductivity of soils, rocks, and sediments in situ with various geophysical methods.

2.3. Correlation between Electrical Resistivity with Moisture Content

In the literature the various models proposed to describe relationships between electrical parameters and soil water content, temperature, or salt content. Electrical conductivity and resistivity are usually measured as electrical parameters in laboratory and field conditions. Relationships between soil water content and electrical parameters were measured in field and laboratory conditions and mostly curvilinear models were obtained. Curvilinear relationships were also proposed between electrical resistivity and temperature. The researcher has been experiment and had proved that exponential relationship between electrical resistivity, soil temperature, and water content based on a series of experiments.

The assessment of soil water content variations more and more leans on geophysical methods that are non invasive and that allow a high spatial sampling. Among the different methods, Direct Current (DC) electrical imaging is moving forward. DC Electrical resistivity shows indeed strong seasonal variations that principally depend on soil water content variations. Although there are many studies between electrical resistivity and water content of agricultural soils, on geotechnical or engineering soils there are little attentions.

Electrical current in soils is mainly electrolytic, based on the displacement of ions in pore water, and is therefore greater with the presence of dissolved salts. Thus, electrical current in soils depends on the amount of water in the pores and on its quality. In most studies concerning the water content, the electrical conductivity of the solution is assumed to remain relatively constant to be neglected against its variation related to water content variation. Prior to field surveys, preliminary calibration of the volumetric water content related to the electrical resistivity is usually performed in the laboratory. Figure 2.1 shows examples of laboratory calibration between the electrical resistivity and the volumetric water content. The electrical resistivity decreases when the water content increases. It can also be seen that for water content below 15 percent, the electrical resistivity rapidly decreases with increasing water content. The relationship between the electrical resistivity and the water content has firstly been studied mainly in the field of petroleum research.

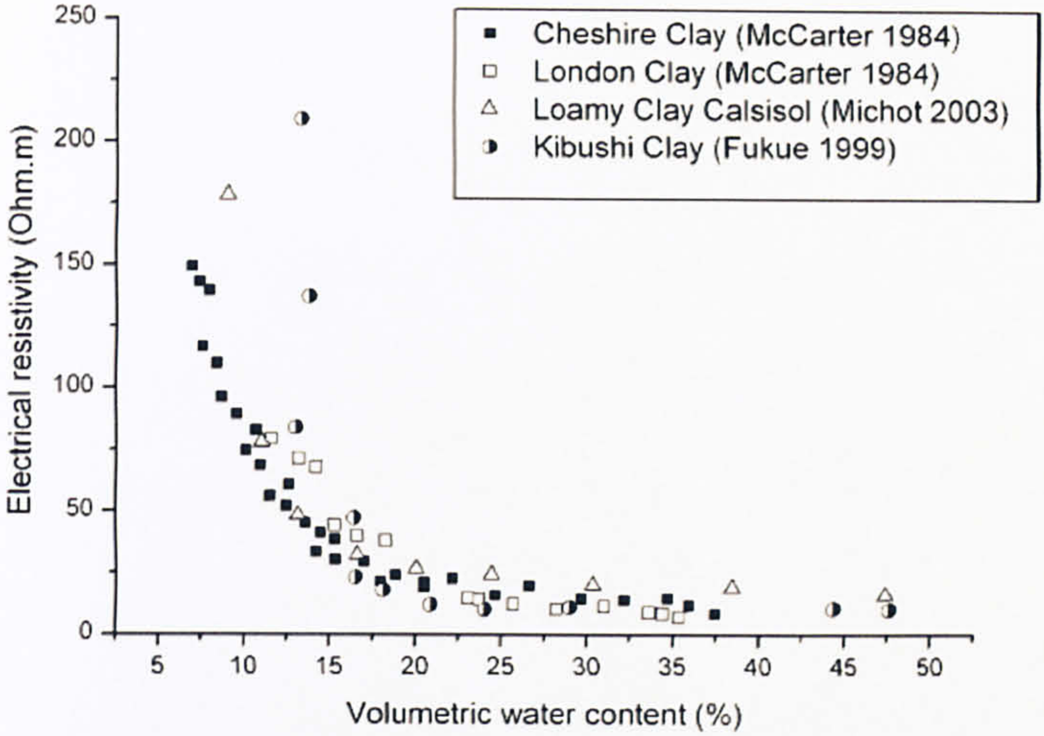

Figure 2.3a: Relationship between the Volumetric Water Content and the Electrical Resistivity for Different Soil Types

2.4. Correlation between Electrical Resistivity with Salt Content

Water and salt content distributions within the soil profile are the main properties causing considerable variations in electrical resistivity or conductivity. The water content and salt distributions in the soil are determined mainly by the saline groundwater and also the different type of mineral of the salt itself.

The effect of the quality (mineralization) of saturating water on the apparent resistivity has been studied by many investigators. Resistivity measurements conducted by Sharapanov et al. (1974), showed indirect, two-segment, linear logarithmic relationship between apparent resistivity and mineralization. For sands, the low gradient segment corresponds to mineralization of up to about 2500 mg/l, whereas higher mineralizations correspond to the higher-gradient segment. Other studies (e.g., Mares, 1984; Palacky, 1988; Kui, 1990; McNeill, 1990) although implying the direct relationship between salinity and conductivity (or indirect for resistivity), however, the nature of this relationship has not been discussed thoroughly. Moreover, Barker (I 990) showed that the relationship between chalk water conductivity and salinity (experimentally determined) constructed on a bilogarithmic scale is not characterized by a straight line, but rather by a parabola.

2.5. Correlation between Electrical Resistivity with pH of the soil

The pH provides a general guide to the nature of possible corrosion. Acidic soils are corrosive. Neutral soils are optimal for the development sulphate-reducing bacteria. Alkaline soils are generally benign; however, exceedingly high pH values can lead to low electrical resistivity.

Development of acidity in soils is a result of the natural processes of weathering under humid conditions. In regions of moderate rainfall, soluble salts do not accumulate except where soil waters seep to lower levels and collect in depressions. However, in regions of high rainfall, not only are soluble salts removed from the soil but the absorbed bases normally present in the colloidal materials of the soil are partially removed, and result in increased acidity. The processes eventually give rise to the condition known as soil acidity. The depth to which this leaching of the bases occurs varies with rainfall, drainage, type of vegetation, and nature of the material present.

The degree of acidity or alkalinity of a soil is expressed as the pH, a value that represents the logarithm of the reciprocal of the hydrogen ion concentration. A pH value of 7 indicates neutrality; lower values, acidity; and higher values, alkalinity. Terms used for soil classification based on pH are defined as follows.

High alkalinity lowers electrical soil resistivity and increase soil corrosivity. Certain corrosive substances in the medium (e.g., chloride ions) and mechanical effects can destroy surface films locally, leading to intensive local corrosion such as pitting and stress corrosion.

Soil Classification Based on pH	
Extremely Acid	Below 4.5
Very Strong Acid	4.5 to 5.0
Strongly Acid	5.1 to 5.5
Medium Acid	5.6 to 6.0
Slightly Acid	6.1 to 6.5
Neutral	6.6 to 7.3
Mildly Alkaline	7.4 to 7.8
Moderately Alkaline	7.9 to 8.4
Strongly Alkaline	8.5 to 9.0
Very Strongly Alkaline	9.1 and Higher

Table 2.5a Soil Classification Based on pH from Corrosion Diagnostics & Engineering

2.6. Electrical Resistivity Measurement

Soil resistivity data is the key factor in designing a grounding system for a specific performance objective. All soil conducts electrical current, with some soils having good electrical conductivity while the majority has poor electrical conductivity. The resistivity of soil varies widely throughout the world and changes dramatically within small areas. Soil resistivity is mainly influenced by the type of soil (clay, shale, etc.), moisture content, the amount of electrolytes (minerals and dissolved salts) and finally, temperature.

When designing a grounding system for a specific performance objective, it is necessary to accurately measure the soil resistivity of the site where the ground is to be installed. Grounding system design is an engineering process that removes the guesswork and "art" out of grounding. It allows grounding to be done "right, the first time". The result is a cost savings by avoiding change orders and ground "enhancements."

The best method for testing soil resistivity is the Wenner Four Point method. It uses a 4-pole digital ground resistance meter, probes, and conductors.

It requires inserting four probes into the test area. The probes are installed in a straight line and equally spaced (Figure 2.2). The probes establish an electrical contact with the earth.

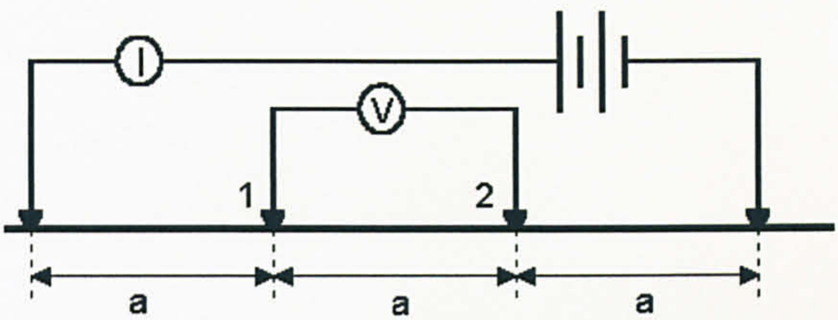

Figure 2.6a: Principle of Electrical Operation

The four pole test meter injects a constant current through the ground via the tester and the outer two probes. The current flowing through the earth (a resistive material) develops a voltage/potential difference. This voltage drop resulting from the current flow is then measured between the two inner probes.

The meter then knows the amount of current that is flowing through the earth and the voltage drop across the two center probes. With this information the meter uses ohms law (R=V/I) to calculate and display the resistance in ohms.

This displayed resistance value is in ohms and must be converted to ohms-meter, which are the units of measure for soil resistivity. Ohms-meter is the resistance of a volume of earth that is one meter by one meter by one meter, or one cubic meter.

To convert from the displayed ohms to ohms-meter, the meter reading is multiplied by 2 and the result multiplied times the probe spacing. The following shows the calculation in a formula.

$$\rho \text{ (ohms-m)} = 2 \times R \times A$$

ρ = soil resistivity in ohm-m (Ωm)

2 is constant

R = digital readout in ohms (Ω).

A = distance between electrodes in ft.

CHAPTER 3

METHODOLOGY

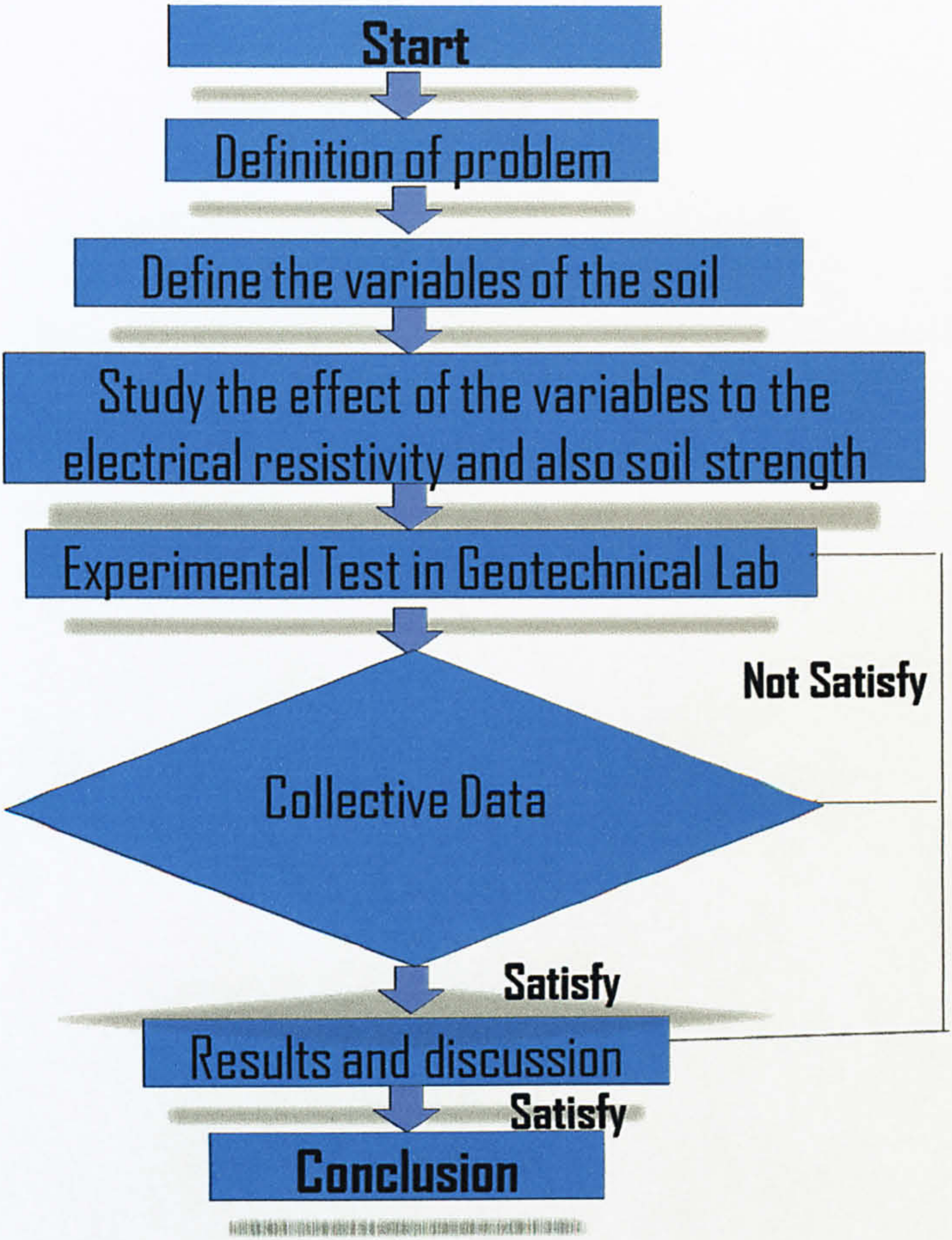

Figure 3a: Flow Chart of Research Methodology

3.1 Research Methodology

This studies was divided into two main phases which are phase one and phase two.

For the phase one concentration was more on research information details such as the fundamental concepts of these studies, find the related information and research especially the journals and paper works for the electrical resistivity in the soil and includes preparation of soil sample for the laboratory test. The soil will be tested on three soil sample, there are; pure sand, pure silt and pure clay. The soil sample must be totally pure soil without mix with any type of soil.

The second phase of this study was on the laboratory test. The tests were conducted in the soil laboratory with special instruments and equipments for testing the soil sample about electrical resistivity with the soil water content. The laboratory works have been tested for each three different parameters of the soil with different values. The shear strength parameters of the soil sample were determined to correlate with the electrical resistivity in soil sample. The data were then elaborate to find the correlation about the electrical resistivity with the soil water content. At the end of these studies, the result were summarized to come out with the relationship of the between electrical resistivity with particle size distribution of the soil and soil shear strength parameters.

3.1.1 Laboratory Works Test

Sand Box

For the lab method on determine electrical resistivity change with different parameters, the authors use sand box apparatus that have been designed to ease handling, save time, cost and give more accurate data. The sand box iwas designed by referring to the Wenner method. The Wenner method is suitable for horizontal structures such as sand box and also will give greater strength signal. Below is the specification of the sand box:

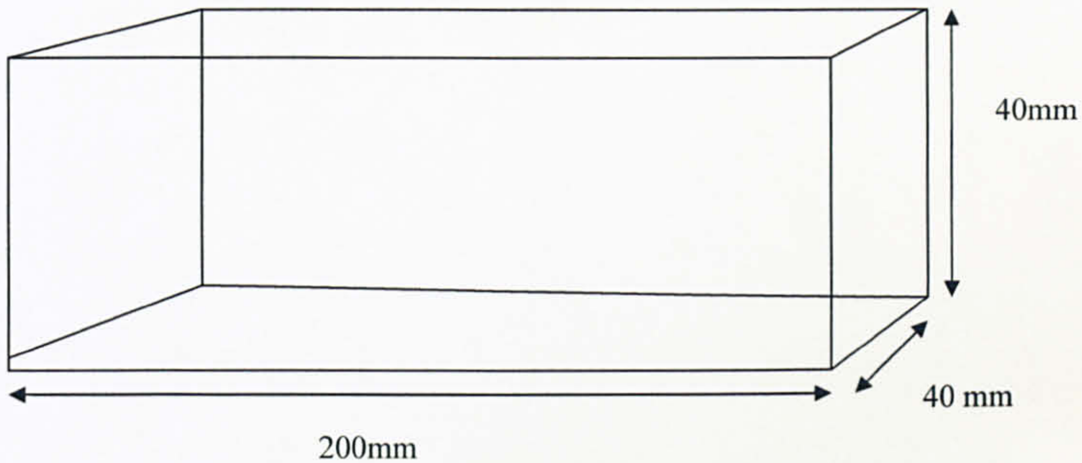

Figure 3.1.1a: The Specification of the Sand Box

Shear Box Test

The shearing resistance offered by the soil as one portion is made to slide on the other is measured at regular intervals of displacement. Failure occurs when the shearing resistance the maximum value which the soil can sustain. The author carry out the shear box test through all set of experiments (water content, salt content, and pH) under different normal pressures, the cohesion (c) and internal frictional angle (Φ) of the soil sample can be determined.

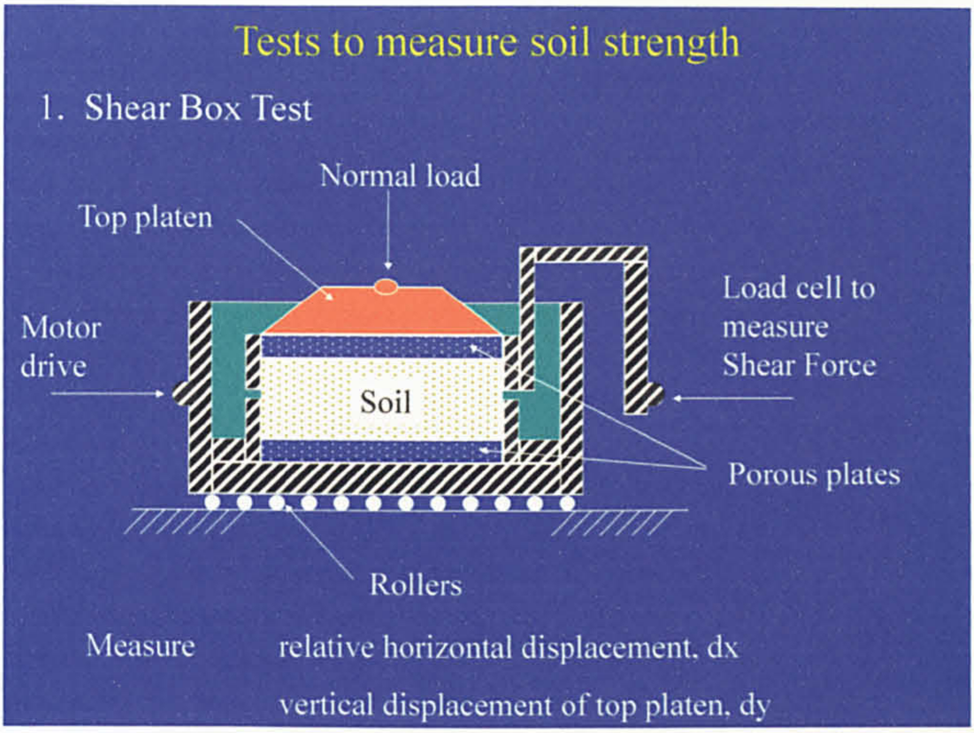

Figure 3.1.1b: The Shear Box Test Diagram

3.1.2 Analysis Data Method

After the laboratory experiment, all the data were analyzed to get the final result. The author have conducted graphical and table method in order to correlate relation between the electrical resistivity with the strength of the soil. The graphs were created using Microsoft Excel.

3.2 Electrical Resistivity Testing Procedures

3.2.1 Apparatus

- Four terminal probes.
- Null balancing ohmmeter or multimeter capable of four wire resistance measurements from one to one million ohms.
- Four insulated wire conductors
- Soil box
- Measuring tape

3.2.2 Soil Type

In this research the author conduct experiment only to one type of soil which is determine as Kaolinite Sand of grade K200. The basic properties of the soil are as below:

- Particle Size Distribution(PSD) : 0.250mm- 2.000mm
- Specific Gravity (SG) : 2.6
- Liquid Limit (LL) : 36.1%
- Plastic Limit (PL) : 33.7%
- Plasticity Index (PI) : 2.4%
- pH : 4.41

3.2.3 Preparation of Soil Sampling

The soil samples were put into the oven for 24 hours to ensure the soil sample totally dried and free from water content. After 24 hours, the soil were taken out from the oven and exposed to the room temperature for 15 minutes. The soil sample were weighted approximately 5000g for each test.

The 5000g of the soil sample were added with change of moisture content, salt content or pH value depends on parameter value need to be determined. The soil sample were mixed up using soil mixture (Figure 3.2) to ensure it will be mix perfectly.

Figure 3.2.3a: Laboratory soil mixture

3.2.4 Equipment Setup

Soil box was rinsed with deionised water before starting test. The wires were connected to the multi meter. A standard soil box have four probes at either end or a pair of electrode pins spaced out between the probes (Figure 3.3). The current source from the ohmmeter was connected to the outer probes, and the potential was measured between the pins.

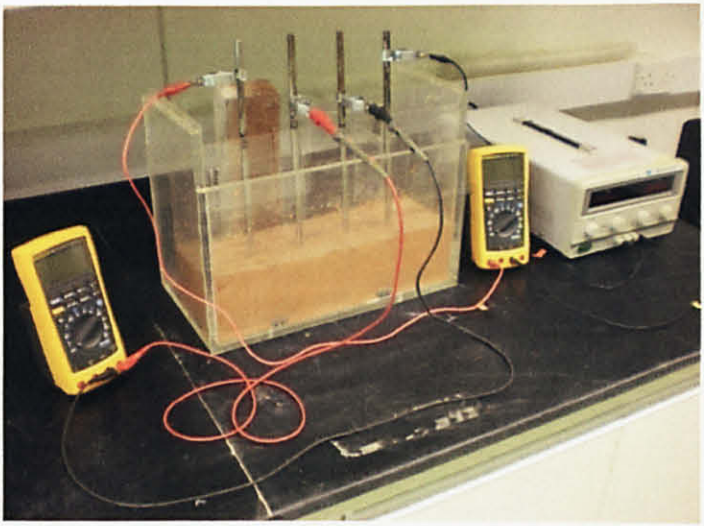

Figure 3.2.4a: Equipments Setup for Laboratory Work Test of Soil Resistivity

3.2.5 Determining Resistivity of Soil

Samples were placed (5000 grams approximately) in a soil box. Fill soil box to top taking care to leave no voids and striking excess off top of box. Fill level must be more than the distance between the probes. This is the resistivity or the resistivity of the soil in its present condition. Soil box was filled up and then the resistivity results were obtained. The same process was repeated until the resistivity stops dropping or starts to rise again. The result for the test was the average resistivity obtained during this process. Report results in ohm (Ω).

3.2.6 Sample Integrity

The soil box was washed with distilled water after each sample to avoid contamination between samples. Clean tools have been used for gathering samples and never transport or store samples in open containers.

3.3 Soil Shear Strength Testing Procedures

After testing the electrical resistivity of the soil sample, the soil samples were taken out from the soil box and put into the pan. The soil sample were tested on shear strength parameters by Direct Shear Box Test Method. The procedures of the testing method were conducted as same as British Standard procedures. Figure 3.4 shows the equipments of Direct Shear Box Test.

Figure 3.3a: Direct Shear Box Test

CHAPTER 4

RESULT AND DISCUSSION

In this chapter, the results were analyzed, discussed and presented in the sub-topic below:

4.1 Electrical Resistivity Result of Different Moisture Content

The experiments were conducted by change the moisture content into four different values which are 10%, 15%, 25% and 30%.The results show as below:

Water Content (%)	**10**	**15**	**25**	**30**
Electrical Resistivity, ρ (Ωm)	615.25	325.50	97.79	58.53
Cohesion, c (kN/m²)	0.8855	1.7645	10.0462	12.2108
Friction angle, Φ (°)	26.49	30.13	27.3	24.89

Table 4.1a: Electrical resistivity results for Different Moisture Content

In order to look at the possible correlation of electrical resistivity obtained and the various soil parameters, the results of the electrical resistivity can be refer to the plotted graph. Graph for electrical resistivity versus water content, cohesion and friction angle are given in Figures 4.1a, 4.1b, and 4.1c.

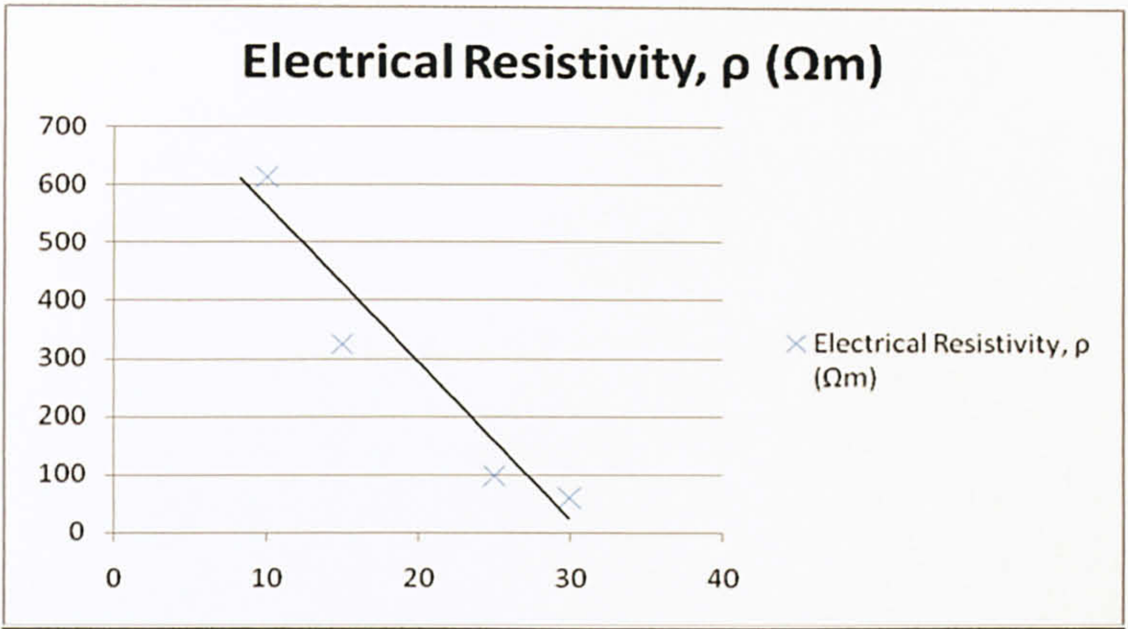

Figure 4.1a: Graph Soil Resistivity vs. Moisture Content

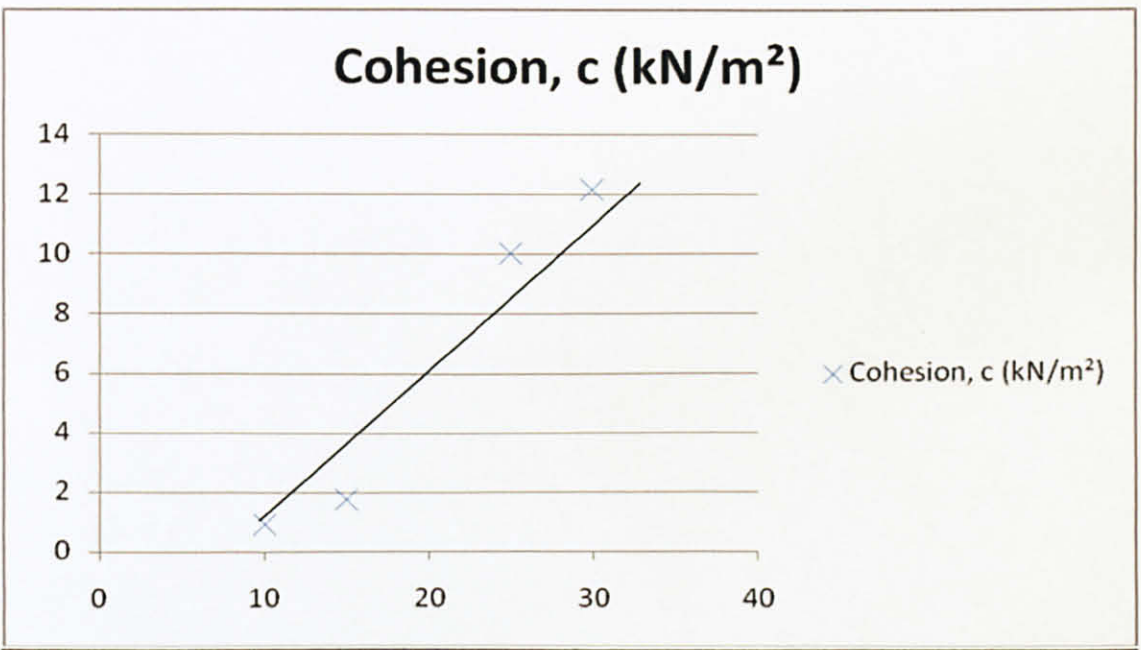

Figure 4.1b: Graph Soil Cohesion vs. Moisture Content

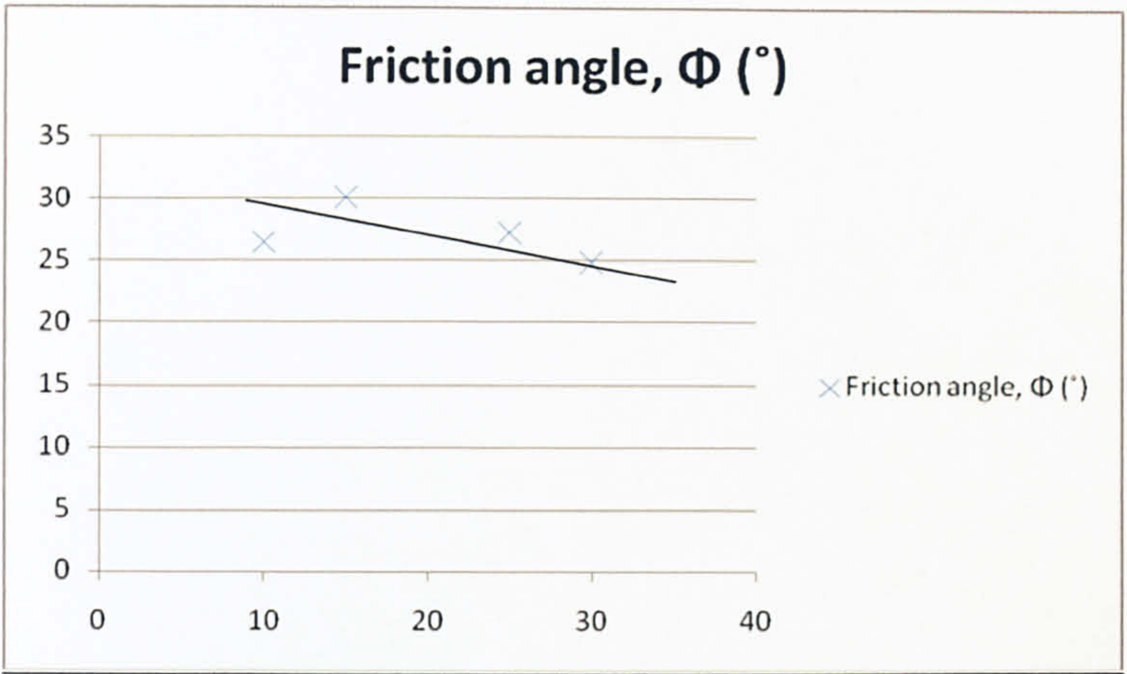

Figure 4.1c: Graph Friction Angle vs. Moisture Content

From the result given in Figure 4.1a, it is clear that electrical resistivity of the soil decrease with increment of water content. Figure 4.1b indicates that when the electrical resistivity decreases, the cohesion of the soil increases. It shows that the cohesion of the soil sample increases as well as increasing of the water content in soil sample. For internal frictional angle result, the angle of friction decreases when the electrical resistivity decreases as shown in Figure 4.1c.

The data above show the strength of the soil increases with incremental of the moisture content. This correlation was expected, as the strength of a soil will decrease with tillage, due to breakdown of natural aggregates and pores. The water will fill pore inside the soil and reduce the effect of tillage.

4.2 Electrical Resistivity Result of Different Salt Content

The experiments were conducted in two conditions, 10% and 30% of moisture content (salt + water content) with three different values of salt content respectively. The value of salt content are 1.6%, 1.9%, and 2.2% for 10% of moisture content 6%, 7.5% and 9% for 30% of moisture content. The results show as below:

Salt Content (%)	**1.6**	**1.9**	**2.2**
Electrical Resistivity, ρ (Ωm)	0.9393	0.8245	0.7089
Cohesion, c (kN/m²)	2.00	1.97	1.39
Friction angle, Φ (°)	26.1	24.7	27.75

Table 4.2a: Electrical resistivity results for Different Salt Content in 10% moisture Content

Salt Content (%)	**6**	**7.5**	**9**
Electrical Resistivity, ρ (Ωm)	0.3394	0.3093	0.2775
Cohesion, c (kN/m²)	16.7	17.5	15.4
Friction angle, Φ (°)	21.29	28.47	25.81

Table 4.2b: Electrical resistivity results for Different Salt Content in 30% moisture Content

In order to look at the possible correlation of electrical resistivity obtained and the various soil parameters, the results of the electrical resistivity can be refer to the plotted graph. Graph for electrical resistivity versus salt content, cohesion and friction angle are given in Figures 4.2a.1, 4.2a.2, 4.2a.3, 4.2b.1, 4.2b.2 and 4.2b.3 for 10% and 30% moisture content respectively.

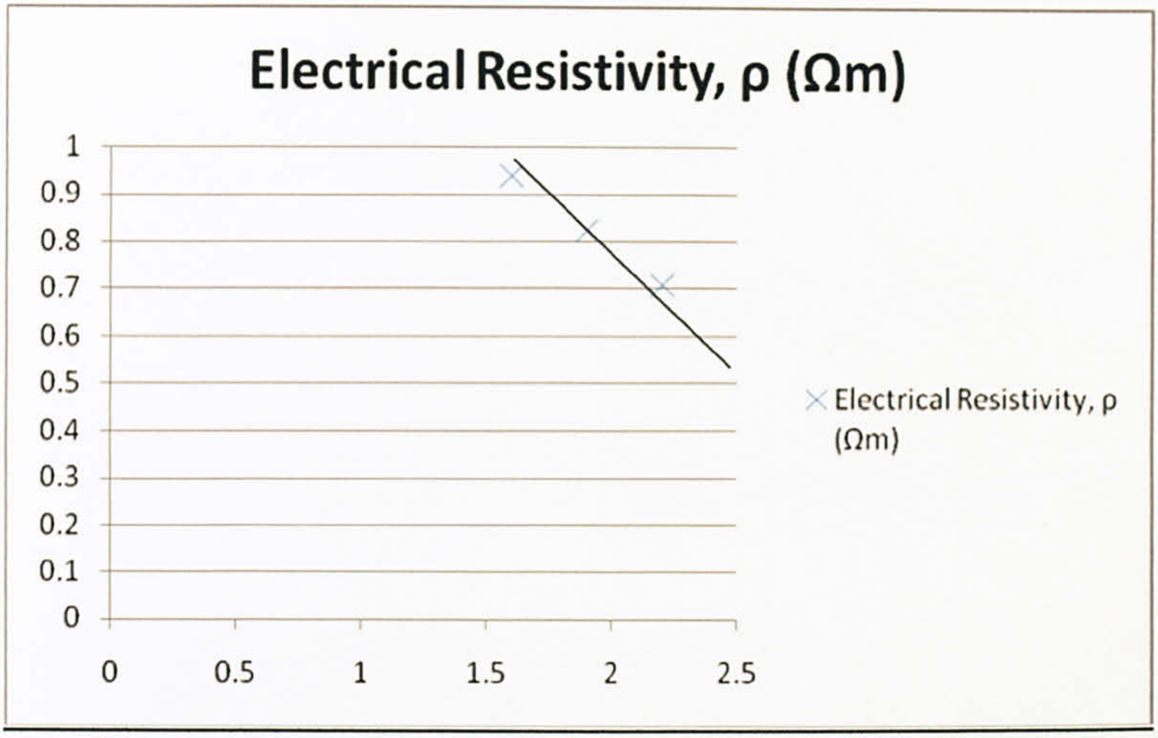

Figure 4.2a.1: Graph Soil Resistivity vs. Salt Content in 10% Moisture Content

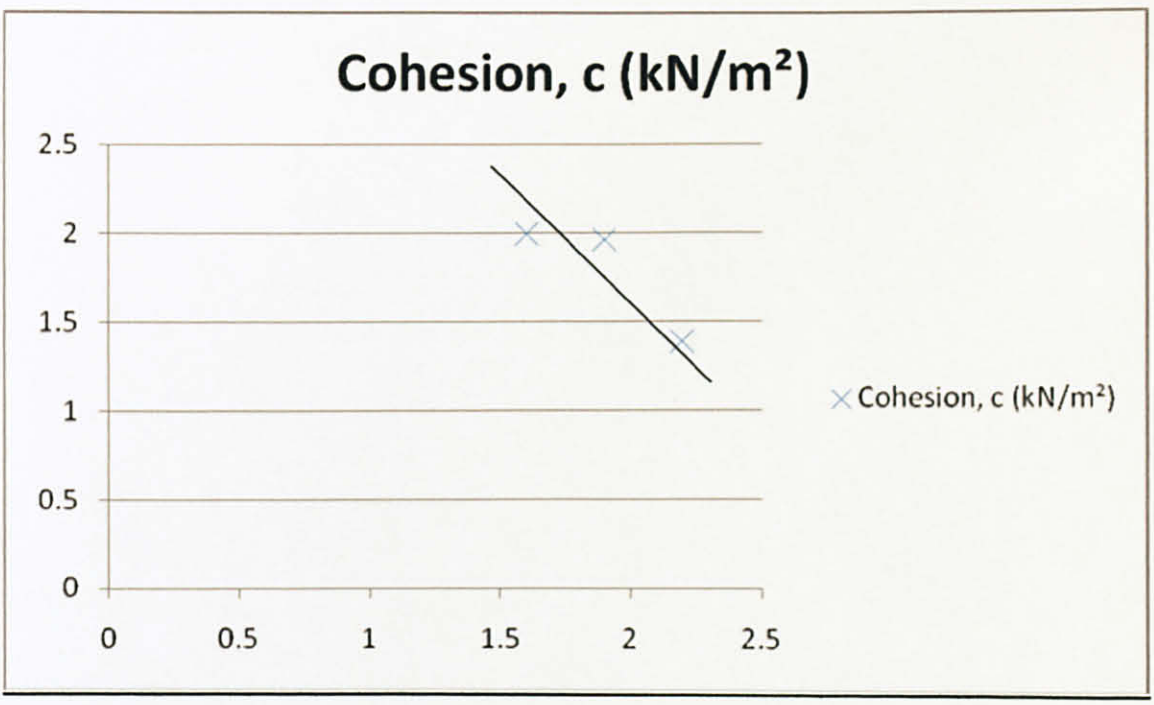

Figure 4.2a.2: Graph Soil Cohesion vs Salt Content in 10% Moisture Content

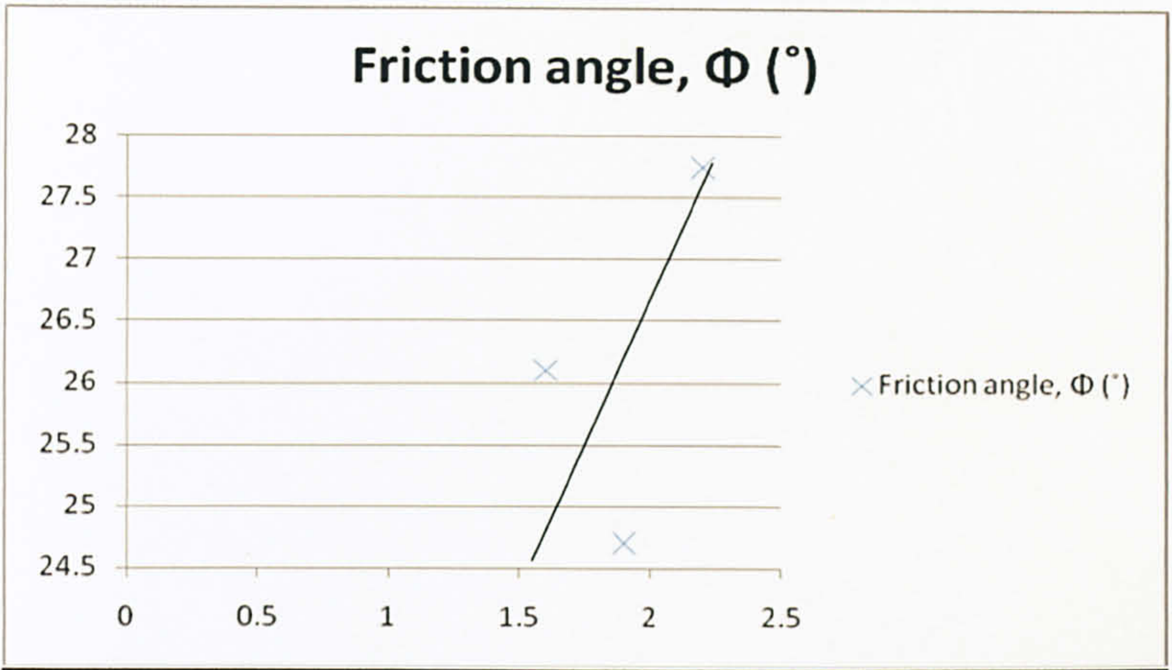

Figure 4.2a.3: Graph Friction Angle vs Salt Content in 10% Moisture Content

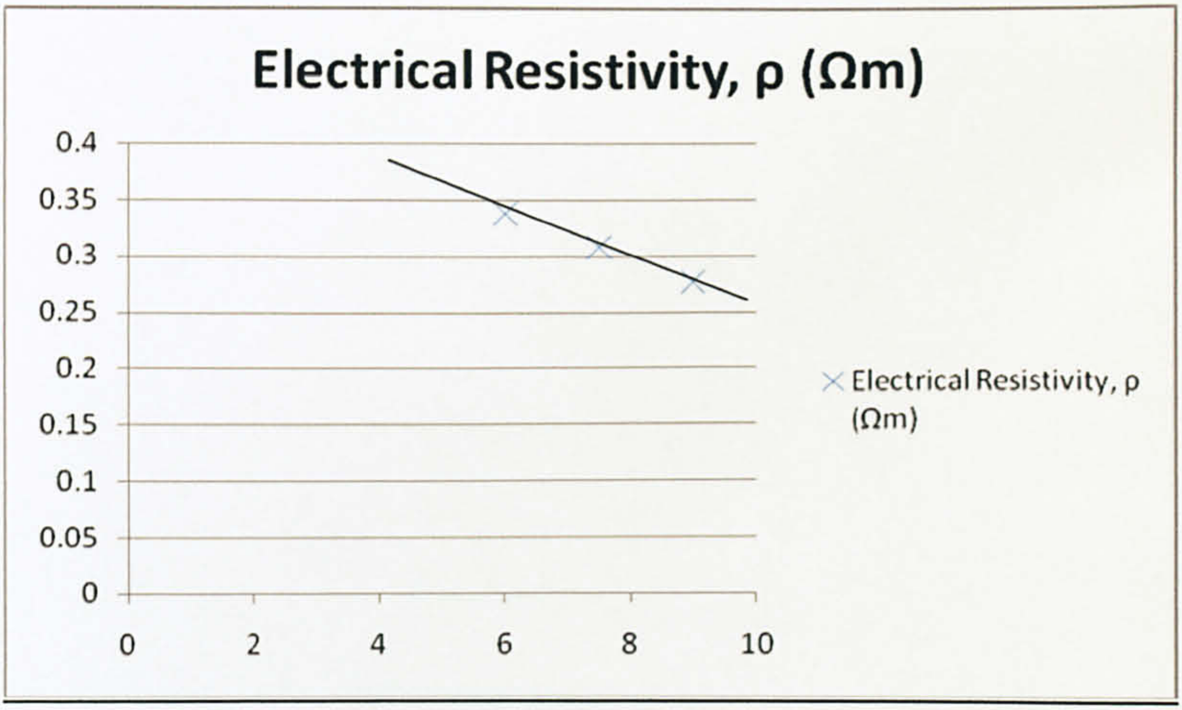

Figure 4.2b.1: Graph Soil Resistivity vs. Salt Content in 30% Moisture Content

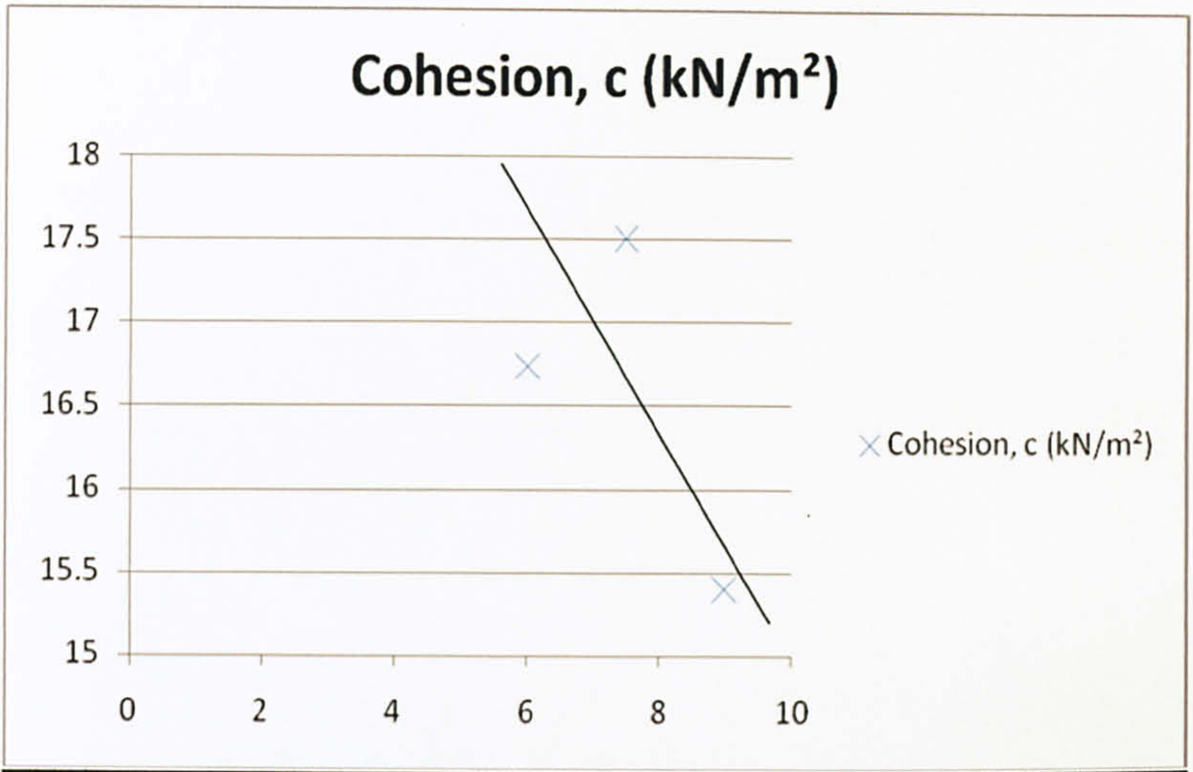

Figure 4.2b.2: Graph Soil Cohesion vs. Salt Content in 30% Moisture Content

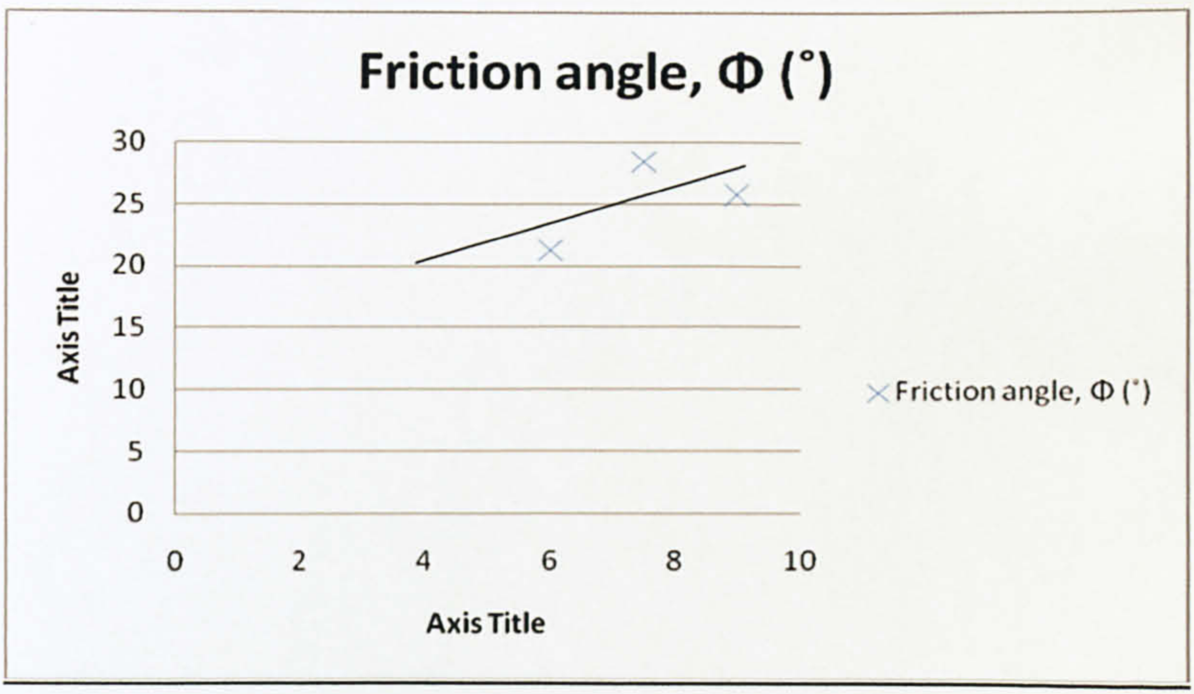

Figure 4.2b.3: Graph Friction Angle vs. Salt Content in 30% Moisture Content

From the result given in Figure 4.2a.1 and Figure 4.2b.1, it is clear that electrical resistivity of the soil decreases with increment of salt content. Figure 4.2a.2 and Figure 4.2b.2 indicates that when the electrical resistivity decreases, the cohesion of the soil decreases. It shows that the cohesion of the soil sample increases as well as decreasing of the salt content in soil sample. For the internal frictional angle result, the angle of friction decreases when the electrical resistivity increases as shown in Figure 4.3.

The data above show the strength of the soil increases with incremental of the salt content. This correlation was expected, as the strength of a soil will decrease with tillage, due to breakdown of natural aggregates and pores. The condition is same with moisture content. The particle of the salt will fill pore inside the soil and reduce the effect of tillage.

4.3 Electrical Resistivity Result of Different pH Value of the Soil

The experiments were conducted by change the pH value of the soil into three different range values which are 4.02, 5.87 and 8.02. The result show as below:

pH Value of Soil	4.02	5.87	8.02
Electrical Resistivity, ρ (Ωm)	58.525	52.32	27.652
Cohesion, c (kN/m²)	11.426	9.0636	11.422
Friction angle, Φ (°)	25.07	25.17	31.82

Table 4.3a: Electrical resistivity results for Different pH value of Soil

In order to look at the possible correlation of electrical resistivity obtained and the various soil parameters, the results of the electrical resistivity can be refer to the plotted graph. Graph for electrical resistivity versus water content, cohesion and friction angle are given in Figures 4.3a, 4.3b, and 4.3c.

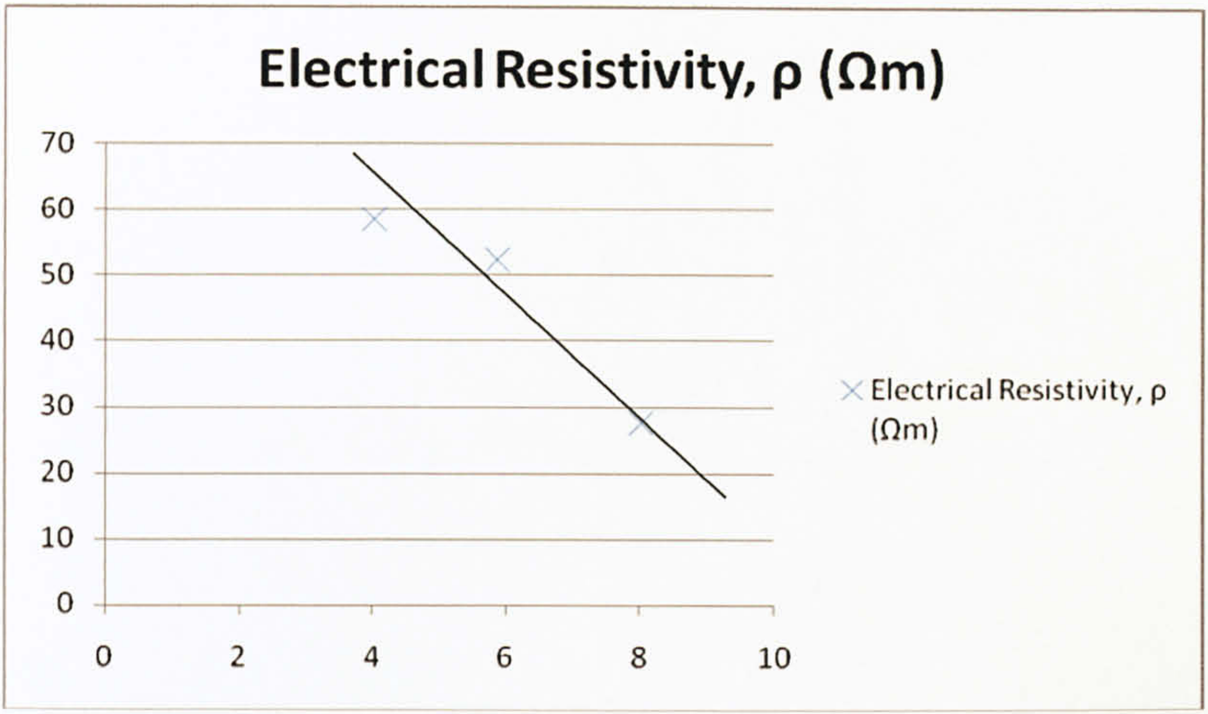

Figure 4.3a: Graph Soil Resistivity vs. pH Value of the Soil

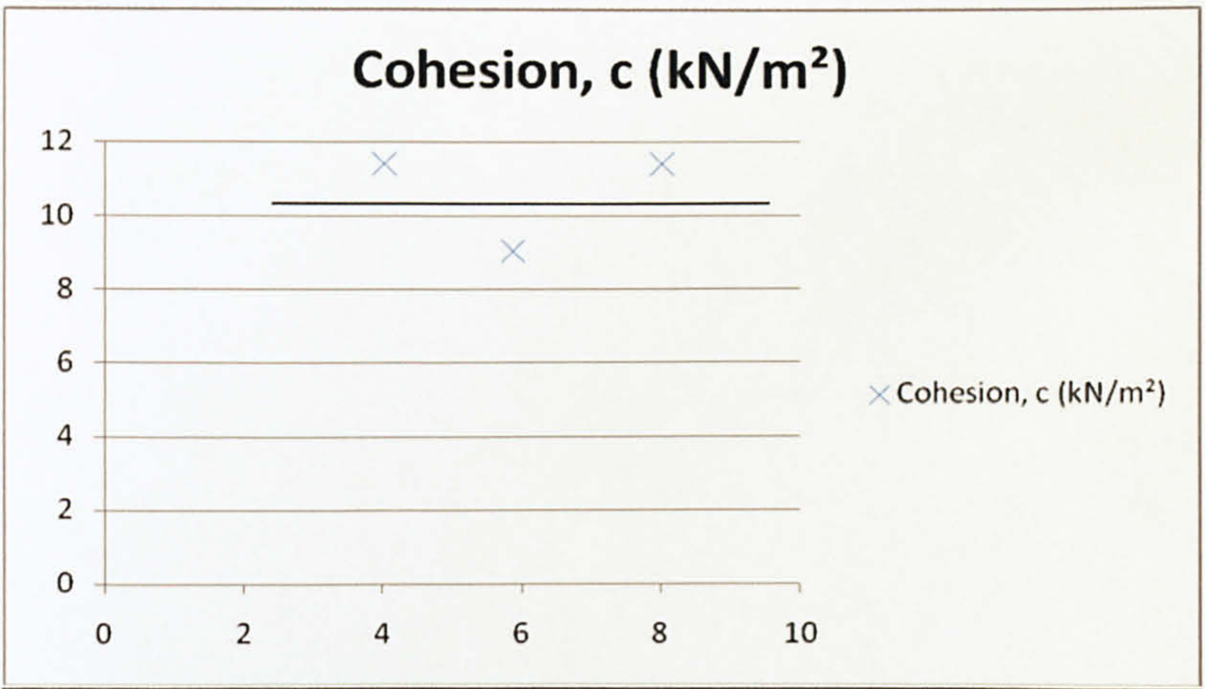

Figure 4.3b: Graph Soil Cohesion vs. pH Value of the Soil

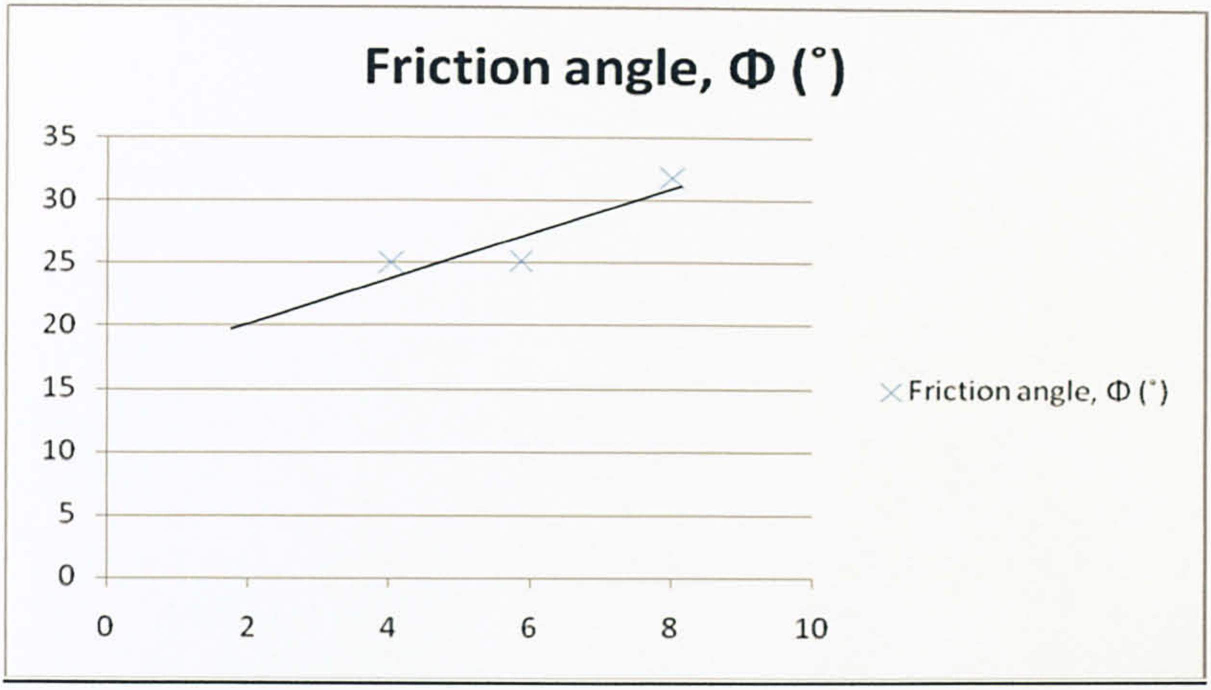

Figure 4.3c: Graph Friction Angle vs. pH Value of the Soil

From the result given in Figure 4.3a, it is clear that electrical resistivity of the soil decreases with increment of pH value. Figure 4.3b indicates that when the electrical resistivity decreases, the cohesion of the soil still the same. It shows that the cohesion of the soil sample remain same although the water content in soil sample is increasing. For internal frictional angle result, the angle of friction increases when the electrical resistivity decreases as shown in Figure 4.1c.

The data above show the strength of the soil remain the same with incremental of the salt content. This correlation was expected, as the increasing pH value of the soil did not increases or decreases the pores inside the soil. The effect of tillage will be the same.

CHAPTER 5
CONCLUSION & FURTHER WORK

5.1 Conclusion

The objective to establish correlation between electrical resistivity with different condition of the soil was reached by the author. The three types of test condition by the author in this research show significant result to the value of electrical resistivity of the soil. The trend for all the soil testing in laboratory results behaves as follows:

PARAMETERS	ELECTRICAL RESISTIVITY
Water Content, ↑	ρ, ↓
Cohesion, ↑	ρ, ↓
Frictional Angel, ↓	ρ, ↓

Table 5.1a: Trend of Moisture Content Result

PARAMETERS	ELECTRICAL RESISTIVITY
Salt Content, ↑	ρ, ↓
Cohesion, ↓	ρ, ↓
Frictional Angel, ↑	ρ, ↓

Table 5.1b: Trend of Salt Content Result

PARAMETERS	ELECTRICAL RESISTIVITY
Water Content, ↑	ρ, ↓
Cohesion, =	ρ, ↓
Frictional Angel, ↑	ρ, ↓

Table 5.1c: Trend of Salt Content Result

5.2 Further Work

Further work can be done to correlate the soil strength value with electrical resistivity of the soil in the appropriate procedure. After that, the result should be compare with field work method to make sure the data are applicable to be use during the soil investigation.

These result obtained are the possible preliminary crude correlation between electrical resistivity and some soil parameters with various soil condition. More detail research need to be conducted to enhance result and to have more detail correlation.

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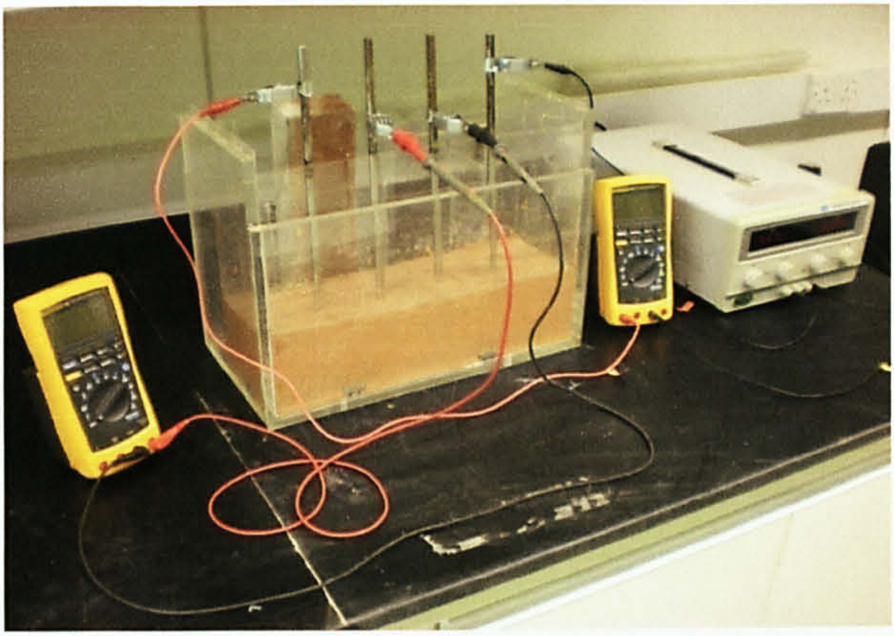
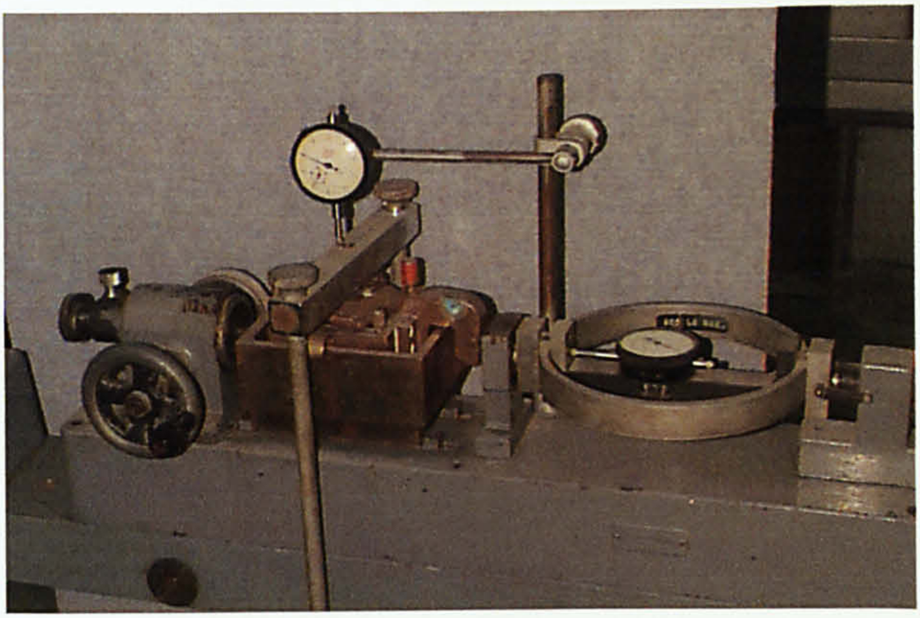
APPENDICES



Appendices 1: Electrical Resistivity Test Equipment



Appendices 2: Shear Box Test Equipment

Electrical Resistance Data Experiment: Moisture Content

10% Moisture Content

Vs	Vr	Ir	R
30	4.2	0.0011	3818.18
20	2	0.0006	3214
10	0.5	0.0001	5000
		Average	4010.73

15% Moisture Content

Vs	Vr	Ir	R
30	5.02	0.003	1673.33
20	2.2	0.0013	1692.31
10	0.9	0.0003	3000
		Average	2121.88

25% Moisture Content

Vs	Vr	Ir	R
30	8.02	0.0131	612.21
20	5.09	0.0081	628.4
10	2.15	0.0032	671.88
		Average	637.5

30% Moisture Content

Vs	Vr	Ir	R
30	6.966	0.0181	384.86
20	4.5466	0.0121	375.75
10	1.9966	0.0052	383.96
		Average	381.52

Electrical Resistance Data Experiment: Salt Content

1.6% Salt Content (10% Moisture Content)

Vs	Vr	Ir	R
15	13.151	1.9084	6.8911
10	6.4941	1.1685	5.5576
5	3.028	0.5114	5.921
		Average	6.1232

1.9% Salt Content (10% Moisture Content)

Vs	Vr	Ir	R
30	5.1789	0.9378	5.5224
20	3.6805	0.6507	5.6562
10	1.7853	0.361	4.9454
		Average	5.3747

2.2% Salt Content (10% Moisture Content)

Vs	Vr	Ir	R
30	5.294	1.2758	4.1496
20	3.5323	0.8144	4.3373
10	1.8537	0.3447	5.3777
		Average	4.6215

Electrical Resistance Data Experiment: Salt Content (continue)

6% Salt Content (30% Moisture Content)

Vs	Vr	Ir	R
15	3.3519	1.573	2.1309
10	2.2483	0.9883	2.2749
5	0.9814	0.4396	2.2325
		Average	2.2128

7.5% Salt Content (30% Moisture Content)

Vs	Vr	Ir	R
15	3.2678	1.3859	2.3579
10	1.9767	0.9969	1.9828
5	0.7043	0.4124	1.7078
		Average	2.0162

9% Salt Content (30% Moisture Content)

Vs	Vr	Ir	R
15	3.1544	1.5676	2.0123
10	1.8794	1.0505	1.789
5	0.6554	0.403	1.6263
		Average	1.8092

Electrical Resistance Data Experiment: pH value of Soil

pH 4.02

Vs	Vr	Ir	R
30	6.966	0.0181	384.86
20	4.5466	0.0121	375.75
10	1.9966	0.0052	383.96
		Average	381.52

pH 5.87

Vs	Vr	Ir	R
30	7.308	0.0213	343.1
20	4.7023	0.0138	340.75
10	2.0361	0.006	339.35
		Average	341.07

pH 8.02

Vs	Vr	Ir	R
30	7.397	0.0399	184.93
20	4.6266	0.0253	182.87
10	1.8337	0.0106	172.99
		Average	180.26