CORRELATION OF SOIL ELECTRICAL RESISTIVITY AND MACKINTOSH PROBE

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Correlation of Electrical Resistivity and Mackintosh Probe

By

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

(Civil Engineering)

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Civil Engineering Programme
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Approved by,

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TRONOH, PERAK
January 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.

ABD MALIK B ABDULLAH

ABSTARCT

In general, soil investigation (SI) incorporating mackintosh probe perhaps produce reliable value of relevant soil parameter. The objective of this project is to obtain on the possible correlation of electrical resistivity and mackintosh probe. This research however, purposely to implement a simple and quick assessment method to predict the soil properties in the soil investigation in the future. Conventional way on doing this work on field require much cost and longer time, hence this research also study on the cost reducing, effective method and the effective time consuming. Field electrical resistivity survey using basic multimeter were conducted on slope and ground level in Universiti Teknologi Petronas compound and the result obtained were compare and correlated with some soil properties obtained from bore hole results. Result from mackintosh blows and electrical resistivity survey shows that there were inconsistencies in the correlation between mackintosh blows and soil electrical resistivity.

ACKNOWLEDGEMENT

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Nowadays, conventional method for finding the strength of soil especially the data that will be use in design the shallow foundation is by using mackintosh probe. This method is widely use in the geotechnical or soil investigation industry. However this method is require more energy for the hammering activity and time consuming. This report is presents the optional method to replace the mackintosh probe. The author is attempting to do the research about correlations between mackintosh probe method and electrical resistivity method to create a new option that can be use in soil investigation.

In completing this study, the data for both electrical resistivity and mackintosh probe were obtained and analyzed in order to do the correlation for the both data. The correlation of both parameters is a very useful for the geotechnical and soil investigation industry because it is useful in order to do a quick assessment for the slope investigation.

1.2 PROBLEM STATEMENT

The usual method that is used to do a soil investigation (SI) incorporating bore hole sampling and mackintosh probe will perhaps produce the most reliable value of the relevant soil parameters for the purpose of actual calculation of factor of safety (FOS) in slopes. However, bore hole sampling and mackintosh is time consuming and very expensive. Moreover, conventional method of soil analysis mostly require disturbing soil while electrical geophysical method on the contrary allow rapid measurement of soil electrical properties such as electrical resistivity and conductivity directly from soil surface to any depth without any soil disturbance. This project is a part of the whole research which is to implement a quick method of establishing the correlation between mackintosh probe with electrical resistivity method in order to replace the conventional soil investigation.

1.3 OBJECTIVES AND SCOPE OF STUDY

To address the discussed problems, the objective of this study is to find possible correlation of soil electrical resistivity with mackintosh probe. This research will be focusing on the relationship between the electrical resistivity and the parameter of soil strength. There are many factors lead to different variation of resistivity result such as mineralogy, soil type, pH, porosity, particle size distribution, moisture content and temperature.

CAHPTER 2

LITERATURE REVIEW

2.1 ELECTRICAL GEOPHYSICAL

Electrical geophysical methods allow rapid measurement of soil electrical properties such as electrical conductivity, resistivity and potential directly from soil surface to any depth without soil disturbance. The in situ methods of electrical conductivity like four-electrode probe and electromagnetic induction are routinely used to evaluate soil salinity (Halvorson and Rhoades, 1976; Chang, 1983; Rhoades, 1989b). Some electrical geophysical methods were used to map groundwater tables (Arcone, 1998), preferential water flow paths (Freeland, 1997a), and perched water locations (Freeland, 1997b); to outline locations of landfills (Barker, 1990); and to evaluate water content, temperature, texture, and structure of soils. However, the relationships between electrical properties and other soil chemical and physical properties are very complex because many soil properties may simultaneously influence in situ measured electrical parameters (Rhoades et al., 1976b.)

Despite the advantages of electrical geophysical methods, their applications to soil study problems are not straightforward and require further study. First, the theory about the nature of development and distribution of soil electrical fields, whose parameters are measured with the electrical geophysical methods, is still being developed (Pozdnyakov et al., 1996a; Pozdnyakova, 1999). Second, the in situ measurements of electrical parameters need a specific calibration in every study to be reliable to monitor different soil properties.

Instead of that, test should be done to identify the soil strength such as direct shear test for sand and unconsolidated undrained test for clay layer. These testing might need time to be fully completed. Besides that, it is impossible to determine the factor of safety of the slope by that time because all the data need to be collected and calculated first. As we know, the subsoil condition varies with time. To have an accurate result, regular checking needs to be done. This might be very costly, thus a quick method needs to be done for cost reducing reason. These studies are very important especially in doing exploration about new method to do the quick assessment on the slope stability that will to be use in industry.

The density of mobile electrical changes, reflected in measured electrical properties, was related to many soil physical and chemical properties. Soil chemical properties like humus content, base saturation, cat ion exchange capacity (CEC), soil mineral composition, and amount of soluble salts are related to the total amount of charges in soils. Soil physical properties, such as water content and temperature, influence the mobility of electrical charges in soils. The electrical parameters were related with soil properties influencing the density of mobile electrical charges in soils by exponential relationships based on Boltzmann's distribution law of statistical thermodynamics.

Electrical geophysical methods used in this study can be broadly classified as methods measuring natural electrical potentials of the ground. Method of self-potential (SP) measures the naturally existing stationary electrical potentials in the soil. Vertical electrical sounding (VES) and electrical profiling (EP) methods measure electrical resistivity or conductivity of soil to any depth when a constant electrical field is artificially created on the surface. VES and EP methods as well as laboratory method of measuring electrical resistivity in soil samples are based on four-electrode principle, but vary considerably in electrode array lengths and arrangements, which make the methods suitable for different applications. The VES, EP, and SP methods evaluate parameters of the stationary electrical fields in soils. All the methods of stationary electrical fields require grounding electrodes on the soil surface.

2.1.1 Self-potential

This method is based on measuring the natural potential differences, which generally exist between any two points on the ground. These potentials are associated with electrical currents in the soil. In this study we the author interested in the measurement of electrical resistant created in soils due to soil-forming process and water/ion movements. The electrical resistant in soils, clays, sand, and other water-saturated and unsaturated soil can be explained by such phenomena as ionic layers, electro-filtration, pH differences, and electro-osmosis. The soil-forming processes can create electrically variable horizons in soil profiles. (Pozdnyakova et al., 2001).

2.1.2 Four-electrode probe

All the electrical resistivity methods applied in geophysic sand soil study are based on the standard four-electrode principle suggested by Wenner in 1915 to minimize soil-electrode contact problems. The four-electrode principle is illustrated in the laboratory conductivity cell (Figure 2.1). The cell is a rectangular plastic box with the current electrodes A and B as brass plates on the smaller sides. The potential electrodes M and N are the rods in the middle of the long side of the cell. A constant current (I) is applied to the two outer electrodes (A and B) and the arising difference of potential (u) is measured between the two inner electrodes (M and N). The electrical resistivity (ER) is calculated from the Ohm's law as

$$ER = K\,(\Delta U / I)$$

Where K is a geometrical factor (m) depending on the distance among electrodes, U Is difference of potentials (mV), and I is magnitude of current (mA). The geometrical factor for a cell is obtained from the calibration solutions of a known resistivity. The sample of soil paste or suspension is placed in a cell to measure electrical resistivity from the readings of voltage and current. The cell construction shown in (Figure 2.1) ensures the induction of static uniform electrical field in the cell.

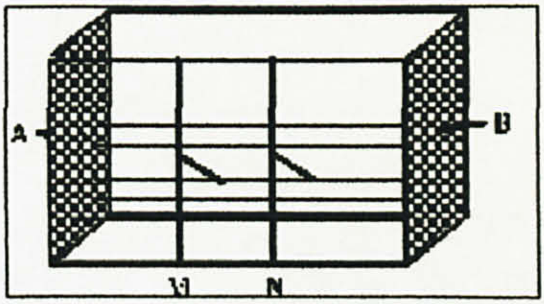

Figure 2.1: Scheme of the four-electrode laboratory conductivity cell. Electrical field lines are shown with thin straight lines (uniform electrical field).

2.1.3 Electrical profiling.

The uniform static electrical field can be created in field conditions to measure soil electrical resistivity or conductivity (Petrovsky, 1925). However, most modern geophysical methods, such as four-electrode profiling and vertical electrical sounding apply non-uniform electrical field to soils through the point electrodes. The electrical resistivity measured with these methods is termed apparent or bulk electrical resistivity, to distinguish it from the resistivity measured in laboratory in homogeneous samples with uniform electrical field. The electrical profiling method is based on the same four-electrode principle as the conductivity cell (Figure 2.1). The electrical field is distributed in a soil volume, which size can be estimated from the distance among AMNB electrodes. The geometric factor (K) can be precisely derived from the array geometry based on the law of electrical field distribution. Using the Laplace's equation in polar coordinates, (Keller and Frischknecht, 1966) derived the electrical potential functions around the source (A and B) and measuring (M and N) electrodes. The geometric factor K can be obtained for central- symmetric four-electrode array of AMNB configuration (Figure 2.2) as

$$K = \pi \frac{[AM]\,[AN]}{[MN]}$$

Where [AM], [AN], and [MN] are the distances (m) between the respective electrodes.

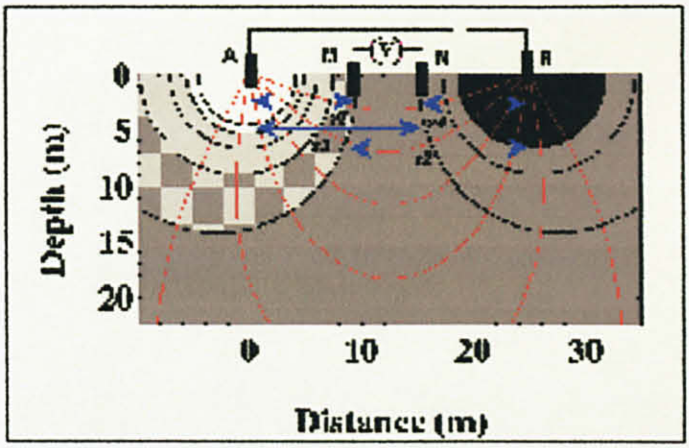

Figure 2.2: Scheme of the four-electrode method. Electrical field lines are shown with thin curvilinear lines (non-uniform electrical field).

2.2 ELECTRICAL RESISTIVITY

Resistivity is a form of survey where the electric current is passed through the ground at regular point on a survey grid. The resistivity in soil varies and depends on the presence of archaeological features, moisture content of the soil and temperature of the soil itself. Soil passes electric current in different levels. Lesser electric current passes through as the resistivity of a given soil is getting higher. The resistivity characterizes materials by their electrical resistance mainly when dealing with groundwater and sometimes can be used to trace the wet zone including both water table and aquifers. Since the phase of rupture often coincide with the wet zone, electrical resistivity method is possible. By grounding two electrodes to the ground and induced the electrical current, the potential difference between two electrodes can be measured. (Kevin Forrester, 2001, p.55) The value of potential measured is depending on the distance between electrodes, the used array, the current induced into the ground and the sensitivity of measuring equipment.

The method can be done either in horizontal or vertical profiling. In the case of vertical profiling, the gap between the electrodes with one another is increased with regular step and the center of array is fixed. For horizontal profiling, the array of potential and current electrodes is moved over the surface. Instead of that, this method can be done using one or more boreholes. If a borehole is used for current and potential electrodes, the procedure and measurement is the same as the surface surveys with only the orientation being different. A form of tomography can be achieved if the potential electrodes are in different boreholes. (Robert Hack, 2000, p.439)

2.3 MACKINTOSH PROBE

Measuring the strength of in situ soil and the thickness and location of underlying soil can be accomplished by using a simple hand device called the mackintosh probe.

Mackintosh probe consist of approximately 16mm diameter shaft couple at the midpoint. The lower shaft contains an anvil and a pointed tip which is driven into the soil. The underlying soil strength is determined by measuring the penetration of the lower shaft into the soil after each hammer drop. Value is recorded in volume of blow in 300mm penetration of the shaft.Mackintosh equipment comprises of the following elements:-

1) Handle

- The handle is located at the top of the device. It is used to limit the upward movement of the hammer

2) Hammer

- The 6 kg hammer is manually raised to the upward and free fall dropped to transfer energy through the shaft to the cone tips

3) Shaft

- The approximately 16mm shaft diameter stainless steel used to prevent the shaft from corrosion and used to absorb energy transfer by the hammer and bring to the cone tips.

4) Cone

- The important parts of the equipment that allow the shaft penetrate into the soil.

Figure 2.3: The way of mackintosh probe was do in order to determine the strength of underlying soil strength by measuring the penetration of the device into the soil.

Mackintosh probes basically are used for detection of weak or shear plane at shallow depth, determination of shallow bedrock profile, and for shallow depth (less than 4m).The ratio of mackintosh probe to undrained shear strength in kPa is about 1. For larger depth, the ratio reduces significantly and often unreliable. Figure 2.4 below show the correlation of mackintosh probe and bearing strength that usually use in soil investigation.

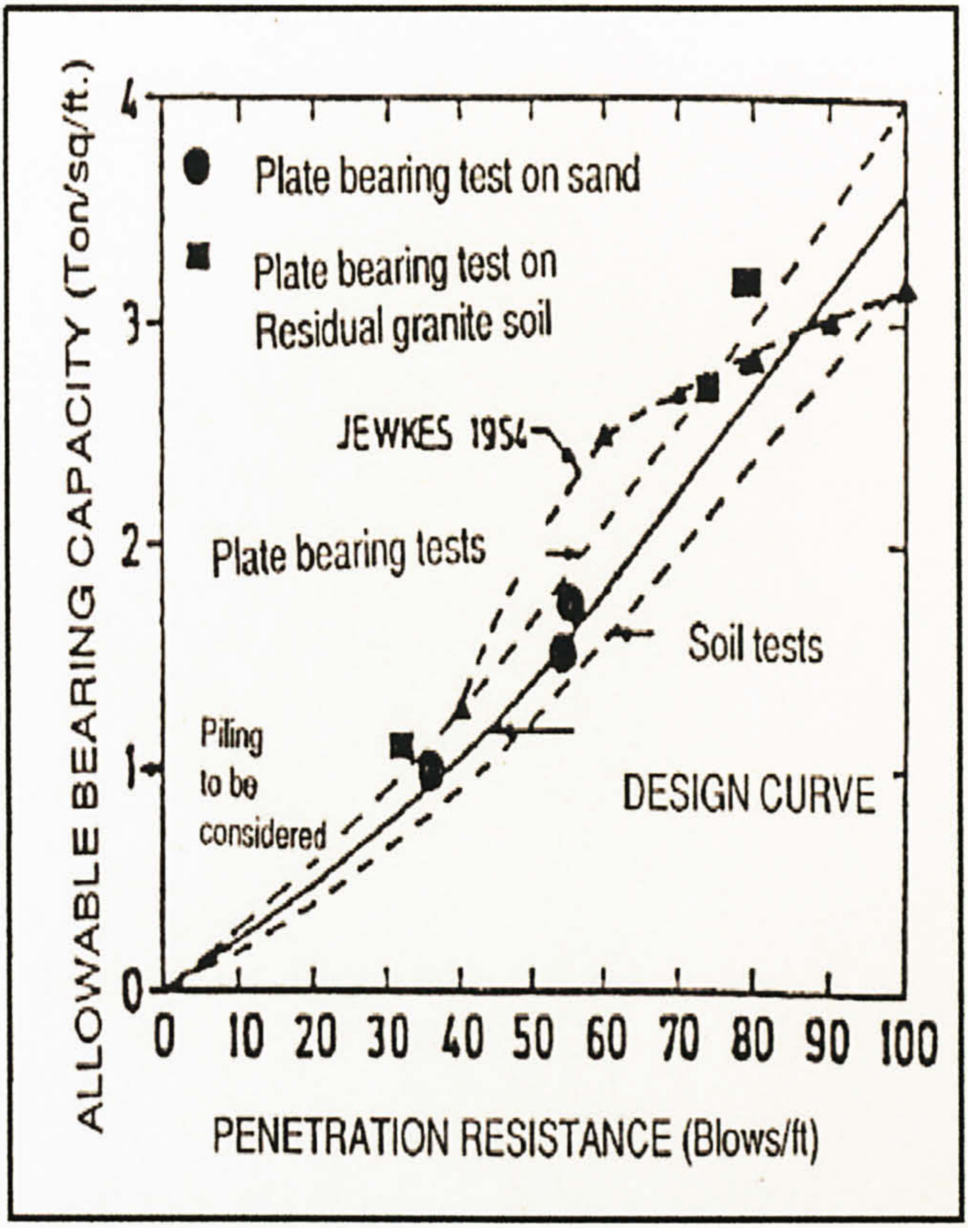

Figure 2.4: Correlation of Mackintosh probe and allowable bearing capacity

2.4 ELECTRODE ARRAYS

There are many types of electrode arrays are possible in resistivity surveys. Table 1 gives the median depth of investigation for various types of electrode arrays for a homogenous sub-surface model. The median depth (Ze) indicates the depth to which a particular array can be used. The choice in the types of array for a field survey is depending on the type of feature to be surveyed (e.g., the sensitivity of the array to vertical and horizontal changes in the subsurface resistivity and the depth of investigation), the sensitivity of the resistivity meter, the background noise level, and the signal strength.

Array	n	Z_e/a	Z_e/L	Array	n	Z_e/a	Z_e/L
Wenner		0.52	0.173	Pole-dipole	1	0.52	
Wenner-Schlumberger	1	0.52	0.173		2	0.93	
	2	0.93	0.186		3	1.32	
	3	1.32	0.189		4	1.71	
	4	1.71	0.190		5	2.09	
	5	2.09	0.190		6	2.48	
	6	2.48	0.190	Pole-pole		0.867	
Dipole-dipole	1	0.416	0.139				
	2	0.697	0.174				
	3	0.962	0.192				
	4	1.220	0.203				
	5	1.476	0.211				
	6	1.730	0.216				

Table 2.1: Median depth (Ze) of investigation for different arrays.

Wenner Array

The Wenner array is best used for horizontal structures, but in the other hand it is relatively poor in detecting narrow vertical structures. It is sensitive to vertical changes in the subsurface resistivity below the center of array and less sensitive to horizontal changes in the subsurface resistivity. This type of array has large signal strength.

Dipole-Dipole Array

This type is fit for vertical structures, vertical discontinuities and cavities, and less for identifying horizontal structures. Dipole-dipole array is sensitive to resistivity changes between the electrodes in each dipole pair the most. The depth of investigation is smaller as compared to the Wenner array. As the values of n become larger, the signal strength becomes smaller.

Wenner-Schlumberger Array

This type of array is moderately sensitive in horizontal and vertical structures. The median depth of this array is greater than the median depth of Wenner array for the same distance between electrodes. The signal strength is higher than the dipole-dipole array and smaller than the wenner array.

Pole-pole Array

This array can be simulated if one current and one potential electrode are placed at a distance more than 20 times the distance between the N and B electrodes. This array is sensitive for noise due to the large distance between potential electrodes.

Pole-dipole Array

This array is asymmetrical and results in asymmetrical apparent resistivity anomalies in the pseudo section for surveys over symmetrical structures. This kind of effect can be avoided by repeating the measurements with the electrodes reversed. The pole-dipole array has the higher signal rather than the dipole-dipole array. It is not as sensitive to noise as the pole-pole array because the distance between the potential electrodes is not large. The signal strength of the pole-dipole array is lower compared to the wenner and wenner-schlumberger arrays but higher than the dipole-dipole array.

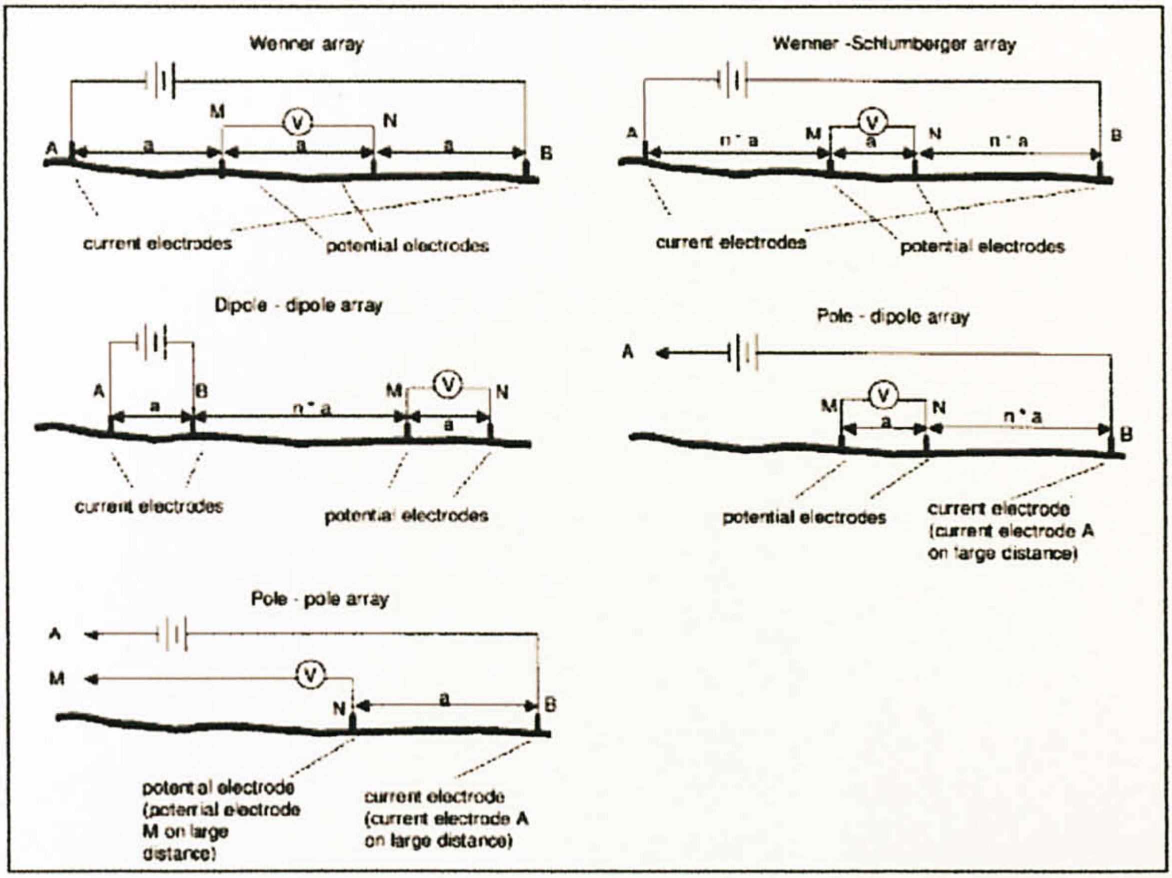

Figure 2.5: Various arrays for current and potential electrodes.

CHAPTER 3

METHODOLOGY

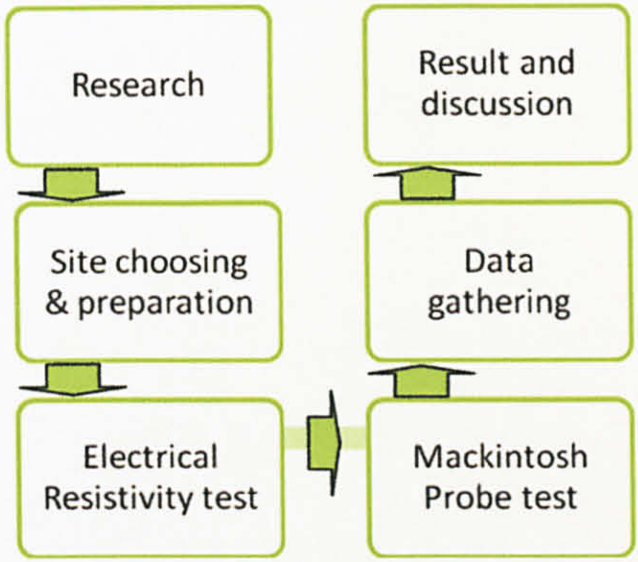

Figure 3.1: Research methodology

3.1 RESEARCH

A lot of research has been done on the early study in order to enhance the familiarization and understanding of the chosen topic. The scopes of research are about the geophysical study in electrical resistivity which is applied in geotechnical site investigation and the slope stability study. The research was obtained from the related journals and websites such as springerlink and sciencedirect. The information gained is summarized and will be used for the further research and activities in this project.

Research based project has been done during FYP1 (Final Year Project 1) where the journal and article were collected in order to perform the research well. Since the research is focused on correlation the soil behavior in terms of resistivity and strength, the test has been done in the field to gather the needed data

3.2 SITE CHOOSING & PREPARATION

Site choosing is very important because it will influence the results of the research. The correct site is selected by evaluating the criteria like ease of mobility for the equipment and available data for the bore hole result. After the criteria has been evaluated a few sites has been chosen in order to complete this research. The site chosen are four on the slope behind the block 14 and two on the ground in the garden area at in front of block 14. Then site preparation is clearing the bushes on the site that will use for the electrical resistivity survey.

3.3 ELECTRICAL RESISTIVITY

After the site is cleared, the resistivity survey is ready to be conducted. First step for the resistivity survey was put all the steel electrode on the ground with the exact distance as per standard for the electrical resistivity wenner array method. Then the equipment was arranged and connected to the electrode. Once all the connection was done the electrical resistivity test can be run and the data jotted in the data log book. This step is repeated with respect to the desired depth. Electrical resistivity instrument consists of

- electrodes
- cables
- jumpers
- hammer
- wire
- power supply

The resistance, R is calculated by using Ohm's law

$$R = \frac{V}{I}$$

Where, V = voltage

I = current

The material resistivity, ρ can be define

$$\rho = KR \qquad \text{K; geometrical factor of electrode}$$

3.4 MACKINTOSH PROBE TEST

Mackintosh probe was not in the civil engineering syllabus for the Universiti Teknologi Petronas civil department, hence laboratory technician Mr Zaini conducted training in order to familiarize author with the equipment. Basically mackintosh probe is an equipment that are use for determine the soil strength especially in design the shallow foundation.

Conducting a mackintosh probe test involved raising and dropping the hammer to the drive the cone on the shaft through the soil. Typically, the volume of blows is recorded after the shaft was penetrating about 300mm in to the soil. This procedure repeated until the shaft was not penetrating after the blows was exceeding 400 times. This test must be conducted by crew of one to three people to calculate the blows and to rise and dropped the hammer. Common error which may occur during testing is the operator not holding the shaft and it may lead the shaft not vertically penetrates into the soil. Hence the data may be having slightly error since the shaft not vertically penetrate into the soil.

3.5 DATA GATHERING

After completing that entire field testing, the data obtained was calculated to get the resistivity of each data obtained. Then in order to completing the correlation the plotting did by using Microsoft Excel. There are meeting conducted between the supervisor, and the author. The meeting basically to discuss about the project details regarding the data collected. During this meeting, the problem faced will be discussed together and try to find the best solution for the problems.

3.6 DATA INTEPRETATION

Results analysis and interpretation which is a part of the research were carried out. The analysis includes the determination of relationship between electrical resistivity and shear strength of the soil parameters with respect to various moisture content, porosity and the change of soil formation

3.7 RESULT

The result is the part when the correlation for the electrical resistivity and the mackintosh probe are made. Hence this correlation were determine whether it is correct and can be use or need to further study.

3.8 HAZARD ANALYSIS

Hazard can occur anytime and anywhere, while preceding this research hazard analysis has been study to prevent it happen and try to avoiding it. Among the hazard that are possible to happen be:-

Electrical shock

While doing field work or laboratory work, there are many electrical equipment that must be use, so the chance for electrical shock happen was quite big and the precaution that must be taken are wearing rubber glove and rubber shoes that can preventing the voltage go through our body to the earth.

Hand hit by hammer

During, field work the author will deal with hammer to put down the electrode into the soil there are possibility that hammer will hit the hand. The precautions that must be taken are carefully while dealing with hammer and wear the safety glove.

Eye injury

When field work and laboratory work many risk can appear from surrounding if no caution awareness during working. Eye injury can occur while doing field work since the author have to deal with a few sharp equipment like electrode and cables. In order to prevent eye injury, safety glass must be wear during laboratory and field work.

CHAPTER 4

RESULT AND DISCUSSION

The result below is obtained through electrical resistivity survey and mackintosh probe test at the selected site that has been chosen. The sites consist of slope behind the block 14 which bore hole data has been obtained and site from the ground in the garden compound in front of block 13 and 14.

4.1 SITE 1

Site 1 is located at the bore hole 1, behind the block 14. The data for electrical Resistivity, mackintosh probe blows, and strata description given as in the table 4.1 below. The water table height of this site is 5.15m.

Table 4.1: Correlation data for site 1

Depth (m)	Resisitivity,ρ (Ωm)	Strata description	Mackintosh blow
1	762.8	Silt with some laterite gravel	47
2	810.0	Medium stiff brownish silt	86
3	826.8	Medium stiff brownish silt	157
4	718.3	Medium stiff brownish silt	400

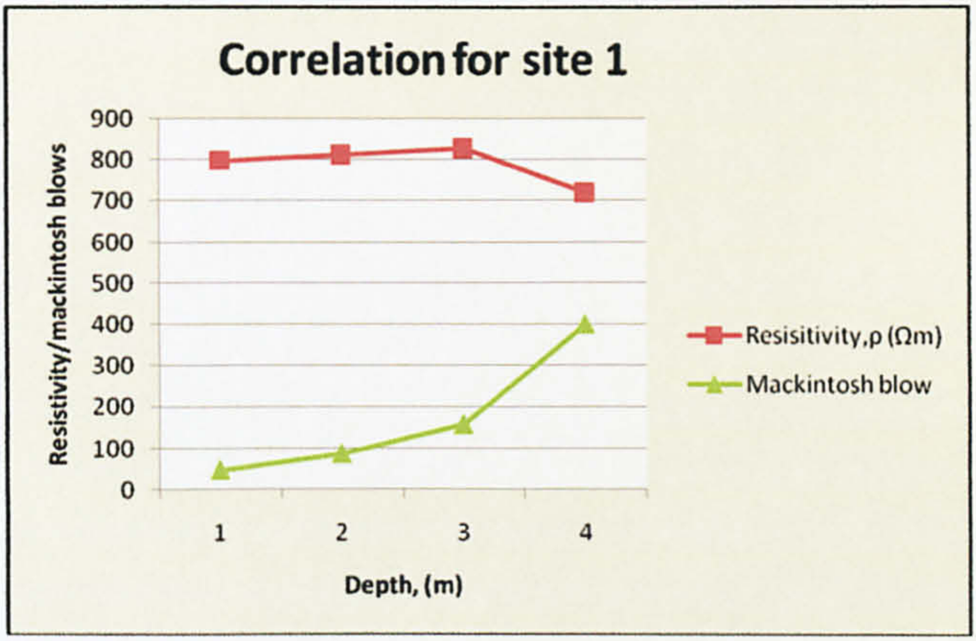

Figure 4.1: Correlation graph of resistivity and Mackintosh blow at site 1

Table 4.1 and figure 4.1 shows there are four correlation point data taken from electrical resistivity survey and mackintosh probe test. The correlation is at depth 1m to 4m from the surface. The trend for this correlation is electrical resistivity increase proportional with mackintosh blows. The soil formation of this site is silt with some laterite gravel and medium stiff brownish silt.

From the overall result, at 1 meter depth from the ground surface the mackintosh penetration is 47 blows while the resistivity is 726.8 Ωm. That means the ground surface is soft and has high moisture content. The further penetration show increasing in number of blows, which means that the hardness of the soil is increases due to change of soil formation and the moisture content of the soil. Moisture content is decreases from the from ground surface until the water table level. The soft soil boundaries are from the first penetration 300mm to seventh penetration 2100mm. The tenth penetration is the boundary of very hard soil since it shows high increasing in the number of blow which is from 86 to 181 blows.

Electrical resistivity survey at site 1 shows the resistivity within the range from 314.5 Ωm to 7959.0 Ωm. The electrical resistivity value for this site is high perhaps due to the strongly consolidated sedimentary rock or dry rock above the ground water surface. There is a questionable value of resistivity for the depth for eight meter since the Ampere value is very small and the negative voltage obtained. Maybe some error occurs during the data taken or the connection is failed. The variation in characteristics within one type of geological material makes it necessary to calibrate resistivity data against geological documentation. The whole data for electrical resistivity survey and mackintosh probe test for site 1 is given on appendix 1 and 2.

4.2 SITE 2

Site 2 is located at the bore hole 2, behind the block 14. The data for electrical resistivity, mackintosh probe blows, and strata description given as in the table 4.2 below. The water table level of this site is 7.85m.

Table 4.2: Correlation data for site 2

Depth (m)	Resisitivity,ρ (Ωm)	Strata description	Mackintosh blow
1	2018.8	Stiff, reddish silt, highly stained with laterite gravel	168
2	1649.7	-	65
3	2080.5	Medium stiff brownish silt	91
4	1218.9	Medium stiff brownish silt	91
5	944.7	Medium stiff brownish silt	82
6	956.2	Medium stiff brownish silt with veins of koalin	69
7	1077.2	-	98
8	2468.3	-	188
9	762.8	Medium stiff brownish silt with veins of koalin	225
10	660	Medium stiff brownish silt with veins of koalin	233
11	2099.8	Medium stiff brownish silt with veins of koalin	244
12	2018.8	Medium stiff brownish silt with veins of koalin	168

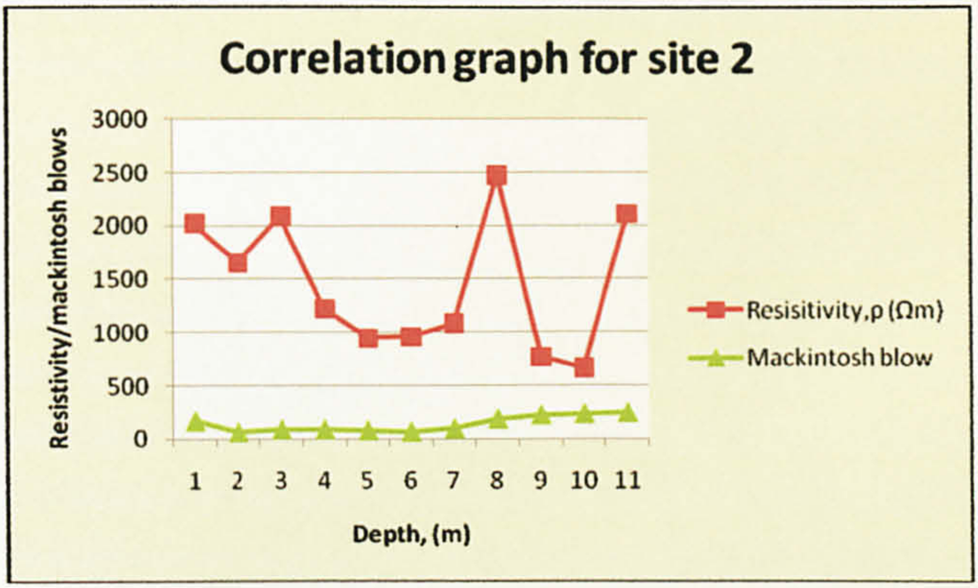

Figure 4.2: Correlation graph of resistivity and Mackintosh blow at site 2

Table 4.2 and figure 4.2 shows there are twelve correlation point data taken from both electrical resistivity survey and mackintosh probe test. The correlation is at depth 1m to 12m from the surface. The trend for this correlation is electrical resistivity increase proportional with mackintosh blows. However at depth 6m, 9m and 10m the electrical resistivity inversely proportional with mackintosh blows. The soil formation of this site is stiff, reddish silt and highly stained with laterite gravel then follow by medium stiff brownish silt and medium stiff brownish silt with veins of kaolin.

From the overall result for mackintosh probe at site 2, the result shows the first penetration is 101 blows. That mean the ground surface is in the medium strength and the moisture content of the soil on the surface layer is very low. The further penetration show decreasing in number of blows, mean the hardness of the soil is decreasing due to increasing moisture content of the soil or the change of soil formation until the 25th blows. The follow penetration shows the number of blows is keep increasing due to increasing of the strength of the soil. The boundary of hard soil is at the 36th penetration since it shows high increasing in the number of blow which 224 blows.

The electrical resistivity data shows the resistivity within the range from 660 Ωm to 4046.6 Ωm. The resistivity presents in this site also high same with the resistivity at the site 1. The whole data for electrical resistivity survey and mackintosh probe test for site 2 is given on appendix 3 and 4.

4.3 SITE 3

Site 3 is located at the bore hole 3, behind the block 14. The data for electrical resistivity and mackintosh probe blows given as in the table 4.3 below. The water table level of this site is 2.06m.

Table 4.3: Correlation data for site 3

Depth (m)	Resisitivity,ρ (Ωm)	Mackintosh blow
2	103.6	85
3	573.6	130
4	1663.4	300

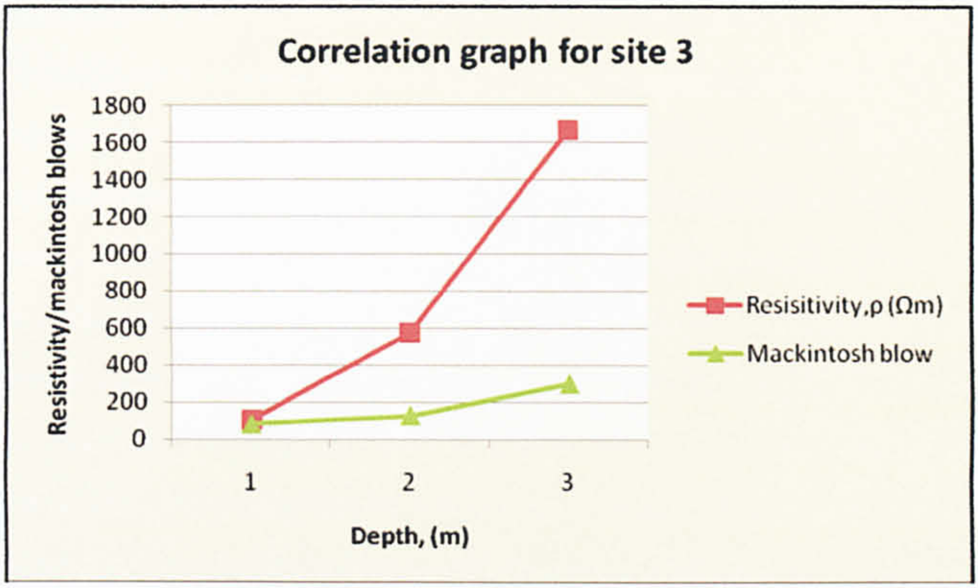

Figure 4.3: Correlation graph of resistivity and Mackintosh blow at site 3

Table 4.3 and figure 4.3 shows there are three correlation points data taken from electrical resistivity survey and mackintosh probe test. The correlation is at depth 2m to 4m from the surface. The trend for this correlation is electrical resistivity increase proportional with mackintosh blows.

From the overall result the soft soil boundaries is from the first penetration until the 9th penetration (2.7m) the volume of blows is range from 15 to 99 except the 6th penetration (1.8m) which have 139 blows. This occurs due to the unconformity of the underground soil distribution. Then, the volume of blows constantly increases until the last 300mm penetration.

The electrical resistivity survey data shows the resistivity at site 3 within the range from 103.6 Ωm to 3835.8 Ωm. From this resistivity value, the formation of soil is within clayley to sandy type of soil.

4.4 SITE 4

Site 4 is located at the bore hole 4, behind the block 14. The data for electrical resistivity and mackintosh probe blows, given as in the table 4.4 below. The water table level of this site is 17.0m.

Table 4.4: Correlation data for site 4

Depth (m)	Resisitivity,ρ (Ωm)	Mackintosh blow
2	1247.2	100
3	1305.1	121
4	1441.8	110

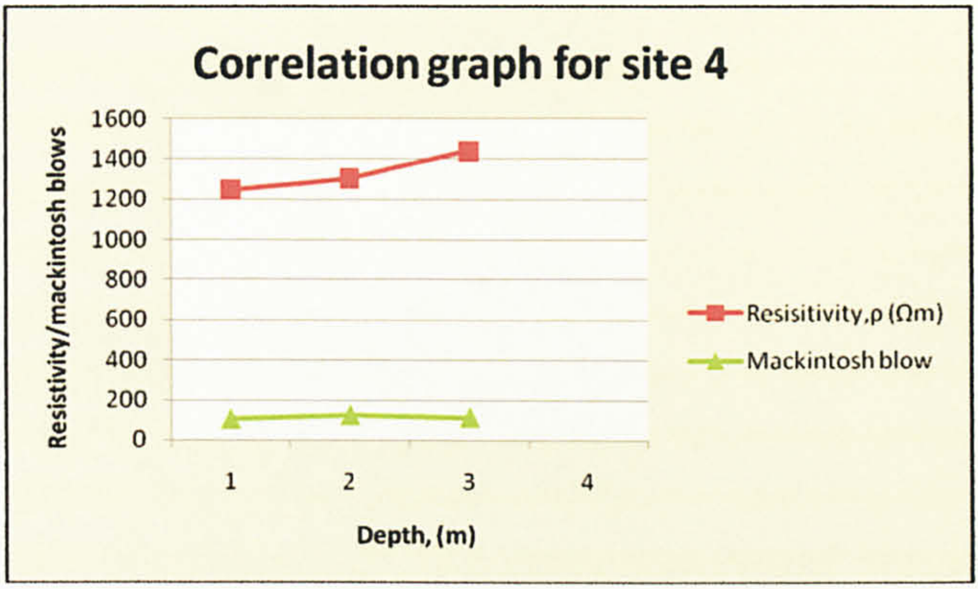

Figure 4.4: Correlation graph of resistivity and Mackintosh blow at site 4

Table 4.4 shows there are three correlation point data taken from electrical resistivity survey and mackintosh probe test. The correlation is at depth 2m to 4m from the surface. The trend for this correlation is electrical resistivity increase proportional with mackintosh blows but for the 4m depth the trend is vice versa.

From the overall result for bore hole 4, the strength of the soil is higher than the soil at bore hole 1. A few factors lead to this condition, first bore hole 2 was far away from the water level which is approximately around 17m away from the water table level hence the moisture content was low and the strength become higher. From the result at every 300mm penetration the volume of blows that we getting higher than 100 blows and then it was constantly increase until the last 300mm penetration

The electrical resistivity survey data shows the resistivity at site 3 is within the range from 1247.2 Ωm to 6857.7 Ωm. From this resistivity value, the formation of soil is within clayley to sandy type of soil.

4.5 SITE 5

Site 5 is located on the ground level in the garden compound, in front of block 13 and 14. The data for electrical resistivity and mackintosh probe blows given as in the table 4.5 below.

Table 4.5: *Correlation data for site 5*

Depth (m)	Resisitivity,ρ (Ωm)	Mackintosh blow
2	424	9
3	406	200
4	331	400

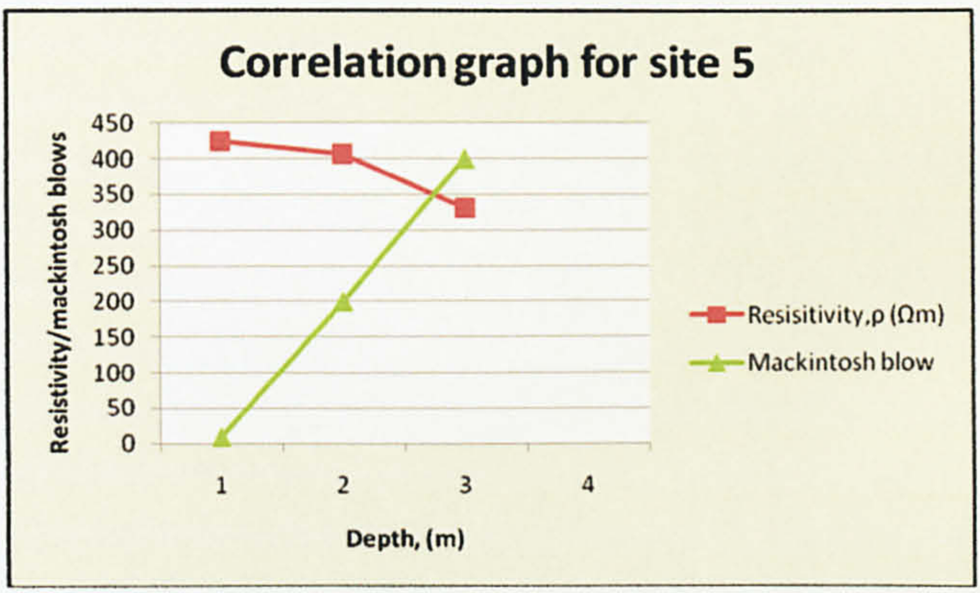

Figure 4.5: Correlation graph of resistivity and Mackintosh blow at site 5

Table 4.5 and figure 4.5 shows there are three correlation point data taken from electrical resistivity survey and mackintosh probe test. The correlation is at depth 2m to 4m from the surface. The trend for this correlation is electrical resistivity increase proportional with mackintosh blows but for the 2m depth the trend is vice versa due to the very weak formation .

From overall result for mackintosh probe at site 5, the result shows first penetration is 231 blows. That mean the ground surface is hard and dry since the test was running during the hot season and the moisture content of the soil on the surface layer is very low. The further penetration show rapidly decreasing in number of blows, mean the hardness of the soil is decreasing due to underground water table level that lead to increasing moisture content of the soil. The soft soil boundaries are from the third penetration to ninth penetration. The tenth penetration is the boundary of very hard soil since it shows high increasing in the number of blow which is from 8 to 200 blows.

The resistivity for the site 5 is varies from 101 Ωm to 467 Ωm that classified the soil in the weathered layer group which contain precipitation type of water.

4.6 SITE 6

Site 6 is located on the ground level in the garden compound, beside of block 14. The data for electrical resistivity and mackintosh probe blows given as in the table 4.6 below.

Table 4.6: Correlation data for site 6

Depth (m)	Resisitivity,ρ (Ωm)	Mackintosh blow
1	95.2	171
2	114.1	253
3	121.8	400

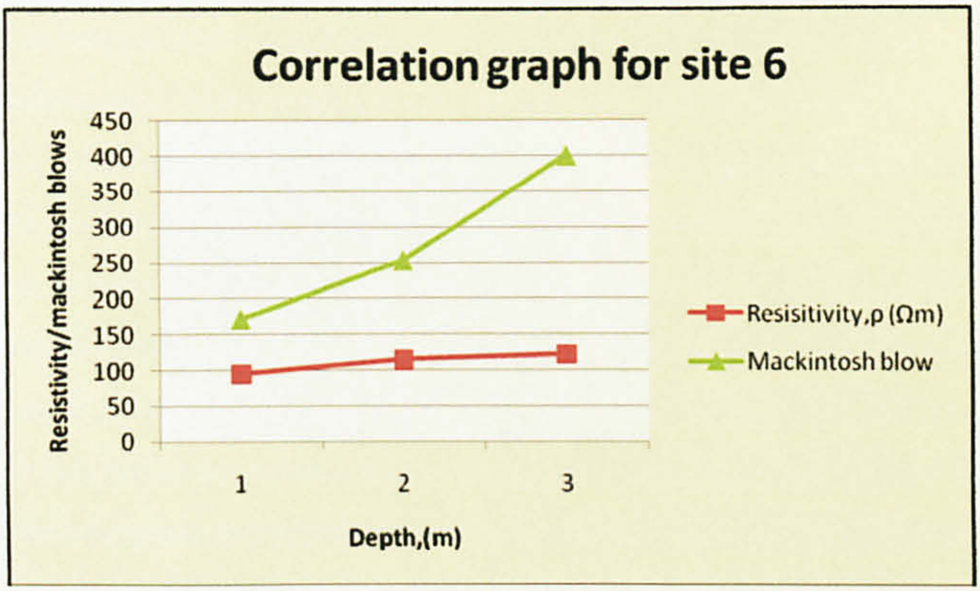

Figure 4.6: Correlation graph of resistivity and Mackintosh blow at site 6

Table 4.6 and figure 4.6 shows there are three correlation point data taken from electrical resistivity survey and mackintosh probe test. The correlation is at depth 1m to 3m from the surface. The trend for this correlation is electrical resistivity increase proportional with mackintosh blows.

From the overall result for mackintosh probe at site 6, the result shows first penetration is 102 blows. The further penetration show rapidly decreasing in number of blows, mean the hardness of the soil is decreasing due to underground water table level that lead to increasing moisture content of the soil. The soft soil boundaries are from the third penetration 900mm to sixth penetration 1800mm. Then the soil strength has increase until ninth penetration is over 400 blows mean very hard soil

For electrical resistivity survey result, resistivity is within the range from 51.0 Ωm to 125.7 Ωm.

In order to look the possible correlation of electrical resistivity obtained and mackintosh probe blows the result were plotting for resistivity/mackintosh blows versus depth where the data for both resistivity and mackintosh blows was at the same depth. The graph was given as in the figure 4.1, figure 4.2, figure 4.3, figure 4.4, figure 4.5, and figure 4.6 with respect to the respective site. From the graph we can see mackintosh probe increase proportionally with electrical resistivity. However in certain a few point they were inversely proportional. Moreover the scale of proportionality between the both parameter is always changes even within the same location. The correlation of the both parameter still cannot be determine since the result did not show any specific correlation between the both parameter.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

From the results, we can conclude that higher the water level from the ground surface, higher the resistivity of the soil due to dry condition of the soil. The moisture content and the distance from the water level is the factor of the stability of the slope and the strength of the soil.

The correlation between mackintosh probe blows and soil electrical reistivity data shows inconsistencies result. This happen because there is a limitation for the mackintosh probe equipment that should be consider. The limitation of mackintosh probe equipment might influence the correlation result that has been obtained. At this point there is no specific correlation between electrical resistivity and no of blows (mackintosh probe). Hence the correlation is not exactly accurate for the actual field measurement

Further test need to be conducted if the further confirmation is required. However further test must consider the limitation of the of the mackintosh probe equipment in order to obtain the accurate correlation.

CHAPTER 6

ECONOMICAL BENEFITS

This research can be divided into two the most part which are the data gathering part and the data analysis part. To complete this research the both part must be done in order to get the correlation for the both data. For the first part, the data from from mackintosh probe test and soils electrical resistivity must be obtain for the analysis and the correlation in the next task. While the second part, the data that has been obtained is analyses and correlate to completed the research. The first part requires much equipment and a little money has been spent for this part. The second part is about analysis and the correlation, there is no money spent in this part.

6.1 Electrical resistivity survey cost

In the first part, electrical resistivity survey must be completed to obtain the resistivity data from the six site that we had chosen during the preliminary stages of this research. This electrical resistivity survey requires a few equipment like electrodes, cables, jumpers, hammer, wire, power supply and multimeter. All the equipment are borrowed from the Civil Engineering Department and Petroleum and Geosciences Department except for a few new electrode has been bought. This research requires more electrodes to complete the entire six sites that have been chosen. The cost of new electrode is about RM 40.00 per 10 feet. Six sites that have been chosen require about 40 electrodes and the length for each electrode is about 1 feet. Then the total cost for this new electrode is RM 160.00. The other equipment was available in the Geotechnical and Geosciences laboratory.

6.2 Mackintosh probe test cost

Mackintosh probe test is the second data that must be obtained in other to complete the correlation for the both data. Mackintosh probe equipment is borrowed from Geotechnical laboratory. When the mackintosh probe test has been completed the steel shaft that has been drive into the soil must be take pull up to the ground surface. In order to complete the task a pair of hand jack is require. The jack was borrowed from automotive laboratory from Mechanical department. There is no cost for the mackintosh probe test.

Since Universiti Teknologi Petronas has been provided about RM500 for each student to complete their final year project, the provided money was used in order to buy the new electrode that required and completed this research. The total cost for this project is RM160.00.

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APPENDICES

1) Result for resistivity survey at Site 1

Depth (m)	Amp	Volt 1	R (Ωm)	Ωm
1	**0.02**	**2.428**	**121.4**	**762.8**
	0.01	**1.195**	**119.5**	**751.1**
2	**0.02**	**1.289**	**64.45**	**810.0**
	0.01	**0.649**	**64.9**	**815.8**
3	**0.02**	**0.877**	**43.86**	**826.8**
	0.01	**0.4146**	**41.46**	**781.6**
4	**0.02**	**0.5716**	**28.58**	**718.3**
	0.05	**1.3072**	**26.11**	**656.3**
5	**0.02**	**0.6470**	**32.35**	**1016.3**
	0.04	**0.9460**	**23.65**	**743.0**
6	**0.016**	**0.1815**	**11.34**	**427.7**
	0.01	**0.1267**	**12.67**	**477.7**
7	**0.02**	**0.3491**	**17.46**	**767.7**
	0.05	**0.5717**	**11.43**	**502.9**
8	**0.001**	**-0.1583**	**158.30**	**7959.0**
	-	-	-	-
9	**0.02**	**0.5470**	**27.35**	**1546.6**
	0.05	**0.7177**	**14.35**	**811.7**
10	**0.02**	**0.1093**	**5.465**	**343.4**
	0.04	**0.2002**	**5.005**	**314.5**
11	**0.02**	**0.2132**	**10.66**	**736.8**
	0.025	**0.2326**	**9.30**	**643.1**
12	**0.02**	**0.3392**	**16.96**	**1278.8**
	0.01	**0.2945**	**29.45**	**2220.5**

2) Result for mackintosh probe test at Site 1

Penetration for 300 mm	No. of blows
1(300)	39
2(600)	50
3(900)	47
4(1200)	38
5(1500)	85
6(1800)	83
7(2100)	86
8(2400)	181
9(2700)	211

10(3000)	157
11(3300)	157
12(3600)	273
13(3900)	400

3) Result for resistivity survey at Site 2

Depth (m)	Amp	Volt 1	R (Ωm)	Ωm
2	0.02	3.2130	160.65	2018.8
	0.03	4.6308	154.36	1939.7
3	0.02	1.7503	87.52	1649.7
	0.03	2.1480	71.60	1349.6
4	0.02	1.6555	82.78	2080.5
	0.029	1.9319	66.17	1663.0
5	0.001	0.0388	38.8	1218.9
	-	-	-	-
6	0.02	0.5011	25.06	944.7
	0.03	0.7448	24.83	936.1
7	0.02	0.4348	21.74	956.2
	0.03	0.6149	20.5	901.6
8	0.02	0.4286	21.43	1077.2
	0.03	0.5877	19.59	984.7
9	0.02	0.8730	43.65	2468.3
	0.01	0.7156	71.56	4046.6
10	0.02	0.2428	12.14	762.8
	0.01	0.1411	14.11	886.6
11	0.02	0.1910	9.55	660.0
	0.04	0.3841	9.60	663.5
12	0.02	0.5569	27.85	2099.8
	0.01	0.4911	49.11	3702.8

4) Result for mackintosh probe test at Site 2

Penetration for 300 mm	No. of blows
1(300)	101
2(600)	71
3(900)	92
4(1200)	98
5(1500)	107

6(1800)	96
7(2100)	168
8(2400)	99
9(2700)	86
10(3000)	65
11(3300)	57
12(3600)	50
13(3900)	91
14(4200)	75
15(4500)	69
16(4800)	91
17(3300)	91
18(3600)	69
19(3900)	59
20(6000)	82
21(6300)	71
22(6600)	66
23(6900)	69
24(7200)	74
25(7500)	95
26(7800)	106
27(8100)	98
28(8400)	104
39(8700)	138
30(9000)	188
31(9300)	183
32(9600)	161
33(9900)	225
34(10200)	227
35(10500)	170

36 (6000)	224
37 (6300)	233
38(6600)	319
39(6900)	245
40(7200)	244
41(7500)	400

5) Result for resistivity survey at Site 3

Depth (m)	Amp	Volt 1	R (Ωm)	Ωm
2	*0.01*	*-0.0825*	*-8.25*	*103.6*
3	0.01	0.304	30.43	573.6
4	0.01	0.6622	66.22	1663.4
8	0.01	-0.2649	-26.49	1330.8
10	0.01	-0.2313	-23.13	1452.5
12	0.01	0.5089	50.9	3835.8

6) Result for mackintosh probe test at Site 3

Penetration for 300 mm	No. of blows
1(300)	15
2(600)	33
3(900)	37
4(1200)	40
5(1500)	55
6(1800)	139
7(2100)	85
8(2400)	88
9(2700)	99
10(3000)	130
11(3300)	300
12(3600)	400
13(3900)	300
14(4200)	300

15(4500)	325
16(4800)	400

7) Result for resistivity survey at Site 4

Depth (m)	Amp	Volt 1	R (Ωm)	Ωm
2	0.01	0.993	99.3	1247.2
3	0.01	0.6923	69.23	1305.1
4	0.01	0.574	57.4	1441.8
8	0.01	0.31	31.0	1557.4
10	0.01	0.357	35.7	2241.9
12	0.01	0.91	91.0	6857.7

8) Result for mackintosh probe test at Site 4

Penetration for 300 mm	No. of blows
1(300)	310
2(600)	145
3(900)	93
4(1200)	102
5(1500)	110
6(1800)	108
7(2100)	100
8(2400)	130
9(2700)	114
10(3000)	121
11(3300)	135
12(3600)	171
13(3900)	110
14(4200)	173
15(4500)	150
16(4800)	83
17(5100)	135
18(5400)	145

19(5700)	229
20(6000)	400

9) Result for resistivity survey at Site 5

Depth (m)	Amp	Volt 1	Volt 2	R (Ωm)	Ωm
2	0.1	3.380	207	33.8	424
	0.12	3.960	242	33.0	414
3	0.1	2.116	204	21.2	406
	0.12	2.540	251	21.2	399
4	0.1	1.326	208	13.3	331
	0.12	1.592	247	13.3	334
6	0.1	1.240	216	12.4	467
	0.12	1.395	265	11.6	437
8	0.1	0.518	316	51.8	261
	0.12	-	-	-	-
10	0.1	0.441	246	4.4	276
	0.12	0.484	296	4.0	251
12	0.1	0.204	268	2.0	150
	0.12	-	-	-	-
18	0.1	0.105	224	1.1	124
	0.12	0.107	277	0.9	101

10) Result for mackintosh probe test at Site 5

Penetration for 300 mm	No. of blows
1(300)	231
2(600)	129
3(900)	54
4(1200)	80
5(1500)	25
6(1800)	16
7(2100)	9
8(2400)	6
9(2700)	8
10(3000)	200
11(3300)	>400

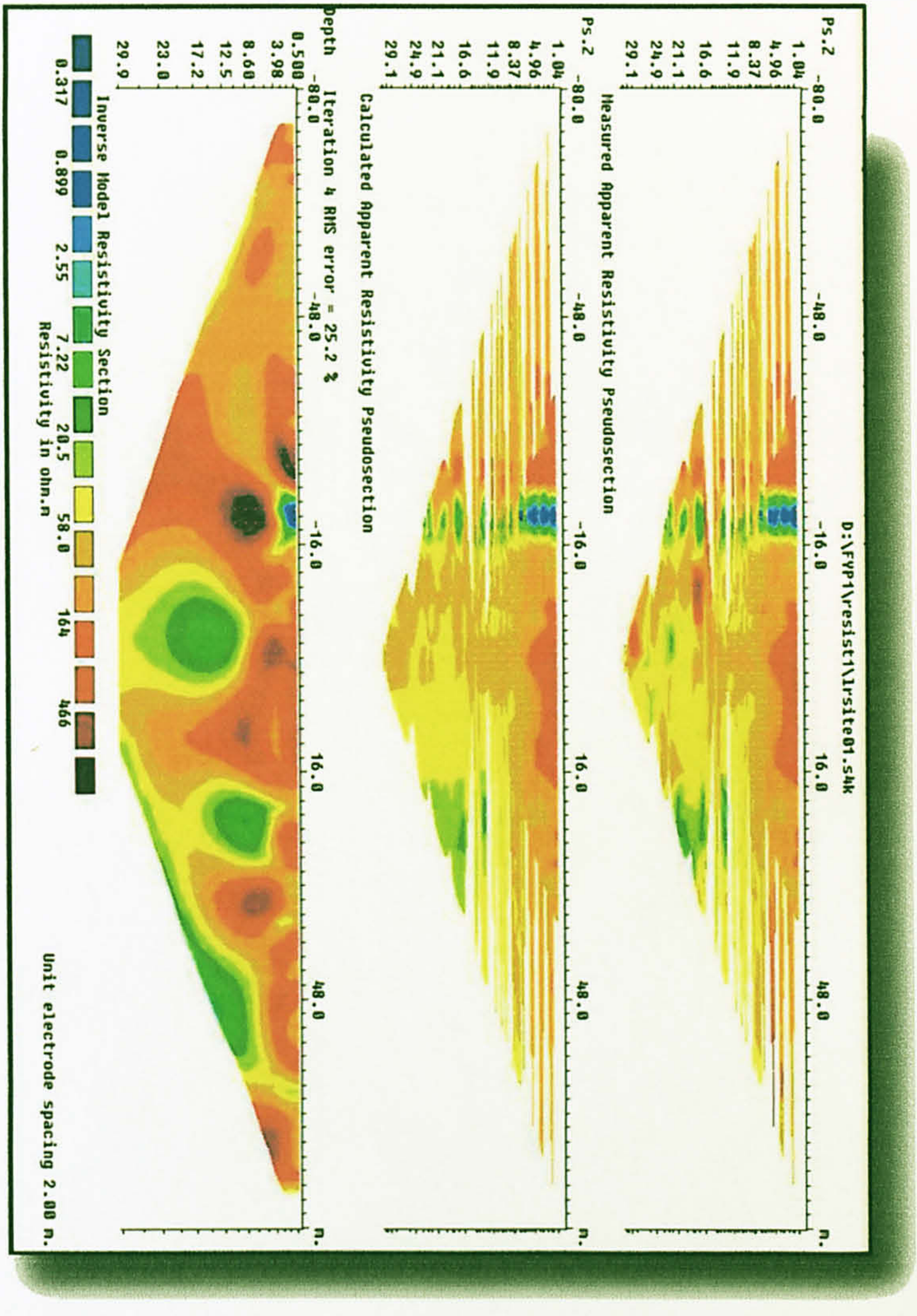
11) Result for resistivity survey at Site 6

Depth (m)	Amp	Volt 1	Volt 2	R (Ωm)	Ωm
1	0.05	0.7575	94	15.15	95.2
	0.1	1.5250	166	15.25	95.8
2	0.05	0.4540	93	9.08	114.1
	0.1	0.9550	165	9.55	120.0
3	0.05	0.3231	141	6.46	121.8
	0.1	0.6667	288	6.67	125.7
4	0.05	0.1621	99	3.24	81.5
	0.1	0.3922	158	3.92	98.6
5	0.05	0.1442	157	2.88	90.6
	0.09	0.3138	315	3.47	109.5
6	0.05	0.1371	177	2.74	103.3
	0.09	0.2625	311	2.92	109.9
7	0.05	0.1111	126	2.22	97.7
	0.1	0.2480	258	2.48	109.1
8	0.05	0.0507	98	1.01	51.0
	0.1	0.1701	189	1.70	85.5
9	0.05	0.1003	74	2.00	113.4
	0.1	0.2164	150	2.16	122.3
10	0.05	0.0831	74	1.66	104.4
	0.1	0.1712	134	1.71	107.5

12) Result for mackintosh probe test at Site 6

Penetration for 300 mm	No. of blows
1(300)	102
2(600)	210
3(900)	171
4(1200)	59
5(1500)	158
6(1800)	175
7(2100)	253
8(2400)	312
9(2700)	400
10(3000)	400

13) Two dimensional electrical resistivity surveys for site 5



Picture 1: After doing the site preparation and site clearance at site 1

Picture 2: Collected data for electrical resistivity survey at site 2

Picture 3: Collected data for electrical resistivity at site 3

Picture 4: Mackintosh probe test at site 6

Picture 5: Connecter was fitted to the rod of the