Landslide and Siphon Method

by

Hadi Haziq Bin Abdul Malek

Dissertation submitted in partial fulfilment of

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CERTIFICATION OF APPROVAL

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project dissertation submitted to the

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Approved by,

(AP. Dr. Nasiman Sapari)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

SEPTEMBER 2011

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.

HADI HAZIQ BIN ABDUL MALEK

ABSTRACT

Landslide is one of the major disasters for damage and loss of life in the world. Every year, this disaster happens. Because of this, many research had been done and method had been introduced in controlling this disaster and reducing the effects. The major factor triggering landslide is the excess of pore water pressure in the soil. The excess of pore water pressure in the slope comes from the groundwater. Controlling the level of groundwater in the soil is vital in order to prevent landslide occurrence. This research aims to control the water level in the soil by the using siphon method and to verify the effects of this system on soil moisture content. This research also analyzes the influence of rainfall on moisture content of soil. Soil's moisture content, bulk density, shear strength and internal angle of internal friction are identified for calculation of factor of safety (FoS). The siphon model was constructed using pvc pipes and two pails. Data collections are divided into several parts. For moisture content, six (6) samples were collected and recorded. From this data, the relationship between rainfall and moisture content of soil is ploted using graphs. The finding shows that the moisture content increases with the presence of rainfall from 0.20 g/g to 0.30 g/g. The moisture content then slowly decreases to 0.20 at the sixth day. The particle size distribution and shear box analyses, were conducted in the study. The data were recorded by using computer and software of ELE international. The results show that soil with siphon pipe has a cohesion and moisture content of 4.85 kPa and 0.3 g/g compared to the soil without siphon pipe which are -4.00 kPa and 0.37 g/g respectively. As such, siphon system can be applied to control the groundwater level for preventing landslide.

ACKNOWLEDGEMENTS

First and foremost, praise to be to the All–Mighty, Allah S.W.T for giving me the opportunity, guidance, strength and patience to complete this dissertation despite several obstacles encountered throughout the course of this research, which at times seem insurmountable.

During the preparation of this study, I have owed many debts of gratitude. I am indebted to my supervisor, Associate Professor Dr. Nasiman Sapari for his critical comments, supports and encouragement. I pray may Allah bless him and his family always. My deep appreciation is also extended to my civil engineering Final Year Project coordinator, Professor Dr. Teo Wee, for his guidance and constructive suggestions at the early stage of this study.

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LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Landslides are one of the major disasters for damage and loss of life in the world. Based on Bora (2011), 45% of disasters in Turkey are results of slope movements. This type of disaster ranked second after the earthquake in terms of causing severe damage to the people. Therefore, many research had been done and method had been introduced in order to control this disaster and also to minimise the effects.

Literally landslide can be defined as the downward and outward movement of slopes-forming materials which composed of rocks, soils, artificial fills or combination of all these. The slopes-forming materials moves by falling, sliding or flowing, either slowly or quickly from one place to another due to gravity (Wang and Manga, 2010). This slope's movement can be triggered by the natural phenomena and human activities. The natural phenomena such as heavy or prolonged rainfall, earthquakes, volcanic eruptions, snow melt and erosion slopes by rivers or sea waves are contributing increase the tendency of slope movements. Human activities such as slope excavation and loading, land-use change, blasting vibrations and water leakage from utilities, or by many combinations of activities and processes, are another factor in triggering the landslide. (Claudio et al., 2011)

Today, many methods and systems can be used in controlling the landslide. The drainage systems are most widely used because of high stabilization efficiency in relation to cost compare to the other methods. This method is designed to remove as much water as possible out of an unstable soil mass (excess pore water). These systems are very efficiency in terms of controlling the level of ground water. Theoretically, by lowering the ground water level the slope became stable and reducing the chances of slope movements. The siphon system is the modern type of drainage system. The great advantage of this type of drainage is it works using pressure concept with no energy used.

1.2 Problem Statement

1.2.1 Problem Identification

There are many types of landslides such as mudslide (Gue et al., 2010), rockslide (Catane et al., 2006 and Gerhard, 1994), and landslide (Wei et al., 2009 and Tang et al., 2011). Those types of landslide are mostly similar. The kinds of material involved and the mode of movement differentiated the types of landslide. Studies have shown that the groundwater level in the slopes is the most significant factor in triggering the landslide. The high groundwater in the slope will produce pore water pressure. This pore water pressure will decrease in the mass shear strength (Murthy, 2006). Therefore, the slope will become unstable. Thus, controlling the level of groundwater become vital to stabilize the slope.

Siphon and Electro Pneumatic drain systems are the modern and efficient solutions to deal with the potential sliding zone. The great advantage of the siphon drain solution is that it works without energy. The electro pneumatic drain works using an electro pneumatic pump by lowering the water table deeper (Nicolae and Dan, 2008). Both systems use the concept of pressure. Theoretically, the water in the slope of the upstream will flow to the downstream because of the pressure at the upstream is lower than the downstream. This flow will continue until the pressure at both stream are stabilized.

1.2.2 Significant of the Project

The analysis of the soil element in the slope is important in determining the treatment of groundwater level. There are three types of soils namely granite, sedimentary and metamorphic. Each soil has different properties. Throughout the laboratory experiment such as Grain sizing, Hydraulics conductivity, Bulk Density and Porosity test, the properties and sensitivity of the soils are determined.

1.3 Objectives of the Project

The objective of the project is to determine the reliability of Siphon Drain system in controlling the level of groundwater. Specifically, this reseach project aims to:

i. analyze the quality of the siphon method in controlling the pore water level.
ii. analyze the influence of rainfall on moisture content of soil in relation to stability .
iii. analyze the sensitivity of the proposed method in this research project.

1.4 Scope of Study

This study involves a few laboratory experiments in determining the parameters of soil sample. The moisture content in the soil will be examined as it is the most important element in triggering the landslide. Data obtain through the analysis will be recorded. From the data, a suitableadjustment can be proposed to the weak soil and identified whether the adjustment can be utilised in a siphon drain.

1.5 Relevancy of the Project

This project is relevant research in the civil engineering field. It is one of the methods in promoting green technology in the construction industries. Siphon method drainage can be an alternative approach in controlling landslide compare to the other method. It is cost effective, no energy used, and can be the most efficient solution of high groundwater level problem.

The analysis of the quality of the soil in a way can help in developing the Siphon drainage system producing better result. This type of drainage is not very popular in Malaysia. Using the data obtained from the experiment, a proper adjustment to the drainage system can be proposed and can be determined whether it can be considered as a better solution.

1.6 Feasibility of the Project

The project will commence by collecting materials such as books, journals, and technical papers on landslide, drainage systems and siphon concept. All available methods that are relevant towards this project are being taken into consideration and selection is based on the reliability as well as time constraint in getting satisfactory result.

Research is carried out continously in order to get a better understanding on this issue and to compare our own findings with the available information.

The project is estimated to be complete within a period of 8 months. All equipments needed to perform this project are available in the Civil Engineering Laboratory UTP. With all the resources provided, this project can be considered as a feasible project within the time frame given.

CHAPTER 2

LITERATURE REVIEW

2.1 Landslide

Landslide can be defined as the downward and outward movement of slope forming materials which composed of rocks, soils, artificial fills or combination of all these. The materials moves by falling, sliding and flowing, either slowly or quickly from one place to another due to gravity (Wang And Manga, 2010).

There are various natural phenomena that can trigger landslides such as heavy or prolonged rainfall, earthquakes, volcanic eruptions, snow melt, and erosion of slopes by rivers or sea waves. Human activities can also trigger landslide such as slope excavation and loading, land-use change, blasting vibrations and water leakage from utilities, or by many combinations of activities and processes (Claudio et al., 2011). There are many types of landslide such as mudslide (Gue et al., 2010 and Lim, 1994), rockslide (Catane et al., 2006 and Gerhard, 1994), and landslide (Wei et al., 2009; Tang et al., 2011). Generally, those types of landslides are mostly similar. The kinds of material involved and the mode of movement differentiated the types of landslide. Landslide can occur on any terrain with given the right condition of soil, moisture, and the angle of slope stability such as at mountain terrains, surface of excavation for highways, buildings and open pit mines. In this research project, 3 cases of landslides are reviewed.

2.1.1 Panluo, China (1990)

Case history at Panluo open-pit mine is a good example of open pit mine landslide. Located in the south western Fujian province of China, Panluo open-pit mine is the largest open-pit iron mine in the Fujian province. In July 1990, an earthquake of magnitude 5.3 in Taiwan Strait and big rainstorms impacted the mine slope, causing tension cracks and large-scale failures. As a consequence a U-shaped landslide was formed. The slope angles varied from 28 to 35. Total potential volume was estimated to be up to 1.0×10^6 m^3. This directly threatened the mine production (Wei et al., 2009)

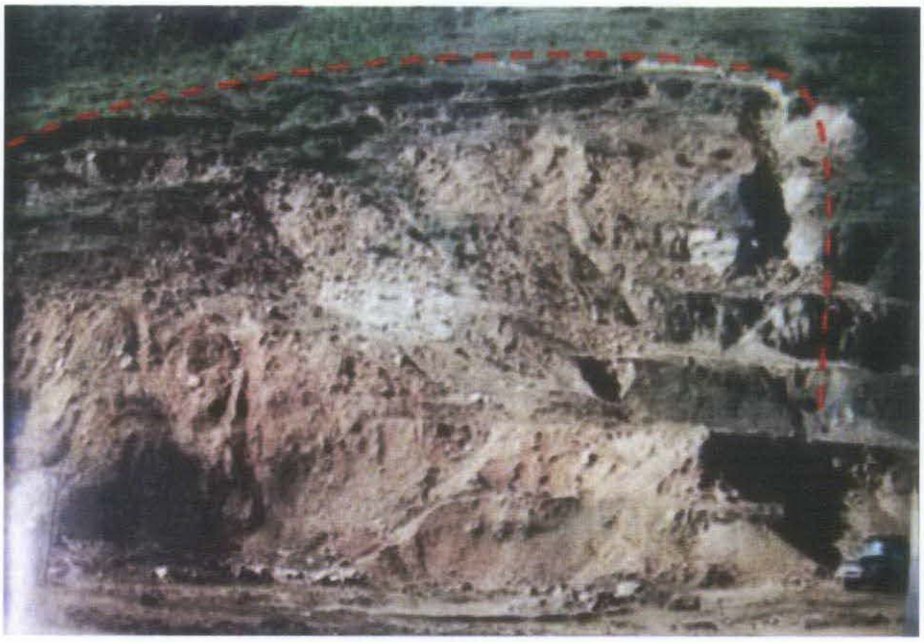


Fig. 1 Landslide view of Panluo open pit mine (Wei et al., 2009)

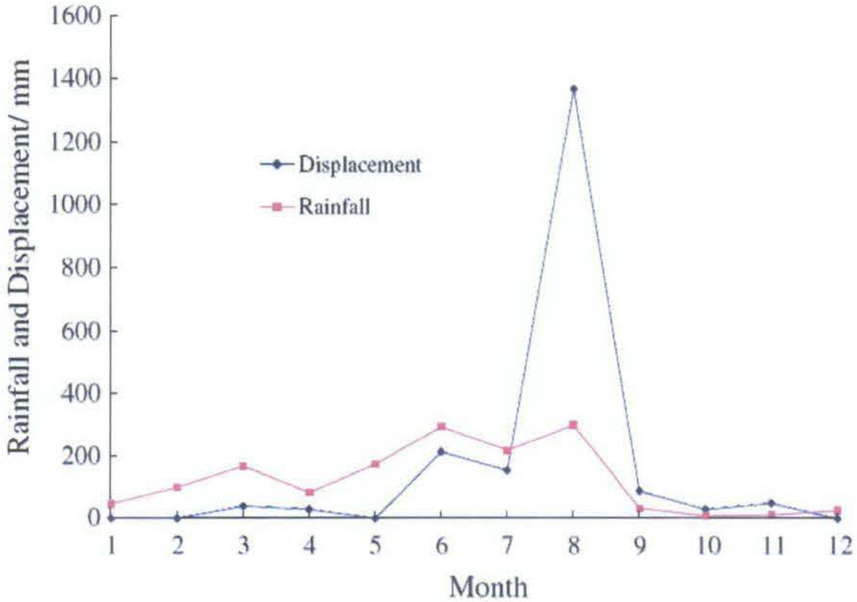


Fig. 2 Relationship of month rainfall and displacement at Panluo open pit mine (Wei et al., 2009)

The cause of this landslide was continuous rainfalls for a week with precipitation of 132 mm per day. Figure 2 shows that the displacement of the landslide. The pore water in the slope of soil was at the critical level in July. The continuous rainfalls after July affected the stability of open-pit mine slope. The soil was saturated with water which past the critical level thus its lost the shears strengths and stability (Tang et al., 2011).

The concept of landslide mechanism in this case is the same with building the sand castles on the beach. The castle will collapse if the sand is too dry, however if the sand is full of water or saturated, it will not take the right shape to start with. It is because the water in the partially saturated sand gives strength. More correctly, it is the negative pore-water pressure or suction pressures that give the strength to hold the sand together. This is the same mechanism that keeps the landslides from happening. If a slope is saturated (too wet) and looses too much strength from the suction pressures, the shear strength along the sliding surface is low and the slope may fail.

2.1.2 Highland Tower, Selangor, Malaysia (1993)

On 11th December 1993, a building collapsed due to the slope failure in Selangor. This incident caused 48 people killed (Gue et al., 2010 and Lim, 1994). Block 1 of the Highland Tower had collapsed after a prolonged period of heavy rain which contributed to a landslide. According to Lim (1994), there was a small stream of water in the hills behind the tower which was diverted through a series of drains and pipes. In 1991, a new development on Bukit Antarabangsa on the other side of the ridge led to land clearing. The water from the construction site was diverted into the same pipe system used to divert the flow of the stream.

The pipe system became overly pressurized and burst at various locations on the hill, and the soil had to absorb the excessive water. The monsoon rainfall in December 1993 worsened the situation. The groundwater level increased and passed the critical level. The soil which was saturated with water becomes mud. Subsequently the slope became unstable with high pore water pressure and triggered landslide. With poorly-constructed retaining walls, the landslide was so strong that it had a weight equivalent to 200 Boeing 747 jets (The Star Online, Documentary on the Highland Tower tragedy, 2010). The soil rammed onto the foundation of block one, pushing it forward for a while before causing it to snap and bringing down the apartment block.

2.1.3 Shiaolin landslide, Taiwan (2009)

The Shiaolin landslide occurred about 1 day after the peak of rainfall intensity. This incident could be attributable to the infiltration behaviour of rainwater through the gravitationally deformed rock body. The source area of the Shiaolin landslide had been gravitationally deformed beforehand. Therefore, the deformed rock body was fractured and permeable, except for the essentially impermeable clayey material and intact rock. These fractures became the pathways for water infiltration that would cause water pressure build up at depth. In contrast to the Shiaolin landslide, many shallow landslides occurred when rainfall intensity was increasing or near its peak (Godt et al., 2006 and Yu et al., 2006).

For large landslides, a time lag between peak rainfall intensity and landslide initiation is commonly observed, considered to reflect the time required for water infiltration to deep level (Lollino et al., 2006; Evans et al., 2007; Chigira, 2009). This difference in terms of landslide timing is attributed to the difference in the effects of water infiltration and pore water pressure build up. Rapid infiltration in shallow soil layers means that pore water pressure responds to rainfall quickly and landslides occur when rainfall intensity is strong. The geological, geomorphologic conditions, and landslide type needs to be taken into account when evaluating the susceptibility of a location to rain-induced landsliding in addition to the variables of rainfall, such as the combination of rainfall intensity and duration or the combination of mean and maximum hourly intensity, duration, and rainfall amount (Caine, 1980 and Guzzetti et al., 2008).

Rock avalanches is different compare to the soil sliding. This is because it does not require materials that are saturated with water. Therefore, it also occurs in partially to completely unsaturated materials (Ching et al., 2010). Thus, different mechanisms have been proposed from those of water-saturated debris flows, including grain collision (Heim, as cited in Ching et al., 2010), fluidization (Kent, as cited in Ching et al., 2010), air-layer lubrication (Shreve, as cited in Ching et al., 2010), pressure from vaporized pore water (Goguel, as cited in Ching et al., 2010), and acoustic fluidization (Melosh, as cited in Ching et al., 2010). However, most studied rock avalanches have been induced by earthquakes. Only a few cases of rock avalanches are induced by rainfall.

The Shiaolin landslide, which was induced by a rainstorm, has clayey material with blocks of sandstone, mudstone, and shale. This clayey material is assumed to be made by shearing during the landslide movement as well as by earlier gravitational deformation. It forms an essentially impermeable layer at the base of the landslide material. Thus, heavy rainfall penetrates downward to the layer of clayey material, where water pressure builds up and decreases the effective stress. This was reported to be the trigger of the initiation of the Shiaolin landslide (Ching et al., 2010).

Ching et al. (2010) also states that after the initiation of the movement, the clayey material probably played an important role to form a lubricating layer at the base of landslide material by keeping high pore pressure during movement. This phenomenon has been investigated in flume tests which shows that the pore pressure increases rapidly with increasing fine-grained content and movement velocity during shearing (Wang and Sassa, 2003). Evans et al. (2007) attributes the long run-out of the Leyte landslide, in Philippines, to the loading of undrained paddy field material in the path of the landslide.

According to Catane et al. (2006), the massive collapse of a mountain ridge straddling the Philippine Fault occurred in the village of Mt. Canabag, Guinsaugon, in the town of St. Bernard, Southern Leyte, on 17 February 2006 is the most catastrophic landslide recorded in the Philippines. The site was in an area of steep topography, poor geologic structures, high rainfall intensity, and susceptible seismicity. The landslide, with an estimated volume of 20 Mm^3, reached a distance of 4.1 km and affected an area of about 3.2 km2. It buried the entire Guinsaugon village with a population of 1,857 from 321 households. This incident happened after nonstop heavy rains for 10 days following a shallow earthquake of magnitude 4.3 on the Richter scale. There are two important pre-conditions for the occurrence of large rockslides: first, a long period for rock disintegration on a mountain slope; and second, the long-term persistence of a stable, supporting abutment lower on the slope. Without such temporary support, the increasing volume of the disintegrating material would be prevented by small-scale, downslope mass movements. Typical consequences of the large rockslides are the movement on internal sliding planes and the development of secondary rockslides. The occurrence, size, and number of the secondary slides mainly depend on the available kinetic energy of the primary rockslide. These findings are based on fieldwork experience on major rockslides in the Alps, the Chilean Andes, and Mount St. Helens, U.S.A (Gerhard, 1994).

2.2 Landslide Analysis

Toll et al. (2011) conclude that the most frequent triggering factor of landslide is rainfall. As in the above cases, the pore water is the most significant element in triggering the landslide. This also have been extensively described by (Bruno et al., 2007; Bora, 2011; Shrestha et al., 2006 ; Wei et al., 2009; Hung, 2000; Catane et al., 2006 and Adriana and La′zaro, 2003). Adriana and La′zaro (2003) states that in tropical countries like Brazil, rainfall is the main triggering mechanism of gravitational mass movements. A series of landslides occured at the end of 1999 and the beginning of 2000 resulted from high intense rainfall in Campos de Jordao, Brazil. The land surface infiltration of water causes a dissipation of negative pore pressures and consequently a decrease in the mass shear strength.

The landslide occurred because of instability slope of the area. The factor of safety of a slope can be determined as follow (Murthy, 2003):

$$F = \frac{\text{Shear resistance}}{\text{Overturning Moment}}$$

Factor of Safety	Guidelines for limit equilibrium of a slope
< 1.0	Unsafe
1.0 - 1.25	Questionable safety
1.25 - 1.4	Satisfactory for routine cuts and fills, Questionable for dams, or where failure would be catastrophic
> 1.4	Satisfactory for dams

Figure 3 : Factor of Safety (Murthy, 2003)

Using the Bishops simplified method (Bishop, 1955), the factor of safety of a slope can be calculated by :

$$F = \frac{1}{\sum W \sin\alpha} \sum \left[\left(c'b + W(1 - r_u) \tan\phi' \right) \frac{\sec\alpha}{1 + \frac{\tan\alpha \tan\phi'}{F}} \right]$$

where: F = Factor of Safety

r_u = pore pressure

W = The total weight of the slide ; W= γbh

c′ Φ ′= Effective values of soil parameters (cohesion and internal angle of internal friction)

γ = unit weight

h = thickness of the slide

α = inclination of the segment of the slip surface

b = horizontal width of the block

Based on the above equation, a guess value of F (FoS) as initial value is necessary in order to solve the Bishop's factor. The initial guess value of F is used to compute the new F. The new F then will be used as the initial guess value for the next new computed and obtained another new F. The procedure is repeated until the last computed FoS is within the specified tolerance. The pore pressure, r_u in the above equation refers to the pressure created from the pore water in the slope. The pore water pressure can be related to the total 'fill pressure' at any point by means of the dimensionless pore pressure ratio, defined as:

$$r_u = \frac{u}{W/b}$$

where: r_u = pore pressure

U= Reaction force acting on the slide,N in opposite direction

W = The total weight of the slide ; W= γbh

From the equation above, the pore water element is a vital component affecting the instability of a slope. This element need to be controlled in order to obtain stable slope. Currently, there are many control methods available for controlling the level of groundwater. The available early warning systems triggering landslide such as MoniFLaIR (Capparelli and Tiranti, 2010), is a single tensiometer per hole developed by ENPC in France and multiple tensiometers used at different depths within a single borehole (Toll et al., 2011), Satellite Remote Sensing and Geospatial Datasets (Yang et al., 2007), observation wells, and electrical piezometer (Troy, 2006). The limit equilibrium analysis is the most common method applied to analyse stability for designing the landslide control treatment (Kim et al., 2004). Because of irremovable demerits such as high investment at one time, exclusion of the effects of some control measures such as drainage measures and other "soft" measures, landslide control methods cannot adapt for such a process (Wei et al., 2005).

2.3 Groundwater Control

There are many types of groundwater control such as the deepwell, ejector or wellpoint systems which mostly used at construction site and also the drainage system such as vertical (pumped wells) and horizontal drains, smart drain, and so on. However, based on FoS evaluation criterion, the drainage system does not improve the FoS value. However, the drainage system can make the slope stable, thus is considered successful as a dynamic control measure of landslide (Wei et al., 2005).

2.3.1 Drainage System

Drainage systems are the most widely used and the most successful stabilization method. These systems result in high stabilization efficiency in relation to cost. However, for a long-term solution, the drains must be maintained to continue functioning (Bromhead, 1992). The drainage systems are designed to remove as much water as possible out of an unstable soil mass (excess pore water). These types of systems are very effective in controlling the level of groundwater. Drainage is often a crucial remedial measure due to the important role played by pore-water pressure in reducing shear strength.

Surface water is diverted from unstable slopes by ditches and pipes. Drainage of shallow groundwater is usually achieved by networks of trench drains. Drainage of the failure surfaces, on the other hand is achieved by counterfort or deep drain which are trenches sunk into the ground to intersect the shear surface and extending below it. In the case of deep landslides, often the most effective way of lowering groundwater is to drive drainage tunnels into the intact materials beneath the landslide (Kyōji and Paolo, 2010).

Siphon and Electro Pneumatic drain systems are new methods to deal with potential sliding zone. The great advantage of the siphon drain solutions is that it works without energy. The electro pneumatic drains works using an electro pneumatic pump by lowering the water table deeper (Nicolae and Dan, 2008).

2.3.1.1 Siphon drain

In the landslip, small diameter siphon drains are placed in vertical drilled drainage wells. These wells are generally spaced at between 3 to 6 meters centre and must be sufficiently deep to reach the layers to be drained. The wells are pumped using siphon tubes and the slope of the ground under the influence of gravity, by introducing the upstream ends of pipes of variable diameters all the way down to the bottom of each well and the downstream end towards an outlet manhole, situated along the slope (Figure 4). The siphon will abstract and flow the water out of the well if the water level rises in the well until the levels in the well fall, provided that the flow rate in the siphon is sufficient to keep the siphon primed. As the water rises towards the top of the siphon the pressure falls, and may approach a perfect vacuum. In the upstream section the low pressure causes small bubbles to appear. These bubbles tend to coalesce into larger ones further downstream. Two forces act on the bubbles, firstly buoyancy and secondly hydraulic force due to the flow in the pipe. If buoyancy becomes the major force, the bubbles will collect at the summit of the pipe and combine into a single large bubble, which in time would break the siphon flow. This can be avoided by using a system that automatically flushes out bubbles by turbulent flow (Nicolae and Dan, 2008).

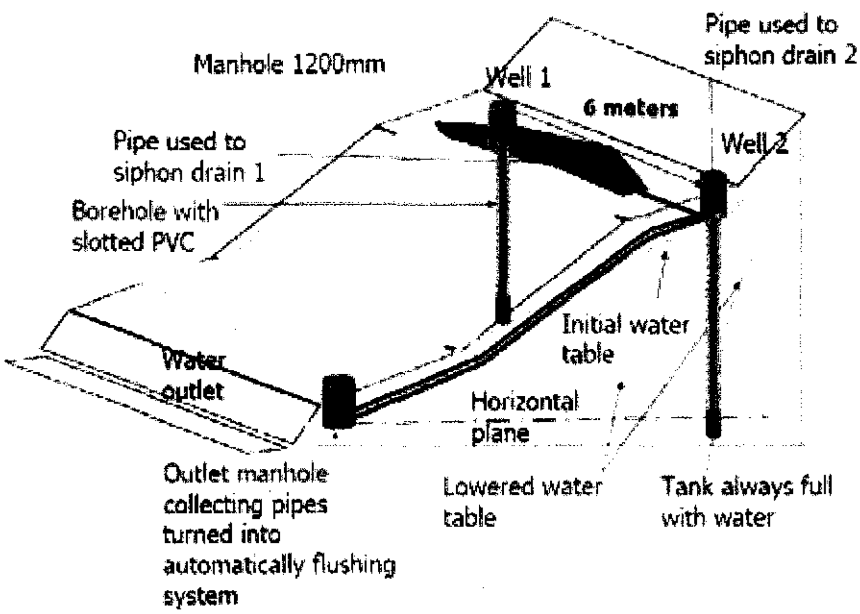


Fig. 4 : Cross Section of a Siphon Drain Network (Nicolae and Dan, 2008)

The flushing system consists of an arrangement of PVC pipes at the downstream end of the siphon pipe which acts as a hydraulic accumulator. When the water level in the upstream end in the drainage well is nearly the same as the accumulator there is no flow in the siphon pipe. When the water in both the well and PVC accumulator rises and reaches a certain level, the stored water is quickly emptied by a simple flushing. The sudden lowering of the level of water in the accumulator causes flow in the siphon pipe which is sufficient to flush out any air bubbles within the siphon (Figure 5). The flow continues until the water level in the well is lowered to the same level as in the accumulator. The water level will then again rise in both the well and accumulator flushing system up to the predetermined level and then the flushing cycle starts again. The siphon system is shown in Figure 5 and Figure 6 (Nicolae and Dan, 2008).

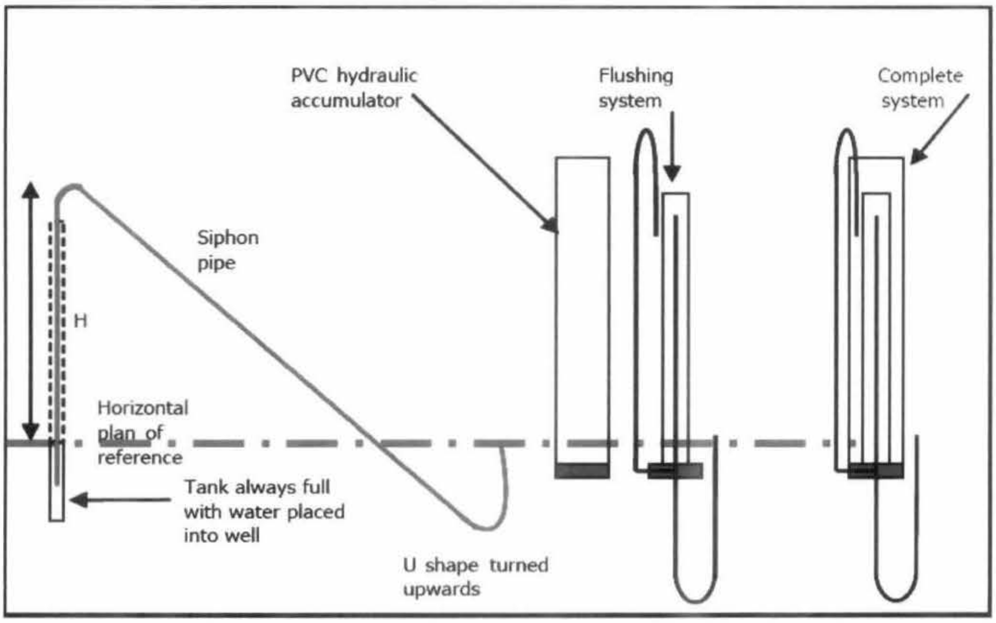
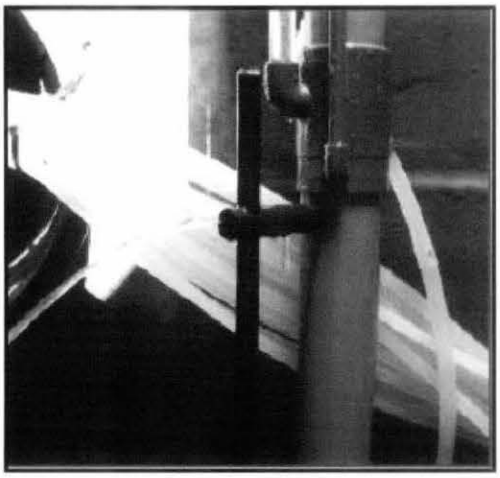


Figure 5 : Siphon Tubing and Flushing System (Nicolae and Dan, 2008)



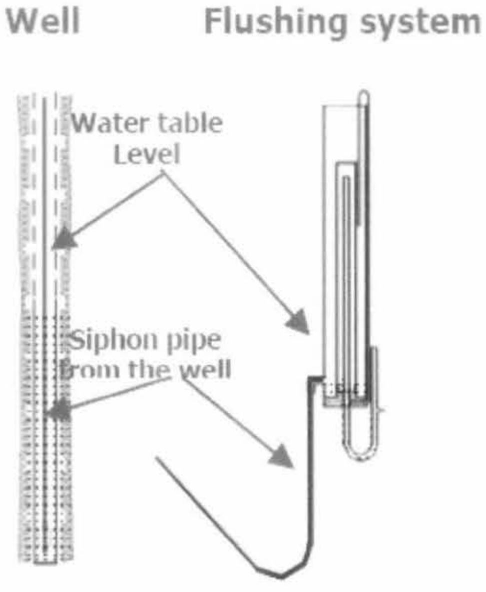


Figure 6 : Flushing Running System (Nicolae and Dan, 2008)

2.3.1.2 Electro-pneumatic Drain

The electro-pneumatic pump has been developed to stabilize landslides by intercepting groundwater at greater depths or lowering groundwater to lower levels than that capable using siphon drain techniques (Bomont, as cited in Nicolae and Dan, 2008). The electro-pneumatic drains are designed similar to that for the siphon drains with a network of manholes and ducting for electrical cabling, the pipes for water discharge and the compressed air supply. The wells are equipped with slotted PVC well casing of 110 mm internal diameter and centralizers and fine gravel filter to ensure its central location and filtering of incoming water. The compressor and the air tank can be located up to 3000 meters away from the control panel, if the configuration of the site needs it, and the air coming into the control panel is cleaned and dried by an air dryer and filters (Nicolae and Dan, 2008).

2.3.1.3 Operating Principle

The electro-pneumatic pump is installed in each well at the required drawdown depth. When the groundwater rises in the well, it enters in and fills the pump through a non-return ball valve at its base. The rising water level first reaches a low level electrical water level sensor and continues to rise, and when it finally reaches the high level sensor, an electrical connection is made by water conductivity. These two sensors (Figure 7) are linked to a relay, which opens a solenoid. Compressed air then passes through the inlet air tube to the electro-pneumatic pump, filling it with air and pushing water out of the pump through the outlet tube to the ground surface to a suitable discharge point. A non-return ball valve prevents any water coming back in the pumping chamber. An electrical cable, which is connected to the water level detector, is linked through the duct to a control panel. The control panel (Figure 7) contains a relay and solenoid that controls the operation of the compressed air-supply pumps. The solenoid switch controls the compressed air supply allowing it to pass from the air compressor and its air tank to the compressed air inlet tube to the pump (Nicolae and Dan, 2008).

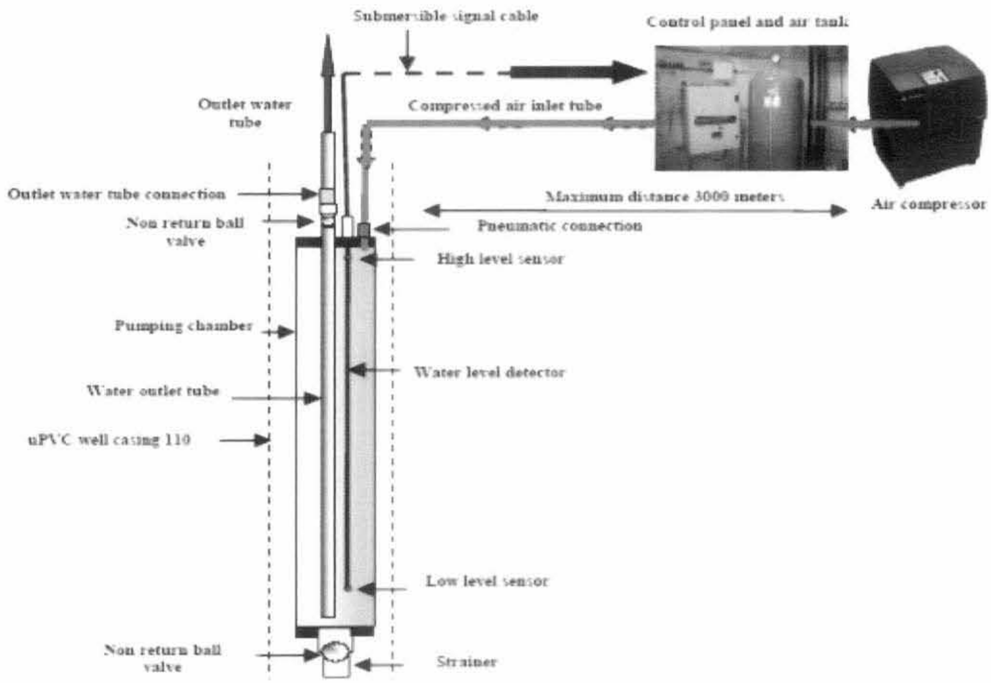


Figure 7 : Electro-pneumatic drain principle (Nicolae and Dan, 2008)

CHAPTER 3

METHODOLOGY

3.1 Project Activities

This research focuses on the groundwater element in the slope affecting the instability of a slope. However, it is necessary to know the conditions of the soil before implementing the shipon method as the control method. Thus, all the sensitivity and parameter of soils need to be identified and tested by experiments. Below are the list of experiments for the soil sample.

Experiments	Objectives
Bulk Density	To determine the moisture contains of the sample
Sieve Analysis	To determine the size distribution of the aggregates of sample
Shear Box Test	To determine the shear strength parameters, c⍰ & ⍰⍰ of the sample

The soil samples were taken from the Universiti Teknologi Petronas hilly area which is located at between block 13 and block 5. All the tools and equipments such as casing for bulk density, rubber hammer, oven for drying samples, and hooker were provided by the civil laboratory department. After discussing with the project supervisor, the location of sample was identified. The sample is taken from a small hill in UTP area which is located at between block 13 and block 5. The samples were collected for 6 days, and were taken on a sunny day, a rainy day and 4 days after the rainy days. The rainfall intensity for the rainy day was calculated. All samples from each day were devided into three set namely sets A, set B, and set C. The sample was also analysed to assess the particle size distribution of granular material of the sample. The third laboratory activity was, the shear box test. All the equipment was provided by the civil laboratory department. Three shear box tests are carried out, one is to determine the condition of the sample, the other one is for soil condition before implementing the siphon method, and the last one is for soil condition after implementing the siphon method. Besides laboratory activities, the other activities are modelling and remodelling the siphon system as landslide control. This process took nearly 5 weeks as many adjustment had to be made. All the materials were purchased from the hardware shops in Taman Maju, Batu Gajah and Ipoh.

Figure 8 : Small Hills of slope in between building 13 and building 5.

3.2 Gantt Chart Work For Final Year Project

Title: Landslide control using siphoning method														
PROJECT/PROGRESS	WEEK													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.1 Consultation with the supervisor: AP Dr. Nasiman Sapari (Sample Experiment, Procedure, Sample location, Model)														
2. Sample Collection														
3.Characterization of sample														
3.1 Bulk density														
3.2 Grain sizing														
4. Report writing (Progress Report, Technical Paper, Dissertation)														

3.3 Key milestone for Final Year Project

No.	Details\Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Consultation with the supervisor: AP Dr. Nasiman Sapri		■	■		■		■			■				
2	Sample Taking & Modelling			■	■	■		■	■	■	■				
3	Sample Experiment							■	■	■	■				
4	Submit Progress Report								■	■	■				
5	Pre-EDX Preparation										■				
6	Pre-EDX											■			
7	Submit Technical Paper												■	■	■
8	Submit Dissertation													■	■

CHAPTER 4

Result and Discussion

4.1 Data Gathering and Analysis

In this research, three tests were carried out to determine the soil properties. The tests were:

1. Bulk Density Test
2. Particle Size Distribution (Seive Analysis)
3. Shear Box Test

4.1.1 Bulk Density Test

Figure 9 : Bulk Casing embeded in the sample location

The Bulk Density Test were carried out to determined together with the moisture content of the sample. There were three sets of sample namely Set A, Set B, Set C. The materials needed in this experiment were :

- 3-inch diameter ring
- rubber hammer
- hooker
- sealabe bags and marker pen
- flat-bladed knife (spatula)
- block of wood
- spatula

The location of the sample is determined from after consulting with the project supervisor, Associate Professor Dr. Nasima Sapari. The sample was taken from a slope of a small hills at between the block 13 and block 5 in UTP area. The surface of the soil at the location was removed with hooker until approximately 30 cm deep from the surface area. Then, the ring was drove into the soil using rubber hammer and a block of wood which was placed at the top of the ring to prevent the ring surface from bending. The ring was driving fully into the soil. Then, it was removed carefully to prevent any loss of soil. The ring surface was compacted with adding the soil and removing the excess soil using the spatula. The ring was sealed with a plastic bag. The weight of the ring with soil is determined before entering into the oven for drying process of 24 hours with 100°-105°. Next, the weight of the oven-dry soil in the ring was measured. All the data were recorded. From this experiment, there are 4 types of parameters of soil can be determined.

1. **Soil Water Content, (g/g)** = [(weight of moist soil - weight of oven dry soil)/ weight of oven dry soil]
2. **Soil Bulk Density, (g/cm^3)** = oven dry weight of soil/ volume of soil
3. **Soil water-filled pore space, (%)** =(volumetric water content x 100)/ soil porosity
4. **Soil porosity, (%)** = soil bulk density/2.65

5. **Volumetric water content, (g/cm3)** = soil water content (g/g) x bulk density (g/cm3)

Below are the data recorded for 6 days. Noted that, for the Day-1 was a sunny day data. Day-2 data was after rainfall of 35mm. Day-3 data was the first day after rainfall day and so on until the fourth day after rainfall. The rainfall intensity was determined by placing an empty cylinder in the sample area location. After the rainfall, the height was noted which in this case is 35mm.

Figure 10 : Beaker determine the rainfall intensity (35mm)

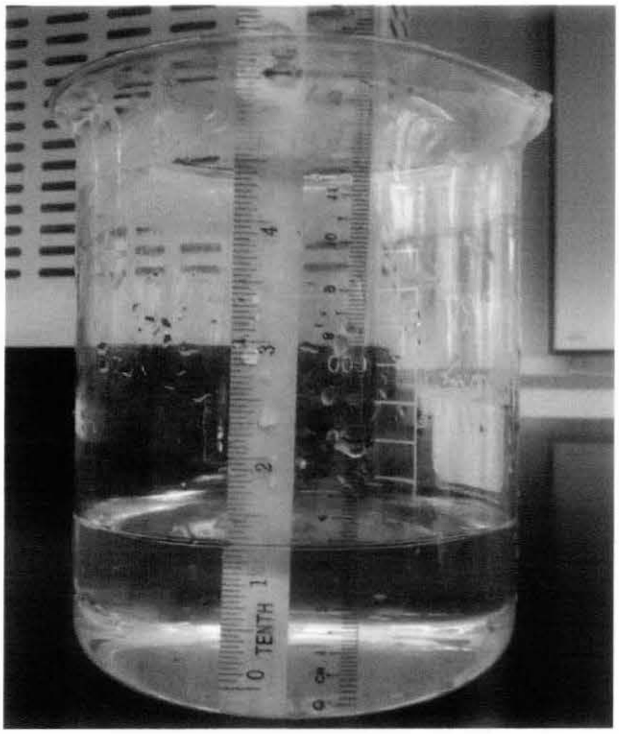


Figure 11 : Beaker in determined rainfall intensity (35mm)

Table 4.1.1-1 DAY-1 (SUNNY DAY)

Set	Weight,g (Soil + Steel Pipe) Before Dry	Weight,g (Soil + Steel Pipe) After Dry	Weight,g (Steel)	Weight,g moist soil	Weight,g dry soil	Volume soil (cm^3)	Soil water content,g/g	Soil water-filled pore space (%)	Soil porosity (%)	Volumetric water content (g/cm3)	Soil bulk density (g/cm3)
A	615.03	540.35	174.19	440.84	366.16	263.63	0.20	59.53	0.48	0.28	1.39
B	670.73	587.91	174.16	496.57	413.75	263.63	0.20	77.04	0.41	0.31	1.57
C	620.60	544.09	171.32	449.28	372.77	263.63	0.21	62.22	0.47	0.29	1.41

Table 4.1.1-2 DAY-2 (RAINING : 35mm)

Set	Weight,g (Soil + Steel Pipe) Before Dry	Weight,g (Soil + Steel Pipe) After Dry	Weight,g (Steel)	Weight,g moist soil	Weight,g dry soil	Volume soil (cm^3)	Soil water content,g/g	Soil water-filled pore space (%)	Soil porosity (%)	Volumetric water content (g/cm3)	Soil bulk density (g/cm3)
A	630.13	524.35	174.19	455.94	350.16	263.63	0.30	80.44	0.50	0.40	1.33
B	657.59	549.91	174.16	483.43	375.75	263.63	0.29	88.38	0.46	0.41	1.43
C	633.14	525.57	171.32	461.82	354.25	263.63	0.30	82.78	0.49	0.41	1.34

Table 4.1.1-3 DAY-3

Set	Weight,g (Soil + Steel Pipe) Before Dry	Weight,g (Soil + Steel Pipe) After Dry	Weight,g (Steel)	Weight,g moist soil	Weight,g dry soil	Volume soil (cm^3)	Soil water content,g/g	Soil water-filled pore space (%)	Soil porosity (%)	Volumetric water content (g/cm3)	Soil bulk density (g/cm3)
A	609.48	517.54	174.19	435.29	343.35	263.63	0.27	68.58	0.51	0.35	1.30
B	637.13	539.57	174.16	462.97	365.41	263.63	0.27	77.59	0.48	0.37	1.39
C	618.69	522.91	171.32	447.37	351.59	263.63	0.27	73.14	0.50	0.36	1.33

Table 4.1.1-4 DAY-4

Set	Weight,g (Soil + Steel Pipe) Before Dry	Weight,g (Soil + Steel Pipe) After Dry	Weight,g (Steel)	Weight,g moist soil	Weight,g dry soil	Volume soil (cm^3)	Soil water content,g/g	Soil water-filled pore space (%)	Soil porosity (%)	Volumetric water content (g/cm3)	Soil bulk density (g/cm3)
A	625.52	537.78	174.19	451.33	363.59	263.63	0.24	69.40	0.48	0.33	1.38
B	664.01	553.11	174.16	489.85	378.95	263.63	0.29	91.93	0.46	0.42	1.44
C	634.94	545.35	171.32	463.62	374.03	263.63	0.24	73.14	0.46	0.34	1.42

Table 4.1.1-5 DAY-5

Set	Weight,g (Soil + Steel Pipe) Before Dry	Weight,g (Soil + Steel Pipe) After Dry	Weight,g (Steel)	Weight,g moist soil	Weight,g dry soil	Volume soil (cm^3)	Soil water content,g/g	Soil water-filled pore space (%)	Soil porosity (%)	Volumetric water content (g/cm3)	Soil bulk density (g/cm3)
A	610.03	530.35	174.19	435.84	356.16	263.63	0.22	61.66	0.49	0.30	1.35
B	650.73	560.91	174.16	476.57	386.75	263.63	0.23	76.32	0.45	0.34	1.47
C	627.60	540.09	171.32	456.28	368.77	263.63	0.24	70.31	0.47	0.33	1.40

Table 4.1.1-6 DAY-6

Set	Weight,g (Soil + Steel Pipe) Before Dry	Weight,g (Soil + Steel Pipe) After Dry	Weight,g (Steel)	Weight,g moist soil	Weight,g dry soil	Volume soil (cm^3)	Soil water content,g/g	Soil water-filled pore space (%)	Soil porosity (%)	Volumetric water content (g/cm3)	Soil bulk density (g/cm3)
A	616.09	540.35	174.19	441.9	366.16	263.63	0.21	60.37	0.48	0.29	1.39
B	668.73	587.91	174.16	494.57	413.75	263.63	0.20	75.18	0.41	0.31	1.57
C	651.10	572.74	171.32	479.78	401.42	263.63	0.20	69.87	0.43	0.30	1.52

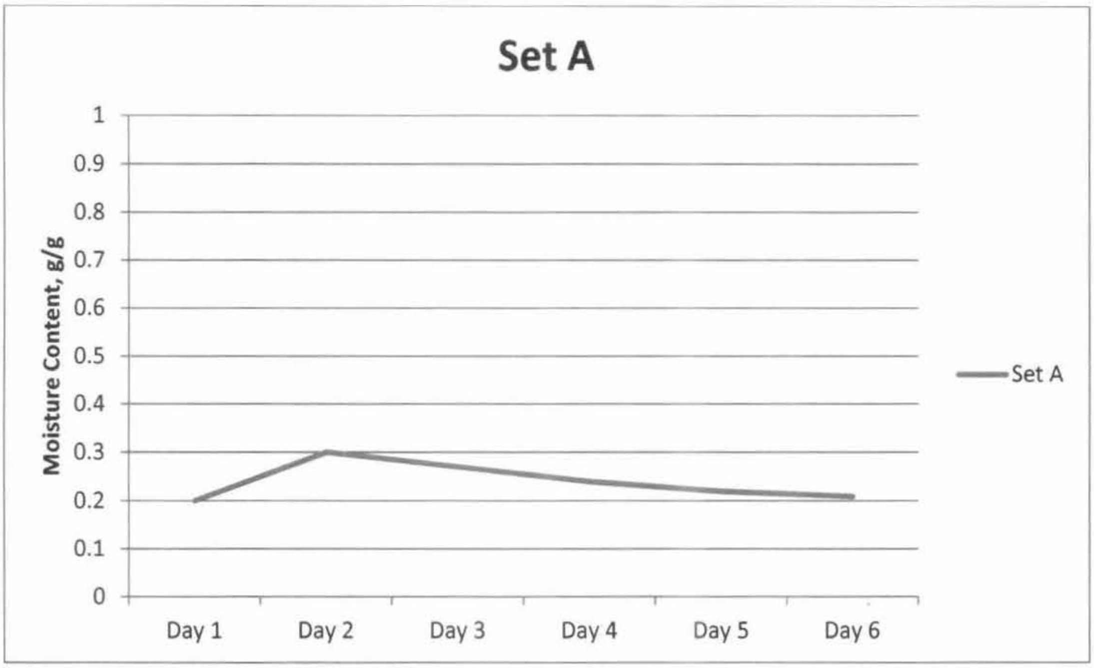


Figure 11 : Moisture Content vs Time (Set A)

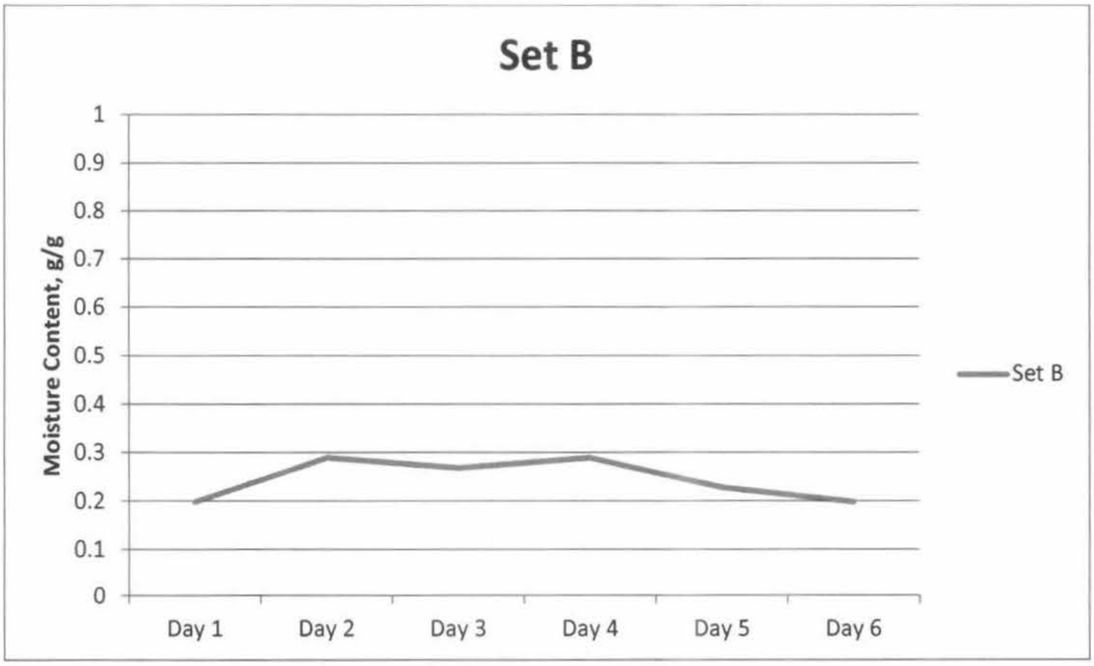


Figure 12 : Moisture Content vs Time (Set B)

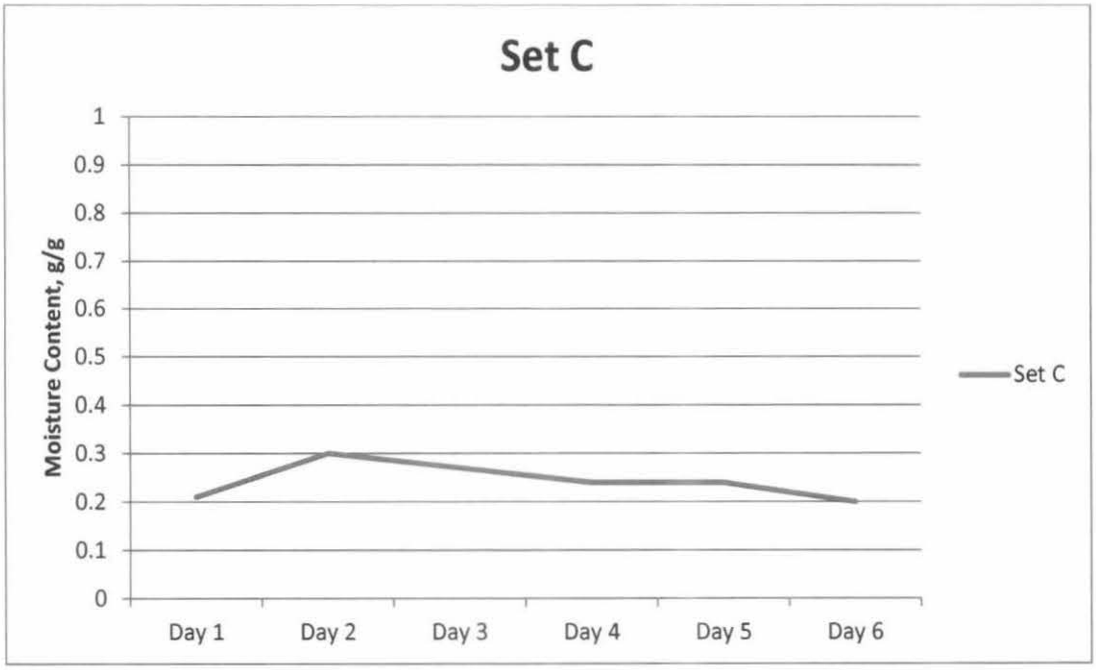


Figure 13 : Moisture Content vs Time (Set C)

Figure 14 : Ring label P4 (Set A) and P5 (Set B) Before Placing in the Oven

From the above data, we can conclude that after the rainfall day which in this case 35mm in day-2, the level of moisture content increases compared to the level of day-1 which is a sunny day. After day-2, the level of moisture content slowly decreases. In day-2, the soil water-filled pore space (%) of the sample can be considered as saturated which 88.88%. This means that, the sample containing more water in the soil compared to the sample in the sunny day.

4.1.2 Sieve Analysis

Sieve Analysis Test consists of shaking the soil sample through a set of sieves that have progressively smaller openings according to the U.S standard sieve numbers. The sieves used for soil analysis was 203mm (8 in) in diameter. Before conduct the sieve analysis, the soil was oven-dried and pounded to break all lumps into smaller particles. The soil then was shaken through a stack of sieves with openenings of decreasing size from top to bottom (a pan is placed below the stack). After the soil is shaken (15 minutes), the mass of soil retained on each sieve was determined. The smallest size sieve that should be used for this test was the U.S No. 200 sieve (BS 1337 : Part 2 : 1990).

After drying the sample for 24 hours at 100°-105°, the weight of the sample was measured and fixed to 500g. After that, weight of every empty sieve is determined. Eight numbers of test seives were stacked on the mechanical shaker with the largest size test sieve (2mm) to the maximum size of material present at the bottom of the stack (63 μm) and a receiver at the bottom of the stack (pan). The soil sample was placed on the top sieve and covered with a lid. The test sieves was agitated on the mechanical sieve shaker for 15 minutes. After 15 minutes, the amout of retained soil on each of the test seives was weighted. The percentage by mass of material on each test seive and cumulative percentage (by mass of total sample) passing each of the seives was calculate. Below are the result from the seives' test.

Screen Opening	Weight of Beaker with sand, g	Weight of empty beaker, g	Weight of Sand retained, g	Cumulative Weight Retained, g	Percentage Finer ,%
2 mm	560.4	469.66	90.74	90.74	81.852
1.18 mm	519.31	425.72	93.59	184.33	63.134
600 μm	488.33	405.78	82.55	266.88	46.624
425 μm	398.8	366.78	32.02	298.9	40.22
300 μm	395.58	358.28	37.3	336.2	32.76
212 μm	379.02	346.06	32.96	369.16	26.168
150 μm	364.75	333.53	31.22	400.38	19.924
63 μm	386.7	326.48	60.22	460.6	7.88
Pan 63 μm	433.55	394.15	39.4	500	0
			∑= 500		

#Weight of initial dry soil = 500.19g (Oven drying for 1 day at 100°-105°)

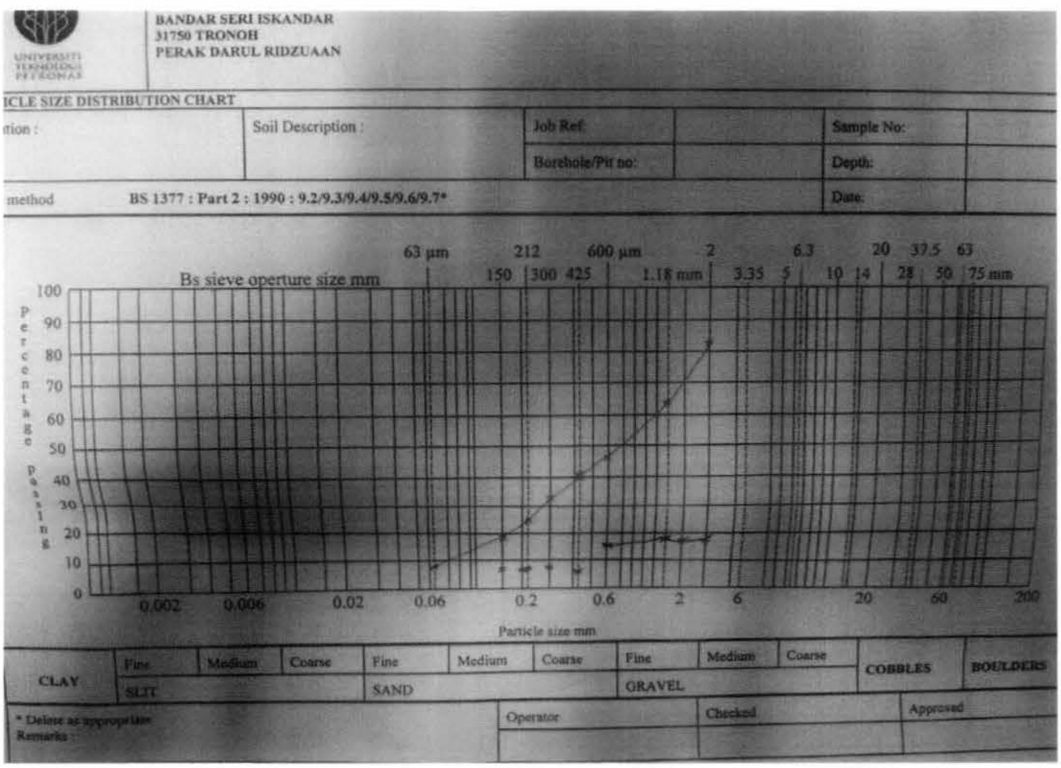


Figure 15 : Particle Size Distribution Chart

In Figure 15, it is shown that the soil sample is in half gravel-sand condition.The curve based on the chart represents the particles sizes in this sample are distributed over wide range indicating well graded. For percentage finer matter, sieve with opening 2mm has the highest percentage finer which is 81.852% while the lowest is sieve with 63 µm opening has 7.88%. Noted that, the initial dry weight of sample is 500.19g, while the final cummulative weight is 500g. This is because of sieve lost i.e. some of the sample are not exactly transfering properly into the pan and become dust. However, due to the small difference in weight, it can be neglected. From this particle size distribution, four parameters can be determined:

1. Effective Size (D_{10}) : This parameter is the diameter in the particle-size distribution curve corresponding to 10% finer. The effective size of granular soils is a good measure to estimate the hydraulic conductivity and drainage through sample.
2. Uniformity Coefficient : This parameter is defined as

$$C_u = \frac{D_{60}}{D_{10}}$$

where D_{60} = Diameter corresponding to 60% finer

3. Coefficient of gradation (C_z) : This parameter is defined as

$$C_z = \frac{D_{30}^2}{D_{60} \times D_{10}}$$

4. Sorting coefficient (S_0) : This parameter is another measure of uniformity and is generally encountered in geologic works and expressed as

$$S_0 = \sqrt{\frac{D_{75}}{D_{25}}}$$

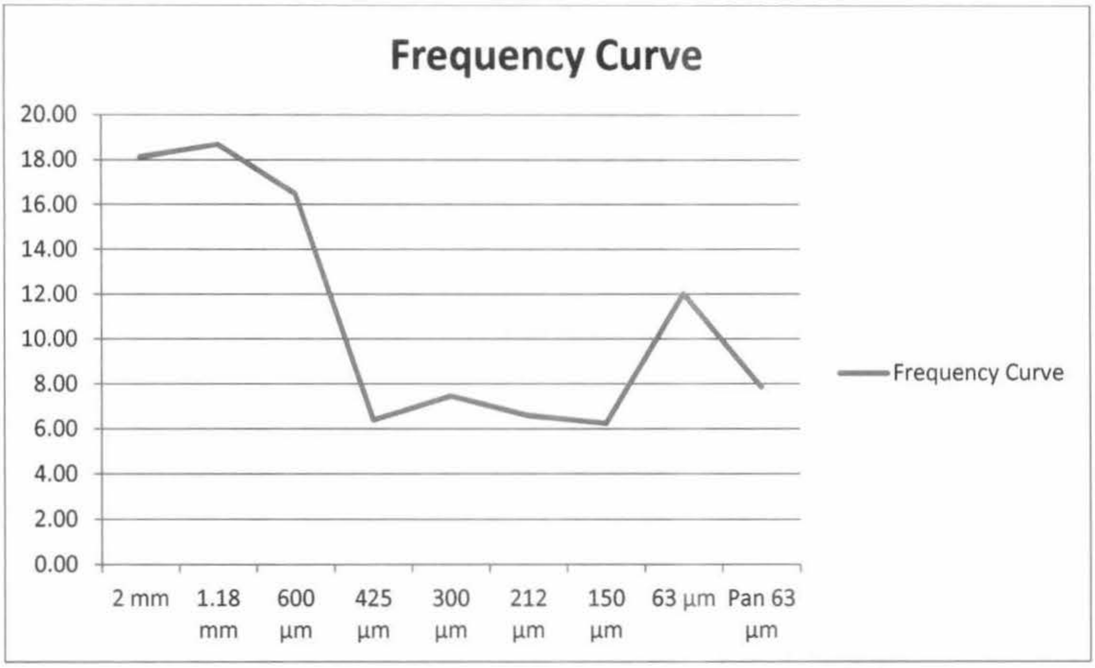


Figure 16 : Percentage Mass Retained vs Opening Sieve

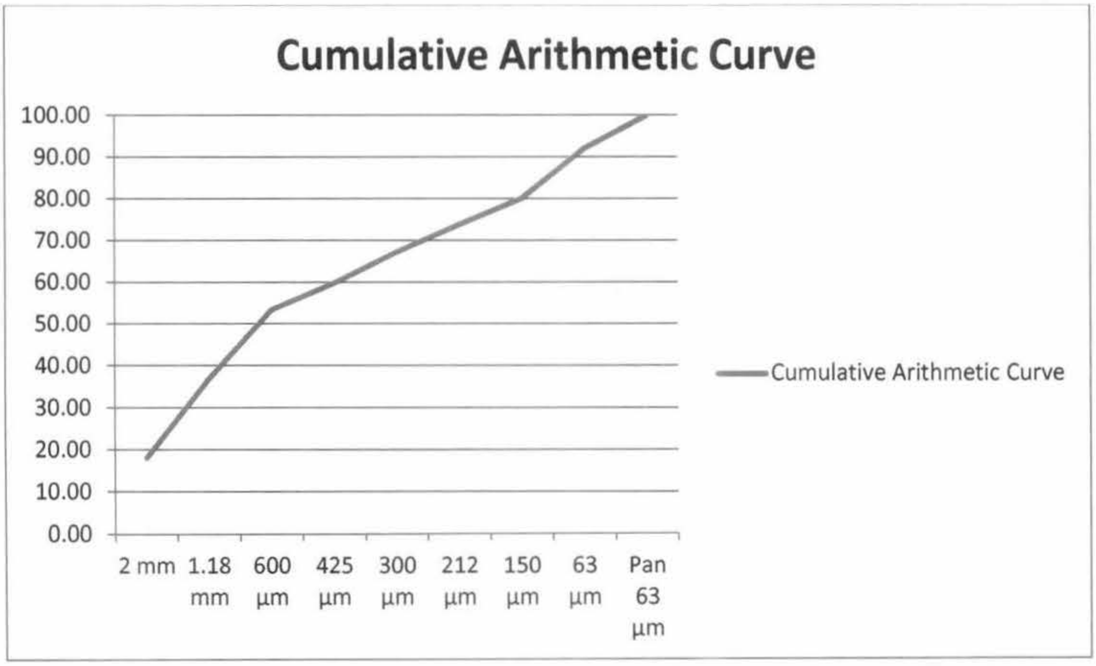


Figure 17 : Percentage Cumulative Mass Retained vs Opening Sieve

Figure 18 : Sample retained at each sieve after test

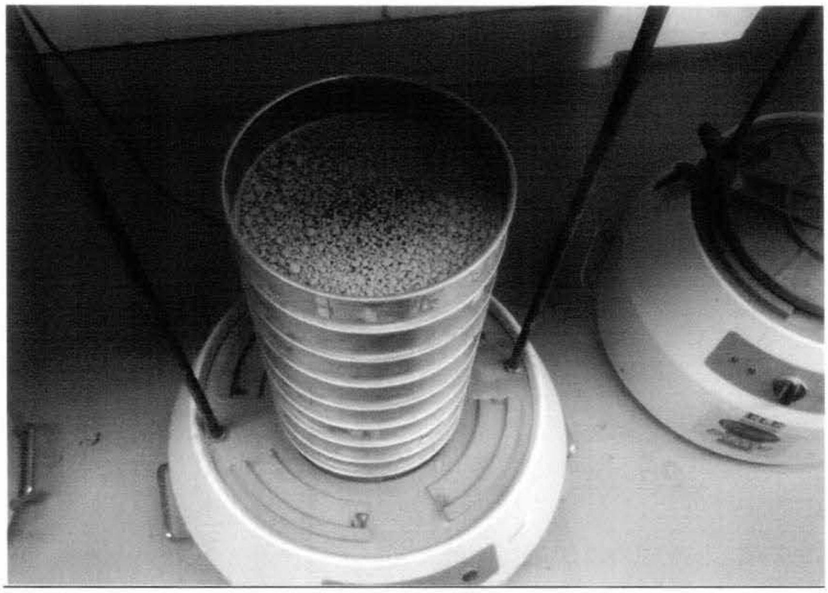


Figure 19 : Seive placing in the mechanical shaker machine

4.1.3 Shear Box Test

This Shear Box test is to determine the shear strenght parameters for the sample. A square prism of soil sample is laterally restrained and sheared along a mechanivally induced horizontal plane subjected to pressure applied normal to that plane. The shearing resistance offered by the soil as one portion was made to slide on the others was measured at the regular intervals of displacement. When the shearing resistance was at maximum value that the soil can sustain, failure would occur. At the end of this test, the relationship between the measured shear stress at failure and the normal applied was calculated.

The soil sample for this test was compacted first in a compaction mould for optimum moisture condition. The number of blow used in this test was 27

according to the protocola at each layer. After compaction process, the sample was taken out to reshape by using a cutter before inserting it in the direct shear box mould. The test was repeated three times with addition of normal load. The normal loading applied are as below:

1st test : 100 kN/m²

2nd test : 200 kN/m²

3rd test : 300 kN/m²

Figure 20 : Soil is placed 1/3 (1 layer) in compaction mould

Figure 21 : Soil compacted with No.of blow 27 at each layer

Figure 22 : Compacted soil is taken out to cut before putting in the shear box mould

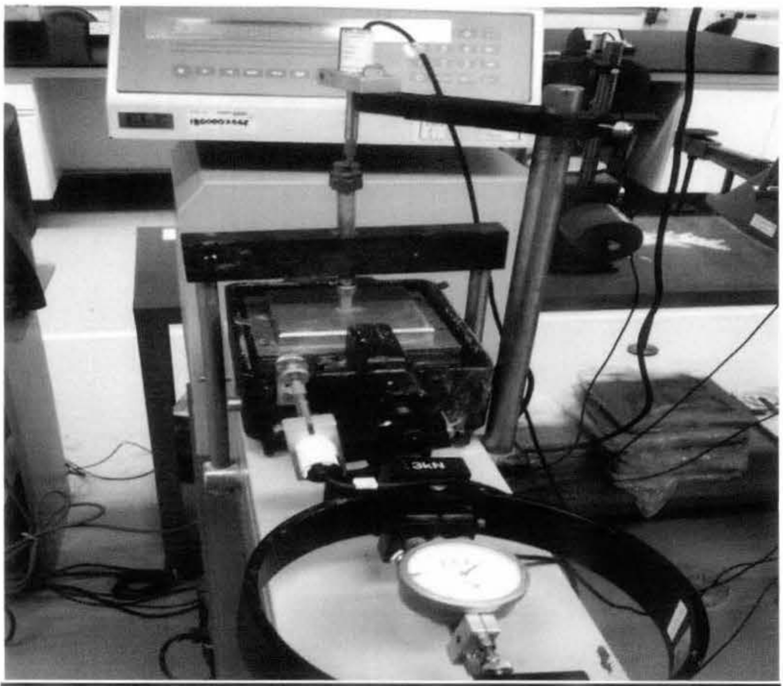


Figure 23 : Shear Box Test Mechine

Figure 24 :Data recorded computerized

Test Summary				
Reference	A	B	C	
Applied Normal Stress	98.1 kPa	196.2 kPa	294.3 kPa	
Peak Strength	23.4 kPa	94.7 kPa	126.0 kPa	
Corresponding Horizontal Displacement	6.949 mm	6.091 mm	9.645 mm	
Residual Shear Stress				
Rate(s) of Shear Displacement	Stage 1: 0.0286mm/min	Stage 1: 0.0286mm/min	Stage 1: 0.0286mm/min	
Final Height	0.68 mm	-1.34 mm	-1.37 mm	
Cumulative Displacement	7.146 mm	6.191 mm	9.845 mm	
Number of Traverses	1	1	1	

Figure 25 :Maximum Shear Stress vs Normal Stress

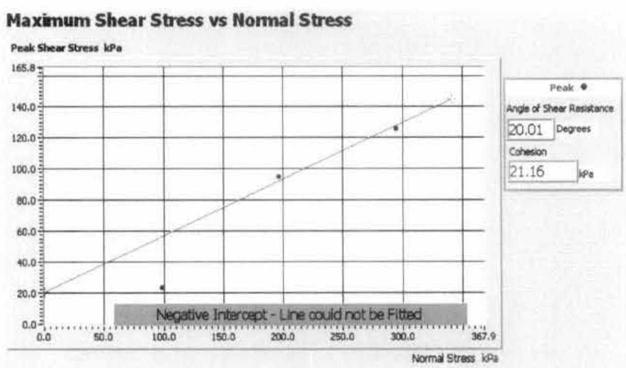


Figure 26 : Maximum Shear Stress vs Normal Stress graph

Figure 25 and figure 26 demonstrate the results from the shear box tests. It was found that, the angle of shear resistance of the sample is 20.01 degrees and the cohesion obtained was 21.16 kPa. The value of cohesion obtained indicates that the soil samples has a good resistance from having a movement. However, the value obtained would be better as it is influenced by uncertainty or error such as the machine itself is sensitive to any external vibration or motion, the soil is not fully compacted during compacting process, and the vertical and horizontal deformation gauge is not in the best position or condition.

4.2 Model Development

In the previous of FYP 1, the proposed model for siphon drain was slightly adjusted due to time constraint. Generally, 2 pail with one full of soil was used and the other one containing with water. Both were placed at different level of height. The types of pipes used for this siphon system was pvc type tied at the both end with geotextile materials as a filter. Therefore only water can go into the pipe. The bottom of the pail A was connected with the transparent pipe as an indicator of water level in the pail that was filled up with soil. The level will be the same with the level shows in the transparent pipe. The open pipe in the Figure 26 was used for connection to place vacuum pump so as to create a low pressure for the water to flow from pail A to pail B. The water will stop flowing when the pressures at both pails are the same. If the water in pail A is added, the water will flow automatically until the level of both bucket are the same.

Mechanism of the Model.

- A Vacum pump was connected to the hole in Figure 26.
- Closed the pipe in the pail B and open the pipe the connected to the vacuum. This was to prevent the water from soil in pail B to flow out. Therefore, only water from soil in pail A was flowing out because of the low pressure created by the vacuum.
- After the level in the transparent pipe slightly decreased, closed the pipe that connected the vacum and open the pipe in the pail B.
- The water in the pail A will slowly decreased as indicated by the transparent pipe.
- The flow will stop when the pressure at both pail is about the same.

Figure 27 : Pail A (Higher level) and Pail B (lower level)

After the water level was decresed, the soil was taken out for determination of moisture content by using oven-dry method.

Sample	Weight of Container, g	Weight, g (Soil + Container) Before Dry	Weight, g (Soil + Container) After Dry	Weight,g moist soil	Weight,g dry soil	Moisture Content,
S1	19	49.03	42.12	30.03	23.12	0.30
S2	20.5	50.1	43.17	29.6	22.67	0.31
S3	24.54	54.02	47.13	29.48	22.59	0.31

Table 4.2-1: Moisture Content after Siphon Method

Comparing the moisture content before using the siphon method in table 4.2-2, it was found that the moisture content was decreasing from 0.37 to 0.31. This means, the water is succesfully flow out and lowering the level of water in the pail A.

Sample	Weight of Container, g	Weight, g (Soil + Container) Before Dry	Weight, g (Soil + Container) After Dry	Weight,g moist soil	Weight,g dry soil	Moisture Content,
S1	19.00	49.05	41.00	30.05	22.00	0.37
S2	20.50	50.55	42.29	30.05	21.79	0.38
S3	24.54	55.23	47.13	30.69	22.59	0.36

Table 4.2-2: Moisture Content before Siphon Method

The soil is taken out for shear box test before and implementing the siphon system to make a comparison in terms of soil strength. Below are the data obtained before and after implementing the siphon:

1) Before the siphon pipe:

Test Summary				
Reference	A	B	C	
Applied Normal Stress	98.1 kPa	196.2 kPa	294.3 kPa	
Peak Strength	23.3 kPa	94.5 kPa	126.0 kPa	
Corresponding Horizontal Displacement	6.053 mm	5.992 mm	9.645 mm	
Residual Shear Stress				
Rate(s) of Shear Displacement	Stage 1: 0.0286mm/min	Stage 1: 0.0286mm/min	Stage 1: 0.0286mm/min	
Final Height	0.68 mm	-1.34 mm	-1.37 mm	
Cumulative Displacement	7.146 mm	6.191 mm	9.845 mm	
Number of Traverses	1	1	1	

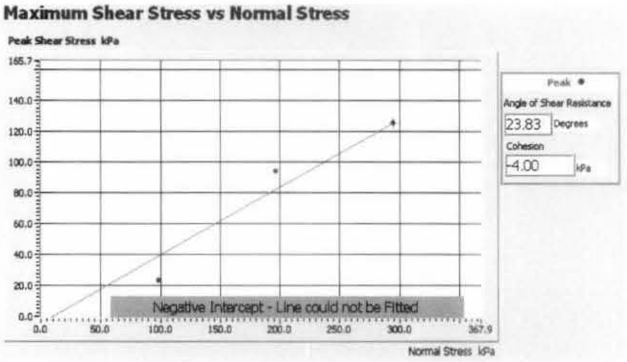


Figure 28: Maximum Shear Stress vs Normal Stress

2) After the siphon pipe

Test Summary				
Reference	A	B	C	
Applied Normal Stress	98.1 kPa	196.2 kPa	294.3 kPa	
Peak Strength	7.8 kPa	68.7 kPa	96.9 kPa	
Corresponding Horizontal Displacement	2.675 mm	6.266 mm	7.460 mm	
Residual Shear Stress				
Rate(s) of Shear Displacement	Stage 1: 0.0286mm/min	Stage 1: 0.0286mm/min	Stage 1: 0.0286mm/min	
Final Height	0.78 mm	-1.28 mm	-1.01 mm	
Cumulative Displacement	6.762 mm	7.861 mm	9.354 mm	
Number of Traverses	1	1	1	

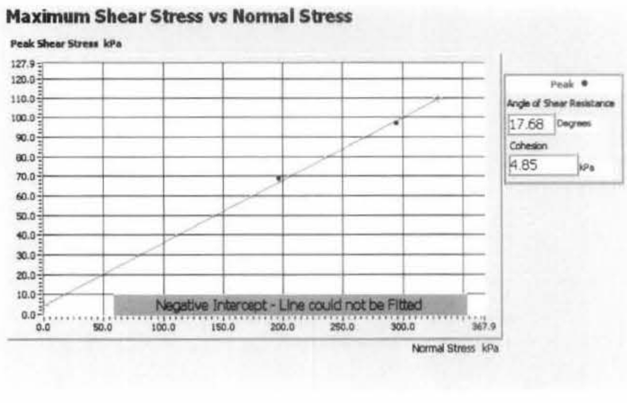


Figure 29: Maximum Shear Stress vs Normal Stress

The above results show that the soil strength is low when it is in saturated condition. By implementing the siphon pipe to the model, the soil strength becomes higher. This can be explained by the observation from the result of the shear box test. The peak strength after implementing is higher for all the three samples. Therefore, the experimental work objectives are achieved.

CHAPTER 5

CONCLUSION

Landslide is a serious hazard that needs mitigation measures. The outcome of this disaster is a very big threat to the human life and affects greatly the human activities. Based on the research, most landslides happened when the groundwater level is increases, particularly during or after a heavy rain fall. The consequence is the slope of the hill or mountain become unstable and started to move, or collapse. Due to this situation, the pore water can be considered as the most significant causes triggering the landslide.

Siphon system can be used for controlling water level in the soil. It is found in this study that the water in the soil can be controlled by using the siphon principle. The Siphoning method increases the cohesion of the soil from -4.00kPa to 4.85kPa. At the same time its reducing the moisture content of soil from 3.7 g/g to 3.0 g/g The pressure principle used in this system is an environmental friendly and requires very little energy to maintain the process. However, clogging problems may arise thus adjustments need to be made for the maintenance of the system.

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