INVESTIGATION OF STRENGTH CHARACTERISTIC OF GABION WALL MADE FROM GRAVEL MIXED WITH TYRE CHIPS

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ABSTRAK

Untuk mengurangkan penimbunan tayar sisa dengan menggunakannya sebagai bahan gantian untuk dinding gabion, keberkesanan penggantian hendaklah disiasat. Objektif utama kajian ini adalah untuk mengkaji sifat kekuatan dinding gabion yang diperbuat daripada batu yang bercampur dengan cip tayar. Beberapa ujian menggunakan cerun dan model dinding gabion dengan hujan tiruan telah dilaksanakan. Dinding gabion disusun secara menegak. Lereng dengan 60 ° kecerunan tanpa dinding gabion atau sokongan diuji terlebih dahulu. Cerun gagal apabila tertakluk kepada hujan 570mm / hr pada minit kedua. 100% batu dan 100% cip tayar dinding gabion diletakkan dan disusun secara menegak di lereng dalam ujian berasingan. Tiada anjakan dinding yang dikesan. Ini bermakna dinding gabion dengan 100% cip tayar sudah memberikan sokongan yang mencukupi untuk mengelakkan dari kegagalan cerun berlaku. Untuk memastikan kebenaran dinding gabion dengan 100% cip tayar boleh memberi sokongan yang mencukupi, dinding gabion dengan 50% batu dan 50% cip tayar diuji pada dimensi cerun yang sama. Tiada anjakan berlaku selepas hujan. Oleh itu, kesimpulan yang dapat dibuat adalah menggantikan batu dengan tayar buangan sebagai bahan untuk dinding gabion boleh digunakan pada projek yang berskala kecil.

ABSTRACT

In order to reduce stockpiling of waste tyre by use it as a replacement material for gabion walls, the effectiveness of the replacement must be investigated. The main objectives of this study were to investigate the strength characteristic of gabion wall made from gravel mixed with tyre chips. Series of test using a slope and gabion walls model with artificial rainfall were conducted. The gabion walls were arranged in vertical order. A 60° slope without any retaining wall or support was tested first. The slope failed when subjected to 570mm/hr rainfall after two minutes. 100% of gravel and 100% tyre chips gabion walls placed and stacked in vertical order at the slope in separate test. There was no displacement of gabion wall detected. This means 100% tyre chips already provide sufficient support to prevent from slope failure happen. To ensure the truth of 100% tyre chips gabion walls can provide sufficient support, 50% gravel and 50% tyre chips gabion walls was tested at the same slope dimension. There was also no displacement occur after subjected to rainfall. Because of that, it can be concluded that replacing gravel with waste tyre as a material in gabion wall can be applied in a small scale project.

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LIST OF SYMBOLS

γ_d	Dry Density
γ	Bulk Density
ω	Water Content
C_u	Coefficient of Uniformity
C_c	Coefficient of Gradation
G_s	Specific Gravity
%	Percentage

CHAPTER 1

INTRODUCTION

1.1 Background of study

In Malaysia, the rains are heavy in November and December. Therefore, many slope failure cases happens during both months. Slope instability can endanger human's life, buildings and roads. Besides, causing the government to bear high maintenance's cost and other costs. Besides that, tyre waste cause many bad impacts on the environment.

A landslide happens in Cameron Highlands on 26 November 2014. This accident happen after a heavy rain. One of the methods to prevent slope failure is by placing gabion wall. In current practice, a gabion is made from 100% gravel assembled together in a wire mesh

In this study, the effectiveness of using new material such as tyre chips to replace gravel is studied. Which percentage of tyre chips that show the most effective strength characteristic of the gabion wall.

To achieve the objective, numerical simulation is conducted to obtain the critical dimensions. Before performing numerical simulation, basic properties test of material is conducted to use as a parameters required for numerical simulation. Next, several slope model and gabion wall is built according to dimension obtained from numerical simulation. The slope model is subjected to artificial rainfall. The displacement of gabion wall and erosion occur due to rainfall will be recorded.

1.2 Problem statement

In Malaysia, heavy rainfall usually happened in the month of November and December. Heavy rainfall caused many disaster and failure that can endanger human's life, buildings and roads. A common disaster that usually happened during these months is slope failure. Slope failure case normally occurred after prolonged rainfall. When slope failure occurred, it caused many losses and damages especially when the slope located near roads or residential area. It also caused the government to bear all maintenance cost and other costs to restore all the damages. Slope failure also have been acknowledged as one of the disaster that can lead to great losses and costs to a government to recover what have been damaged.

On the other hand, amount of stockpiling of waste tyre have been increasing every year due to the increasing number of cars on roads. Tyres waste which are conventionally dumped can caused various pollutions due to it is difficult to decompose and compact. It also can cause growth of dangerous pests and insects such as mosquito which can carry dengue, zika, and yellow fever. Besides, tyre can take up landfill space due to its hollow shape and cause landfill to full in a short time. In other countries, various recycle method of used tyres have been practiced. However, it also can cause many disadvantages. There are many waste tyres recycling alternatives method. For example, some country had made a tyres waste power plant. Although tyres make good burning material, unfortunately it polluted the air because of hazardous compound and toxic gases produced when burning them which is harmful to humans and environment by leaving oily residue. It also releases tremendous number of small particles that can settle deep in the lungs when inhale the air which are contaminated. This usage of this method of recycling need to be reduced.

Moreover, source of gravel had been used widely in construction. Quarry industry also need to maximize the production due to many housing developments and townships had to expand and grow. Because of that, source of gravel maybe limited someday in the future. To overcome all those problems stated, the effectiveness of using new material which is tyre chips as part of material to make gabion walls to increase slope stability was studied.

1.3 Objective of study

The objective investigation on the effectiveness of gabion wall made from gravel mixed with tyre chips is:

1. To obtain the basic properties of soil and tyre chips.
2. To determine the effectiveness of tyre chips and gravel as a material for gabion wall that give best result in stability slope.

1.4 Scope of study

The study focus on making a slope model and determination of basic properties of material that used in the study. Laboratory tests were conducted to obtain basic properties of material that ben used in making slope model. Laboratory test that were conducted are sieve analysis, shear strength test, specific gravity test and permeability test. Next, six slope model and six gabion wall with different percentage of tyre chips was built according to dimension obtained from numerical simulation. An artificial rainfall was also simulated.

CHAPTER 2

LITERATURE REVIEW

2.1 Malaysia's climate/weather

Climate means average weather or description in terms of the mean and variability of relevant quantities over period of time which can be months to thousands or millions of years. The characteristic features of climate in Malaysia are uniform temperature, high humidity and copious rainfall. The rainfall distribution in a country depends on the seasonal wind flow pattern and topographic features. East coast of Peninsular Malaysia, Western Sarawak and the northeast coast Sabah is the exposed area. They experience heavy rainfall during northeast monsoon season. On the other hand, areas that are relatively free from its influence which are sheltered by mountain ranges. It showed that rainfall distribution of the country was depend on seasons. On east coast states, maximum rainfall occurred in November, December and January. Besides that, June and July are driest months' districts. The primary maximum generally occurs in October - November while the secondary maximum generally occurs in April - May. The rainfall pattern over the southwest coastal area is much affected by early morning "Sumatras" from May to August with the result that the double maxima and minima pattern is no longer distinguishable. October and November are the months with maximum rainfall and February the month with the minimum rainfall. The March - April - May maximum and the June - July minimum rainfall are absent or indistinct. The average monthly rainfall (annual) for Peninsular Malaysia is shown in Figure 2.1 (Malaysia Meterological Department,2017).

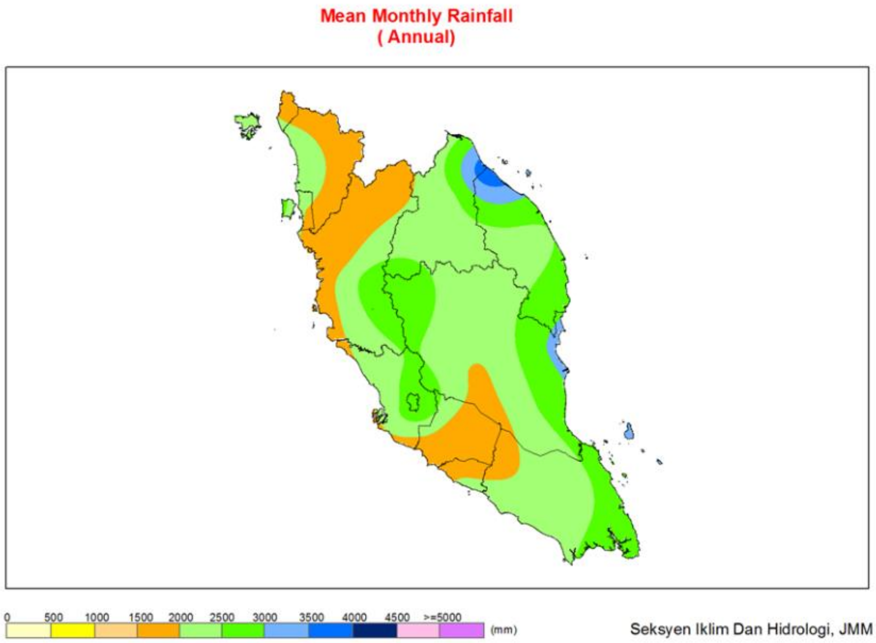

Figure 2.1 Mean monthly rainfall (Annual)
Source: Malaysia Meterological Department (2017).

To show which months have the heaviest rainfall, the precipitation of every month need to be determined first. Precipitation means any form of water which liquid or solid that is falling from sky. It includes rain, snow, sleet, hail and drizzle. Since Malaysia does not experience snow season, then all the precipitation must be consisting of rain only. Some country in Malaysia have placed the station to investigate the precipitation. Only some country the station is placed to represent each part of peninsular Malaysia ("Rainfall precipitation", 2016).

Figure 2.2 Precipitation station around peninsular Malaysia
Source: "Rainfall precipitation"(2016).

Figures 2.3, Figure 2.4, Figure 2.5, Figure 2.6, Figure 2.7 and Figure 2.8 shows the which months have highest precipitation of the rainfall in some country in Malaysia that have established station.

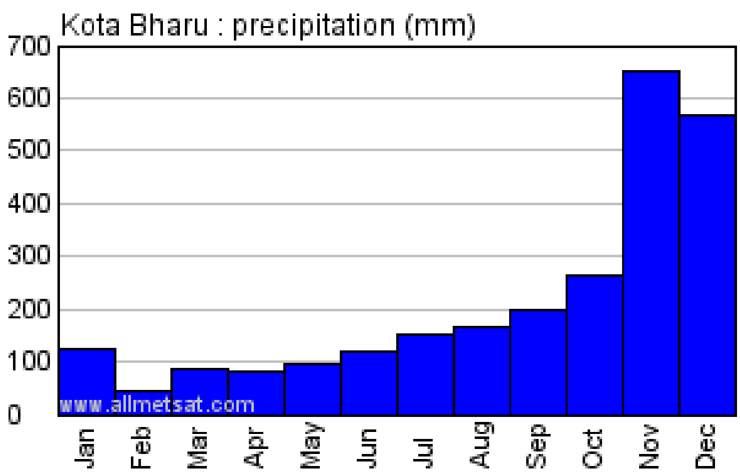

Figure 2.3 Rainfall precipitation in Kota Bharu
Source: "Rainfall precipitation"(2016).

Figure 2.3 shows that Kota Bharu have the highest rainfall precipitation during month of November and December.

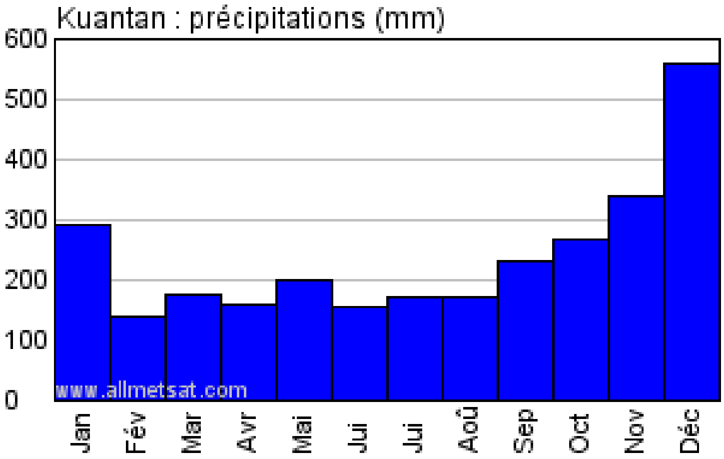

Figure 2.4 Rainfall precipitation in Kuantan

Source: “Rainfall precipitation”(2016).

Figure 2.4 also shows that Kuantan have the highest rainfall precipitation during month of November and December.

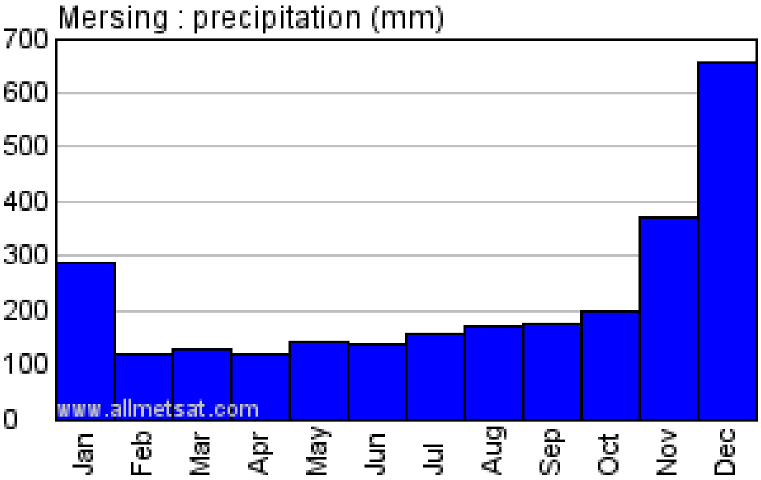

Figure 2.5 Rainfall precipitation in Mersing

Source: “Rainfall precipitation”(2016).

Mersing have the highest rainfall in December and second highest in November.

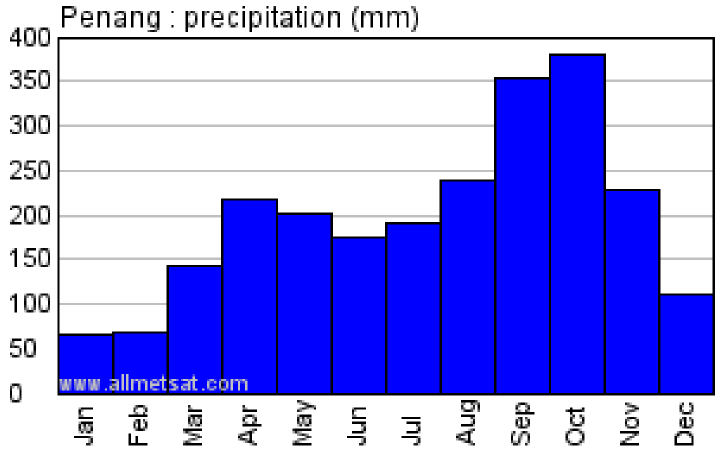

Figure 2.6 Rainfall precipitation in Penang

Source: "Rainfall precipitation"(2016).

While it is different with Penang which have the highest precipitation in both September and October.

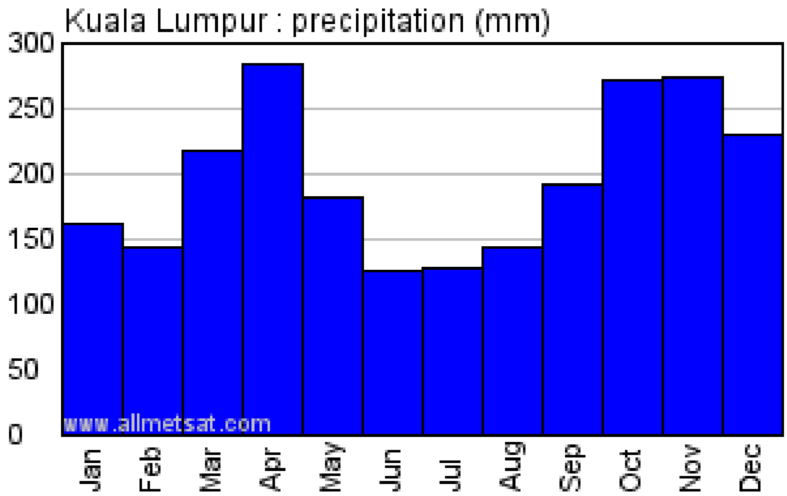

Figure 2.7 Rainfall precipitation in Kuala Lumpur

Source: "Rainfall precipitation"(2016).

Kuala Lumpur also have the highest rainfall precipitation in April.

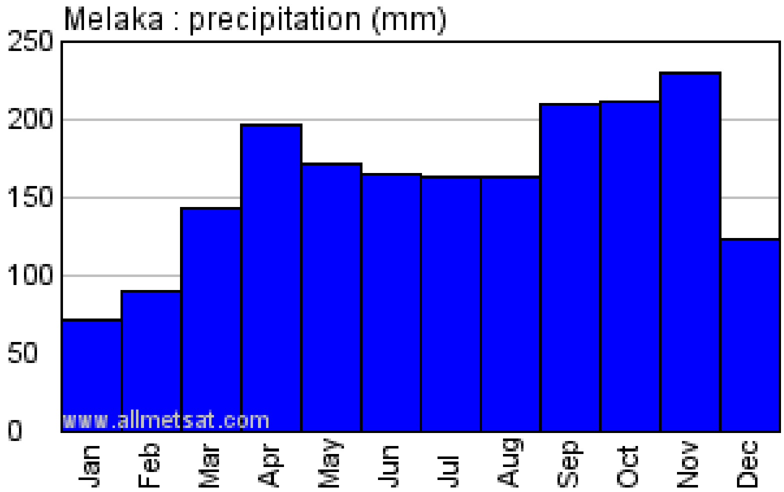

Figure 2.8 Rainfall precipitation in Melaka
Source: "Rainfall precipitation"(2016).

Melaka have constant precipitation from March to November. Based on the bar chart in Figure 2.8, Mersing have the highest precipitation than all station which is month December. The station that is located in east side of peninsular Malaysia tends to have different rainfall precipitation trend than west side. It also showed that the total of rainfall precipitation of all months in the east side have more than the west side. In conclusion, the east side of peninsular Malaysia affecting the Malaysia's rainfall distributions. Malaysia have highest rainfall precipitation on November and December.

2.2 Introduction to slope failure

Slope is defined as an exposed ground surface that's stand with an angle with the horizontal. Slope can be made man-made or natural. It also can fail in various modes (Braja M. Das, 2009). Slope failure usually happen during rainfall or earthquake. Slope failure can cause many disaster and failure that can endanger human's life, buildings and roads. It also can cause many losses and damages especially when the slope located near roads or residential area. It caused the government to bear all maintenance cost and other costs to restore all the damages. Slope failure also have been acknowledged as one of the disaster that can lead to great losses and costs to a government to recover what have been damaged.

Geotechnical engineers are often dealing with the slope stability problems. Engineers are also responsible to analyse slope stability. Engineer will analyse a slope stability by determining the factor of safety. Generally, the factor of safety is defined as equation 2.1 (Braja M. Das, 2009) :

$$F_s = \frac{\tau_f}{\tau_d} \qquad 2.1$$

Where F_s = factor of safety with respect to strength

τ_f = average shear strength of the soil

τ_d = average shear stress developed along the potential failure surface

The shear strength of soil consists of two components, cohesion and friction and may be written as

$$\tau_f = c' + \sigma' \tan \emptyset' \qquad 2.2$$

Where c' = cohesion

$\emptyset'$ = angle of friction

σ' = normal stress on the potential failure surface

$$\tau_d = c'_d + \sigma' \tan \emptyset'_d \qquad 2.3$$

Where the cohesion and the angle of friction that develop along the potential failure surface.

When factor of safety is equal to 1, the slope is impending failure. Usually, when factor of safety equal to 1.5 with respect to strength is acceptable for the design of a stable slope (Braja M. Das,2009).

This study only focus on finite slope. A slope is considered as finite slope when the value of Hcr approaches the height of slope. The general shape of the surface of potential failure is need to be assume when analysing the stability of a finite slope in a homogeneous soil. Culmann approximated the surface of potential failure as a plane. The calculation of factor of safety by using Culmann's assumption gives good results for near vertical slopes. However, a Swedish geotechnical commission have conducted a comprehensive investigation of slope failure in 1920s. He recommended actual surface of sliding might be approximated to be circularly cylindrical. After that time, most common stability analyses of slopes have been made by assuming the curve of potential sliding is an arc circle. However, stability analysis using plane failure of sliding is still being used due to its more appropriate and give excellent results in some cases such as zoned dams and foundation on weak strata. This study focus on only circular failure surfaces analysis. Slope failure also can occur when external stress exceeds soil strength. Hence, slope stability is fundamentally a function of the balance of forces acting on a soil or rock mass. One method that has been widely used for quantifying the force balance is limit equilibrium analysis, which defines the state at which shear stress and shear strength are in equilibrium (Braja M. Das,2009).

There are various procedures of stability analysis. In general, it is divided into two major classes which Mass procedure and Method of slices. Mass procedure is useful when the slope is assumed to be consist of homogeneous and it's not happen to in most natural slopes. Besides that, in Method of slices procedures, there are number of vertical parallel slices that is divided from the soil above the surface of sliding. The stability of each slice is calculated separately. This technique is versatile where the no homogeneity of soils and pore water pressure can be taken into consideration. Variation of the normal stress along the potential failure surface also will be accounts. Figure 2.9, Figure 2.10 and Figure 2.11 show various mode of slope failure can happen.

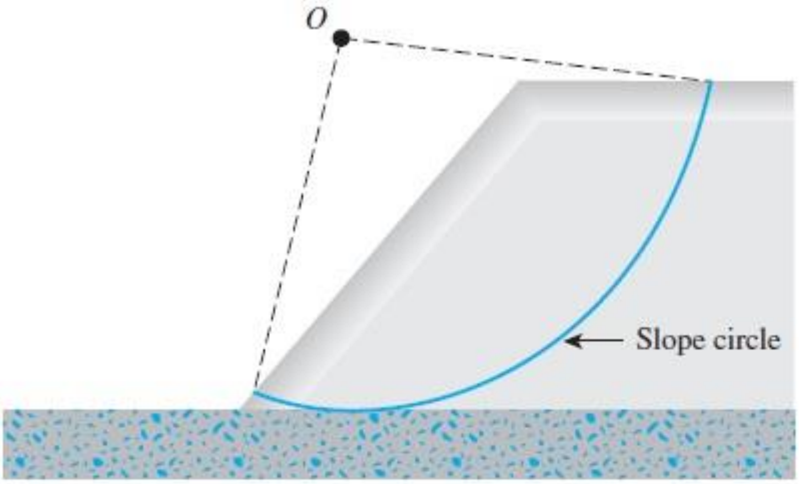

Figure 2.9 Slope failure in slope circle.
Source: Braja M. Das (2009).

Figure 2.10 Shallow slope failure
Source: Braja M. Das (2009).

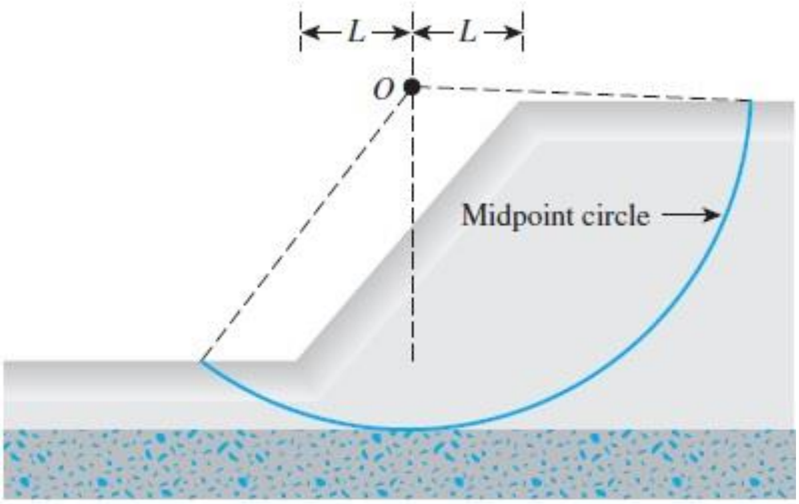

Figure 2.11 Base failure

Source: Braja M. Das (2009).

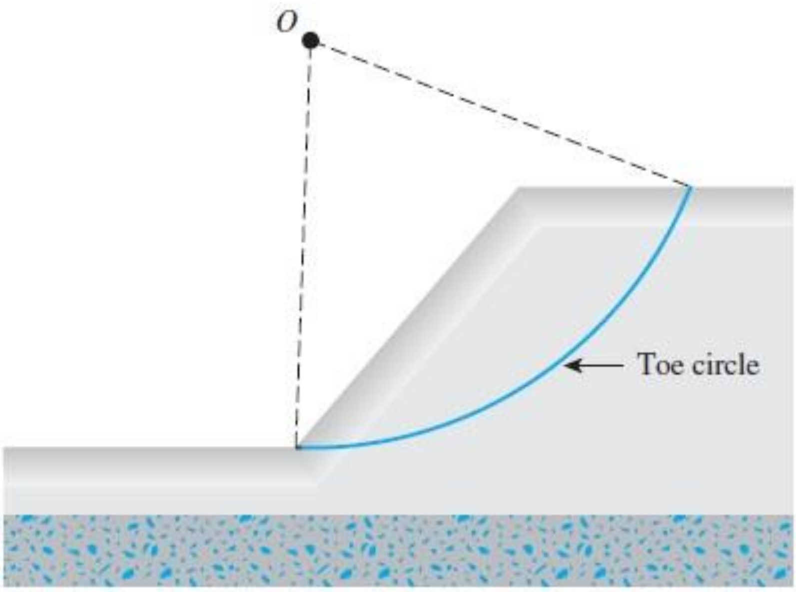

Figure 2.12 Toe circle.

Source: Braja M. Das (2009).

2.3 Mode of slope failure

Slope failure popularly known as landslide. Slope failure can occur in various type of slope. Slope can fail in various mode. Failure mode can be different according to type of soil and slope. Every mode of slope failure has its condition and categories. Cruden and Varnes (1996) classified the slope failure into five major categories (Braja

M. Das, 2009). In general, finite slope failure occurs in one of the following modes as shown in Figure 2.9, Figure 2.10, Figure 2.11 and Figure 2.12. When the failure occurs in such a way that the surface of sliding intersects the slope at or above its toe, it is called a slope failure as shown Figure 2.12. The failure circle is referred to as a toe circle if it passes through the toe of the slope and as a slope circle if it passes above the toe of the slope. Under certain circumstances, a shallow slope failure can occur, as shown in Figure 2.10. When the failure occurs in such a way that the surface of sliding passes at some distance below the toe of the slope, it is called a base failure. The failure circle in the case of base failure is called a midpoint circle.

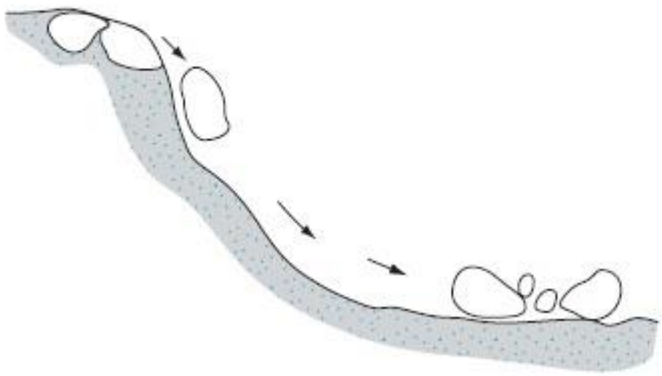

Figure 2.13 “Fall” type of landslide.
Source: Braja M. Das (2009).

There is large amount of soil mass has slid down a slope. This mode of slope failure happened when detachment of soil or rock that fall down a slope. Figure 2.12 shows how fall type landslide happen.

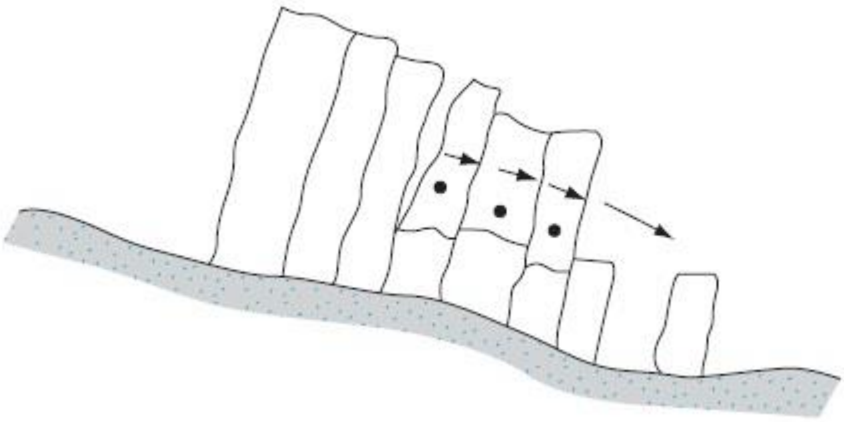

Figure 2.14 "Topple" type of slope failure.
Source: Braja M. Das (2009).

This happen when soil or rock cause its rotation about an axis below the centre of gravity of mass being displaced. Figure 2.1 shows topple type of slope failure.

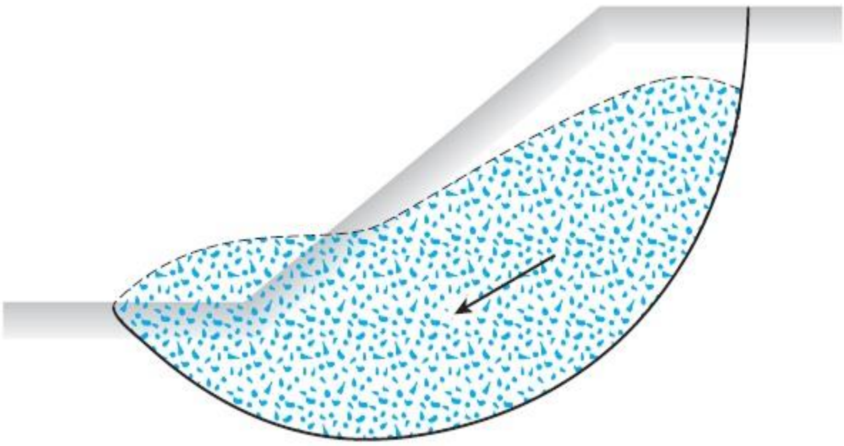

Figure 2.15 Slope failure by "sliding".
Source: Braja M. Das (2009).

This mode is observed when the downward movement of soil mass occurring on surface rupture. Figure 2.15 shows slope failure by sliding.

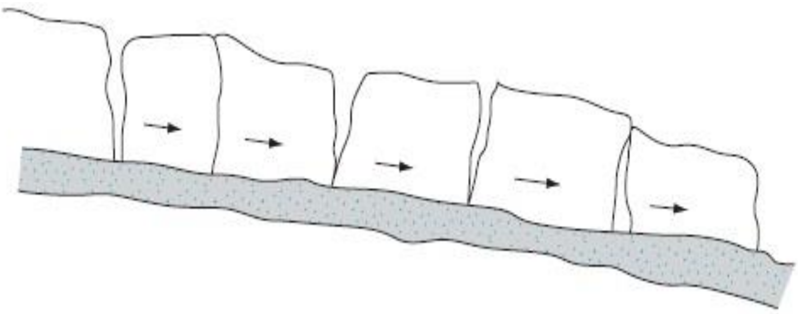

Figure 2.16 Slope failure by lateral "spreading".
Source: Braja M. Das (2009).

This type of failure is by translation. It caused by sudden movement of water bearing seams of sands or silts overlay by clays or loaded by fills. Figure 2.16 shows slope failure by lateral spreading.

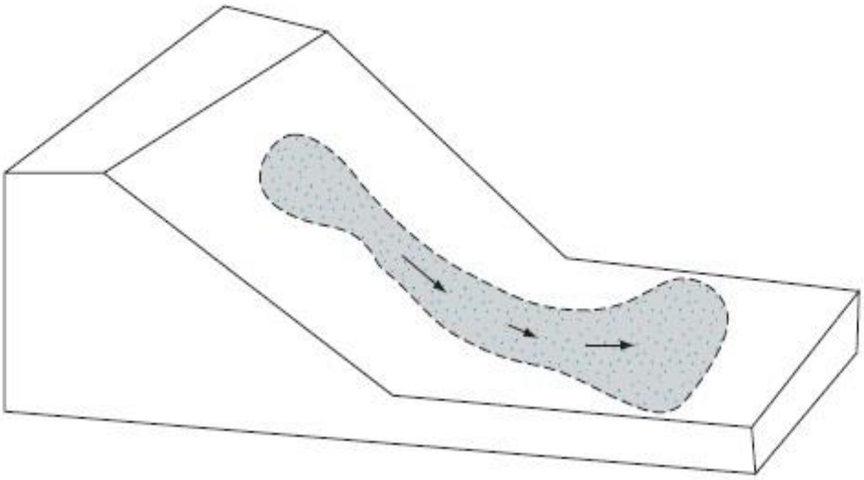

Figure 2.17 "Flow" type slope failure.
Source: Braja M. Das (2009).

Soil mass will move downward and flow like a viscous fluid. Figure 2.17 shows the flow type of slope failure.

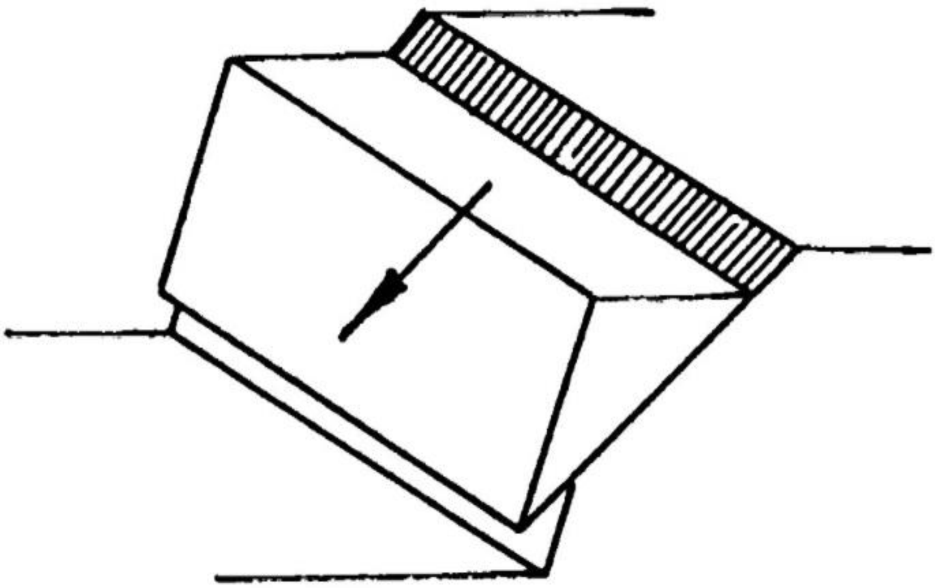

Figure 2.18 “Plane” type soil failure.

Source: Braja M. Das (2009).

TYPE OF MOVEMENT		TYPE OF MATERIAL		
		BEDROCK	ENGINEERING SOILS	
			Predominantly coarse	Predominantly fine
FALLS		Rock fall	Debris fall	Earth fall
TOPPLES		Rock topple	Debris topple	Earth topple
SLIDES	ROTATIONAL	Rock slide	Debris slide	Earth slide
	TRANSLATIONAL			
LATERAL SPREADS		Rock spread	Debris spread	Earth spread
FLOWS		Rock flow	Debris flow	Earth flow
		(deep creep)	(soil creep)	
COMPLEX		Combination of two or more principal types of movement		

Figure 2.19 Types of landslide. Abbreviated version of Vernes’ classification of slope movements.

Source: Vernes (1978)

This failure resulted by structural discontinuities like interface between weathered rock. This failure can lead to sliding action along the failure surface. Then, planar failure occurs (Anand Paul, 2016). Figure 2.18 shows plane type soil failure.

2.4 Cases of slope failure in Malaysia

2.4.1 Landslide in Bukit Nanas Forest Reserve, Kuala Lumpur, Malaysia

There was a landslide that occurred on 7 May 2013, at north side of Bukit Nanas Forest Reserve opposite the Dang Wangi LRT station. Nine cars parked at the car parks near the forest along Jalan Ampang, which is believed have buried during tragedy. There is no casualties and injuries happened during the tragedy. The length of the landslide is measured to be about 150 meters at the toe of the slope. The height is measured to be about 30 meters high. The landslide happened due to increase of groundwater level after prolong and heavy rainfall. Frequency and intensity of the rainfall also increase and can cause the high rate of infiltration. High rate of infiltration can reduce the suction of the soil and resulting low strength of the soil. The failure occurred at the loses top soil layer which had encountered grade 4 to grade 6 of weathering process. The weathered soil contained weak bedding planes and foliation surface which are prominent discontinuities that control the landslides. The strength of this type of soil will be reduced by the presence of water (Kasim, Norhidayu & Osman, Khadijah & Anuar Mohd Yusof, Mohd., 2014).

Figure 2.20 Landslide in Bukit Nanas.
Source: Kasim et al (2014).

2.4.2 Landslide of Highland Towers

A landslide occurred causing the collapse of Highland Towers in Kuala Lumpur, Malaysia. It also caused in 48th death according to report. One major cause of the tragedy was improper soil testing. The peripheral of site came about undermining. Another contributing factor was failure of the retaining walls under heavy rains and causing a landslide and affect the building. Inadequate retaining wall to contain the site and the building lie on it also cause this tragedy. There were also design errors and improper soil's bearing test (Kazmi et al, 2017).

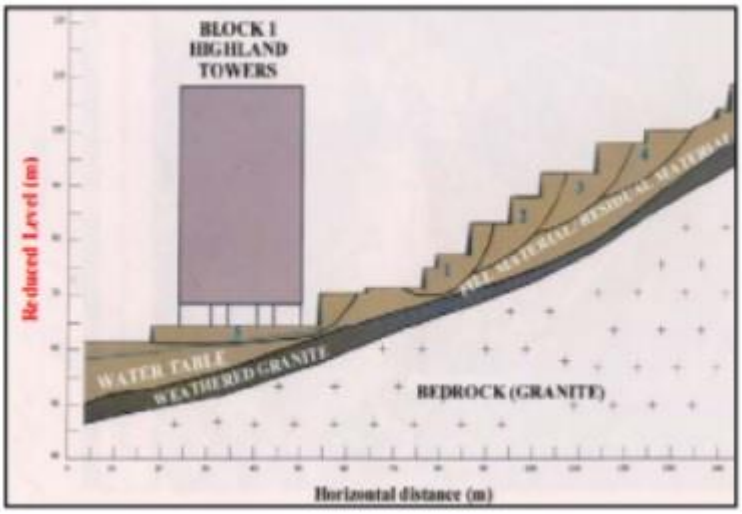

Figure 2.21 Sequence of retrogressive landslides
Source: Jamie (1993).

Figure 2.22 Highland Towers after collapse.
Source: Jamie (1993).

Figure 2.23 Highland Towers during collapse.
Source: Jamie (1993).

2.5 Current practice / method to ensure stability of slope

2.5.1 Retaining wall

Retaining walls are the walls that are designed to retain or hold in place a large amount of soil. Retaining walls are mainly used to expand the usable of the level are of property in residential applications. However, it also used to stabilize the slopes surrounding a structure such as road or buildings. For example, if buildings that is built on a hillside or having steep slopes surrounding the buildings or any other side of it, then build a retaining walls can help improve the stability of the slopes. Retaining wall designs vary depending on various factors (Sinai Construction., 2012).

There are several types of retaining walls depending on how they work to oppose the lateral pressure of the soil they are holding back. The most common are gravity walls, anchor walls, sheet piled walls, and cantilever walls. Figure 2.23 shows various type of retaining wall and its mechanism of force and how it works to support a slope.

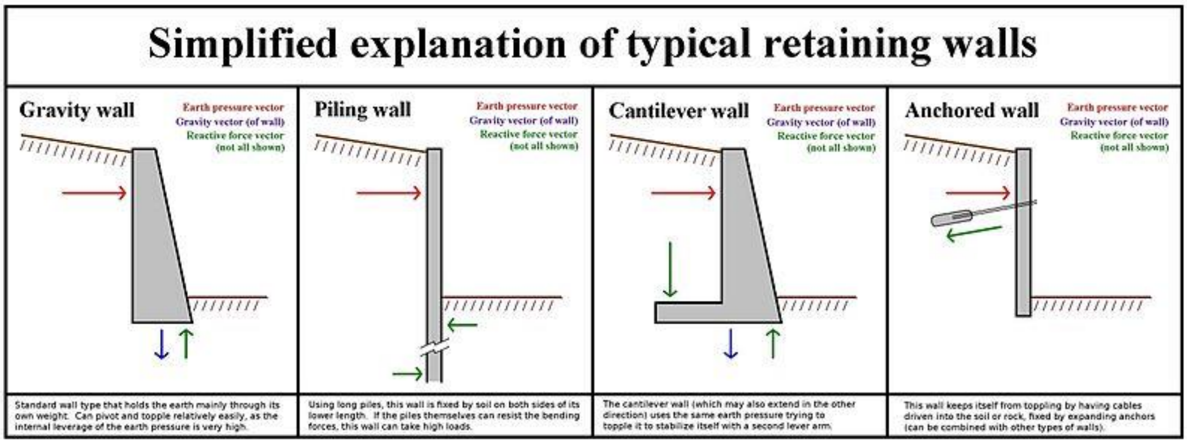

Figure 2.24 Various type of retaining wall with explaination how it works.
Source: Braja M. Das (2009).

2.5.1.1 Gravity Wall

This type of retaining wall uses only the force of gravity acting on its own mass that is, its weight to hold back the soil. This is one of the more common types of retaining walls, a gravity wall is only as effective as its own weight. Should the lateral pressure from the soil and water exceed the gravity wall’s weight, it will fail (Sinai Construction., 2012). Figure 2.24 shows various type of gravity wall.

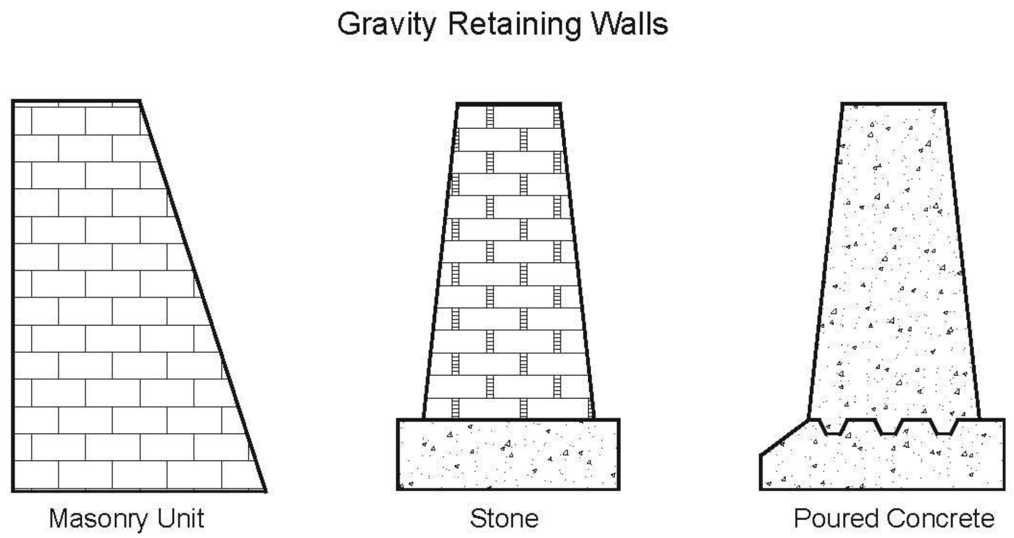

Figure 2.25 Type of gravity wall
Source: Amber (2010).

2.5.1.2 Cantilever Wall

A cantilever wall uses the weight of the soil in conjunction with its own weight to counter lateral pressure. Imagine an L-shaped concrete structure or an inverse T-shaped concrete structure. In either case, there's soil resting on top of the horizontal leg of the wall. Thus, the weight of the soil itself stabilizes the wall (Sinai Construction., 2012).

2.5.1.3 Anchor Walls

Anchor walls utilize anchors and cables to secure (affix) the wall to stable earth some distance into the slope. Like a cantilever wall, an anchor wall also makes use of the soil to stabilize itself (Sinai Construction., 2012). Figure 2.25 shows an example of anchored well in 3-dimensional sketch.

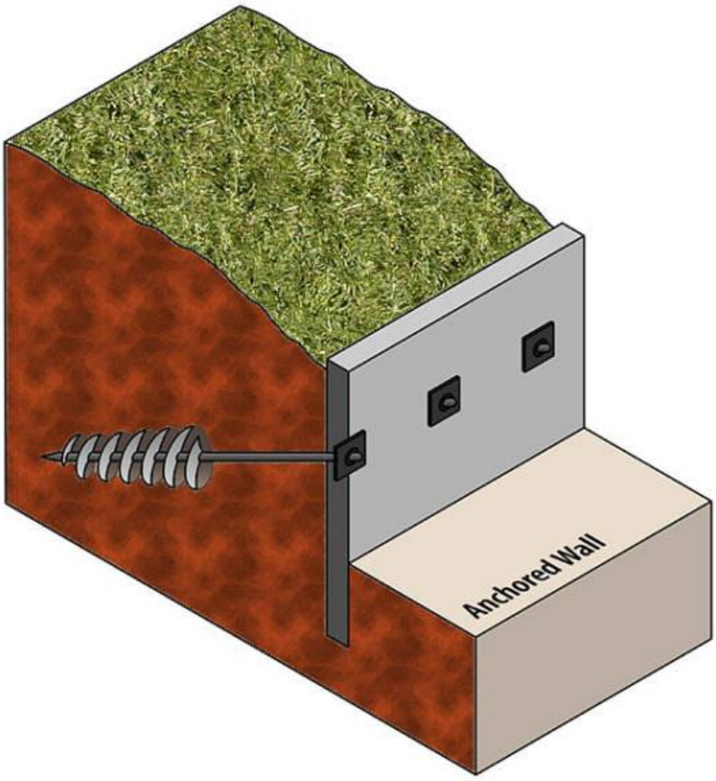

Figure 2.26 3 dimensional sketch of anchored wall.
Source: Paul (2016)

2.5.1.4 Sheet Piling

Sheet piles are often used as temporary retaining walls. In this type of retaining wall, steel, wood or vinyl planks are driven into the ground. This kind of slope stabilization technique also utilized in projects involving soft soils and regions where there is not much space for repair equipment manoeuvring. Sheet piles can be made of wood planks, vinyl or steel. They are normally driven 2/3 of their length into the ground and installed in such a way that the sheets overlain. If the aboveground height of the sheet piles surpasses the usual measure, anchors are utilized to tie the sheet pile faces to load bearing soil (Sinai Construction, 2012). Figure 2.17 shows application of sheet pile retaining wall at the slope.

Figuire 2.27 Sheet pile retaining wall.
Source: Kingsman (2017).

2.5.1.5 Drainage

Excessive water on a slope can cause slope to loss it strength. Excessive water can destabilize a slope, may cause sudden movement of soil, and can cause landslide. A rapid increase or decrease of water in slopes can cause a sudden soil movement. Water runoff in slopes can increase erosion. Besides, it exerts pressure that supporting structures may cannot handle the pressure. This can overcome by install drainage system in slopes. The planned drainage system must be able to efficiently channel water away from the slope without affecting slope stability or causing erosion (Sinai Construction, 2012).

2.6 Waste tyres

Amount of stockpiling of waste tyre have been increasing every year due to the increasing number of cars on roads. Tires that are just discarded are a serious environmental problem. The sheer volume of tires discarded each year almost 300 million tires in the United States alone makes safe disposal troublesome (Marc Lallanilla., 2017). Based on 2010 report by the European Tyre and Rubber Manufacturer's Association, 1.4 billion tyres have been sold worldwide each year. The life of tyres can be extended through retreading or regrooving but eventually and they will end up become scraps (Yeow, G. , 2011). Discarded tires are an ideal breeding ground for mosquitoes and other disease-carrying animals because their hollow, rounded shape holds water for a long period. When disposed in a tire stockpile, used tires are frequently burned outdoors, which makes an ugly black smoke that contains harmful compounds. Tires are also an issue in landfills: Their hollow, rounded shape takes more space in landfills. Also, tires frequently don't stayed buried they have the unfortunate habit of trapping gases like methane and then "bubbling up" through landfills (Marc Lallanilla., 2017). There are many waste tyre recycling technologies but each has its advantages and disadvantages. Because of that, finding an efficient waste tyre recycling technologies is troublesome because of its composition. Its composition is rubber, carbon black, steel and some additives. It causes waste tyres are hard to breakdown and separate, which makes reprocessing hugely challenging. Hence, efficient method to recycle waste tyres is needed (Itziar Iraola Arregui, 2016). Figure 2.27 shows stockpiling of waste tyres at the landfill in 2014. Jim (2014) said that 90% of tyre waste have been gone due to ground rubber become roadways, playground equipment and auto floor mats. This prove that some country trying to reduce stockpile of tyre and the have succeed. This can encourage other country to reduce, reuse and recycle waste tyres.

Figuire 2.28 Colorado’s tyres mountain at landfill.

Source: Jim (2014).

2.7 Tyres recycling activities

There are many recycling activities have been implemented in and outside of the country. Each waste tyres recycling method have its advantages and disadvantages. One of the waste tyres recycling method have been practiced is devulcanisation. When devulcanisation is implemented, it will breaks the bonds that hold the individual polymer chains together and create a network. Devulcanisation will convert waste tyres into smaller fragments that can be mixed, processed and vulcanised again. Beside that, there also grinding recycle method. This method involve on reducing waste tyres to a fine grains, crumb like substance. These fine grains can be blended and used as a filter in plastics or any other applications that is need fine grains. There are also have new trend focused on using these materials as sound absorber. The disadvantage of this methods is that it need very high temperatures and caused end product being downgrade. This advantage can be overcome if temperatures are controlled but this only can be done by using large quantities of liquid nitrogen that, in turn, increase the cost of the process (Itziar Iraola Arregui, 2016). Next is pyrolysis. Pyrolysis has been known as an attractive thermochemical process to overcome the waste tyre disposal difficulty while allowing energy recovery (Juan Daniel Martinez et al, 2013). Pyrolysis consist of burning the material at high temperatures in an atmosphere free of air to obtain gas, an oil and a solid. Pyrolysis will separate carbon black from tyres and the volatile matter that is released has potential of renewable energy recovery based on significant proportion of natural rubber present in tyres (Juan Daniel Martinez et al, 2013). This process also creates various forms of toxins and carbon dioxide which are harmful to the environment (Yeow, G. ,2011, February 01).

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter explains about the procedure to accomplish the objectives of this study. It also showed what are needed to be done accordingly to the plan to complete this study. It started from laboratory test on the material that were used as material to make gabion wall to determine the basic properties. Basic properties test that were conducted includes sieve analysis, particle density test, specific gravity test (gravel and tyre chips), standard proctor test and constant head permeability test. Then, follow by preparation of material that were used to simulate the rainfall and to build slope model. Next, slope model was developed and finally, the necessary experiments were executed.

3.2 Research flow chart

This subtopic showed the flow chart to symbolize the flow of this research.

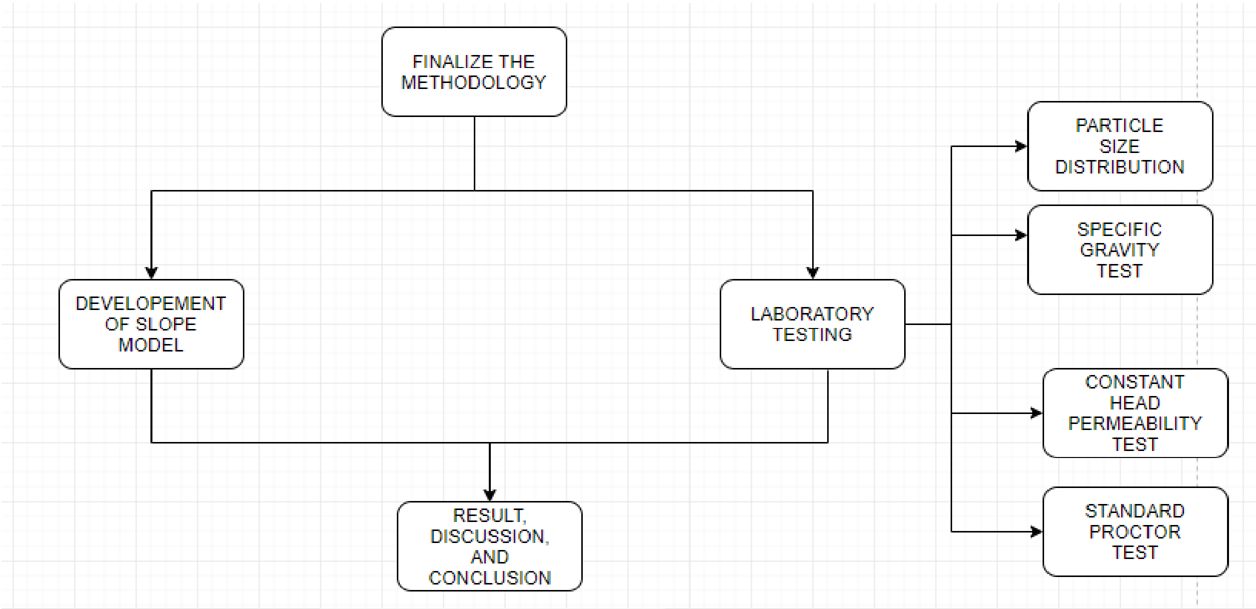

Figure 3.1 Flow chart of this research.

3.3 Laboratory test (sand, gravel, tyres)

Sand, gravel, and tyres must be tested beforehand. Gravel and tyres must be tested first because these material were needed to make the gabion walls. The properties of gravel and tyres that were used, might affected the strength of the gabion walls.

Table 3.1 Laboratory test that is required for sand to obtain the basic properties.

Test	Description
Sieve analysis	To obtain the particle size distribution
Falling Head Permeability test	To obtain the permeability of the soil
Specific Gravity Test	To determine specific gravity of the soils.
Standard Proctor Test	To determine dry unit weight and optimum water content

Table 3.2 Laboratory test that is required for gravel to obtain the basic properties.

Test	Description
Sieve analysis	To obtain the particle size distribution
Falling Head Permeability test	To obtain the permeability of the soil
Specific Gravity Test	To determine specific gravity of the soils.
Standard Proctor Test	To determine dry unit weight and optimum water content

Table 3.3 Laboratory test that is required for tyre chips to obtain the basic properties.

Test	Description
Sieve analysis	To obtain the particle size distribution
Falling Head Permeability test	To obtain the permeability of the soil
Specific Gravity Test	To determine specific gravity of the soils.
Standard Proctor Test	To determine dry unit weight and optimum water content

Table 3.4 Laboratory test that is required for gravel and tyre chips (80%, 60%, 50%, 20%) to obtain the basic properties.

Test	Description
Falling Head Permeability test	To obtain the permeability of the soil
Specific Gravity Test	To determine specific gravity of the soils.
Standard Proctor Test	To determine dry unit weight and optimum water content

3.4 Preparation of materials

Some materials need to be prepared in advanced before the developement of the slope model. Gabion walls were prepared first. Since gabion walls were made of gravels and tyres chips, the tyre chips need to be prepare first. Tyres was cut and shreded into smaller pieces to produce the tyre chips. Next, gabion cages were assemble into a box shape to filled it with gabion walls material and tied it. The cage is made from wire mesh. The dimension of the gabion wall also have been scaled according to real size gabion that currently been used. Besides, a container was prepared to develope the slope model in it. The container is clear and visible to observe the test from outside. Moreover, a rain projecter was constructed to simulate rainfall. Rainfall intensity 570mm/hour has been used according to the Malaysia’s highest rainfall intensity data obtained.

3.5 Development of slope model

The slope model was built in critical dimension to ensure the slope stability is only depend on the gabion wall. It is also to simulate a slope that is nearly fail which have lowest factor of safety but not less than 1. Various slope angle have been tested to finding the critical dimension of slope for this type of soil.The critical dimension that have been obtain is 60° was used to develope a critical stability slope model. Next, the slope model was built in a container and gabion walls stacked in vertically. The equipment for measuring the displcaement of gabion wall was installed.

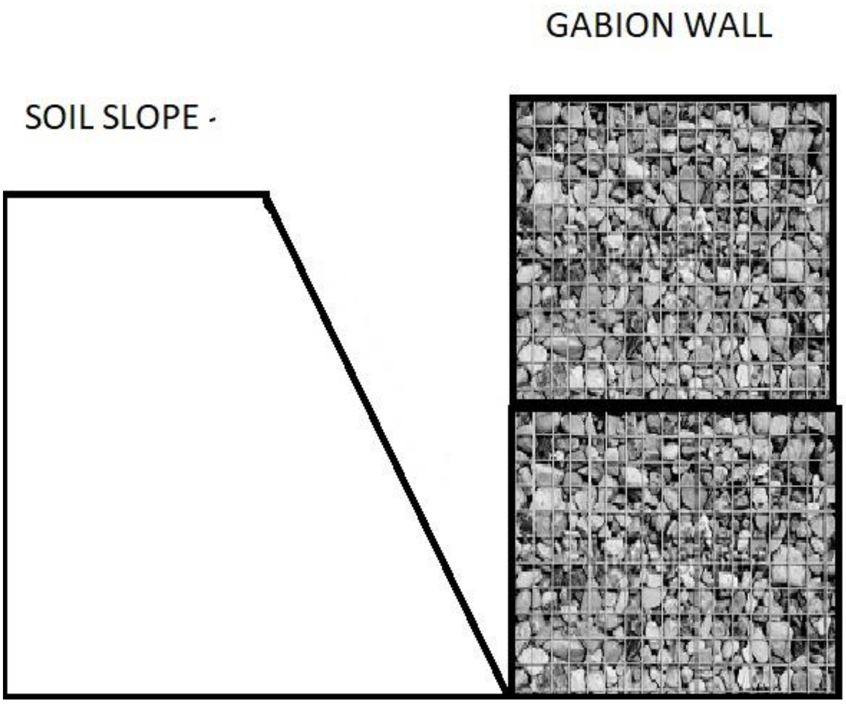

Figure 3.2 Arrangement of gabion wall at the slope model.

Figure 3.3 Apparatus setup

Figure 3.4 Digital transducer was used to measure the movement of gabion wall

Figure 3.5 Output of readout Device

3.6 Testing process

Slope was built according to critical dimension that is obtained. After all apparatus has been installed, artificial rainfall intensity at 570mm/hour was simulated. The displacement of gabion wall was detected by the equipment. Time of rainfall and displacement of gabion walls reading were recorded. The slope was subjected to rainfall for 5 minutes. After 5 minutes, slope is rebuilt to test the next gabion walls.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter show the result obtained for this study. Results that is need to obtain based on the objective declared. Physical properties of material that were used to construct the slope model were being test in advanced. Specific gravity test, Constant Head Test, Standard Proctor Test and Sieve Analysis results obtained. Then, the slope model was tested under artificial rainfall. The value of displacement of the gabion wall and time of the rainfall was recorded.

4.2 Sieve Analysis Test

By conducting sieve analysis test, specific particle size distribution curve can be obtained. The particle size distribution curve is used to determine the following parameters for a soil that have been tested.

First parameter is Effective size (D_{10}). This parameter can show the diameter in the particle size distribution curve corresponding to 10% finer. The effective size of a granular soil is a good measure to estimate the hydraulic conductivity and drainage through soil.

Second is Uniformity coefficient (C_u). This parameter is defined as equation 4.1.

$$C_u = D_{60} / D_{10} \qquad 4.1$$

$$C_c=(D_{30})^2/(D_{60} \times D_{10}) \qquad 4.2$$

Where D_{60} is diameter corresponding to 60% finer. Soils with $C_u \leq 4$ are considered to be "poorly graded" or uniform. Soils with $C_u > 4$ are consider to be well graded.

Third is Coefficient of gradation (C_c): This parameter is defined as equation 4.2. For well−graded soils, $C_c \sim 1$.

To interpret curve of particle size distribution, equation 4.1 and equation 4.2 were used. The coefficient of uniformity, C_u of sand is 2.35 and coefficient of gradation, C_c is 1.15. For gravel, it's have the value of the uniformity coefficient, C_u is 1.07 and coefficient of gradation, C_c is 1.00 and the value of the uniformity coefficient, C_c for tyre chips is 0.99 and coefficient of gradation, C_c is 1.40.

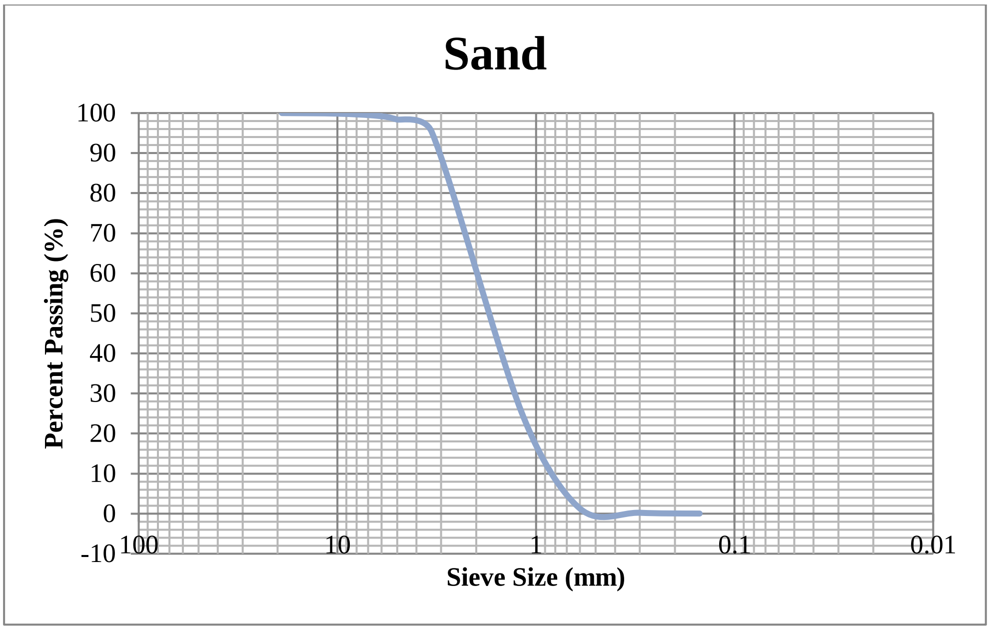

Figure 4.1 Particle Size Distribution Curve of Sand.

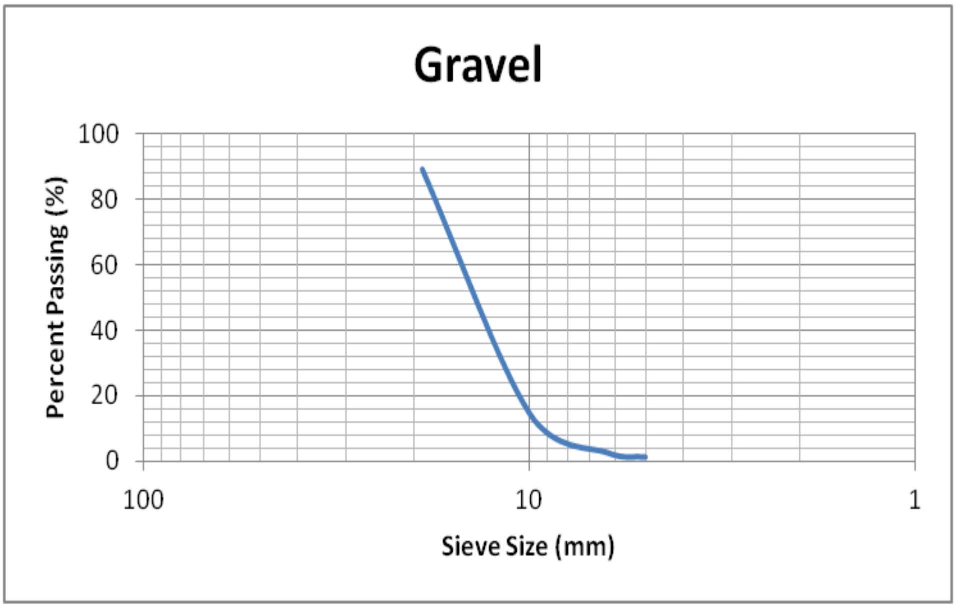

Figure 4.2 Particle Size Distribution Curve of gravel.

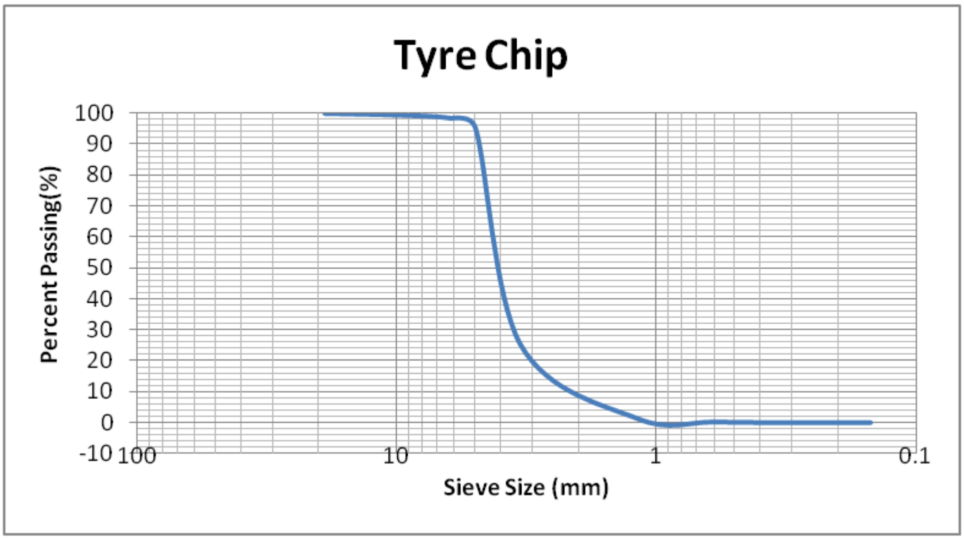

Figure 4.3 Particle Size Distribution Curve of tyre chips.

4.3 Specific Gravity Test

Specific gravity is the ratio of the unit weight of a given material to the unit weight of water. The specific gravity of soil solids is often needed for various calculations in soil mechanics. It can be determined accurately in the laboratory. Most of the soil specific gravity values fall within a range of 2.6 to 2.9. The specific gravity of solids of light-coloured sand, which is mostly made of quartz, may be estimated to be about 2.65; for clayey and silty soils, it may vary from 2.6 to 2.9.

Seven sample were used for this test and the samples had seven different percentages of tyre chips. Each specific gravity obtained from equation 4.3. Table 4.1 shows summary of specific gravity for each mixture.

$$Gs = \frac{A}{A-(C-D-B)} \tag{4.3}$$

Table 4.1 Specific gravity of each mixture sample.

Gravel (%)	Tyre Chip (%)	Specific Gravity
100	0	2.17
80	20	2.01
60	40	1.76
50	50	1.58
40	60	1.34
20	80	1.13
0	100	0.96

Table 4.1 shows the specific gravity of mixed gravel and tyre chip. The specific gravity is found to be decreased when percentage of gravel decreased.

The specific gravity of sand by pycnometer method is calculated by using equation 4.3.

$$Gs = \frac{W2-W1}{(W4-W1)-(W3-W2)} \qquad 4.3$$

Table 4.2 Specific gravity for sand.

Test No.	Unit	1	2	3
Mass of density bottle	g	26.88	27.19	31.28
Mass of bottle + stopper (w1)	g	31.95	32.18	36.31
Mass of bottle + stopper + dry soil (w2)	g	41.95	42.18	46.31
Mass of bottle + stopper + soil + water (w3)	g	146.54	145.89	149.62
Mass of bottle + stopper + water (w4)	g	132.33	131.71	135.58
Mass of dry soil (w2-w1)	g	10.01	10.01	10.01
Mass of water (w4-w1)	g	100.38	99.53	99.28
Mass of soil + water (w3-w2)	g	104.59	103.71	103.32
Specific gravity		2.38	2.39	2.48
Average specific gravity			2.41	

To determine the specific gravity for coarse grain like gravel, different test and apparatus was used. The result of specific gravity for seven samples with different percentage of mixture gravel and tyre chips obtained from specific gravity test is tabulated in Table 4.4. Each specific gravity can be determined by using equation 4.4. Table 4.3 shows the description of symbols used in equation 4.4.

Table 4.3 Table of description of sample

No	Description
A	Weight of Sample
B	Weight of Bowl + Lid + Water
C	Weight of Sample + Bowl + Water + Lid
D	Weight of Cage

Table 4.4 Table of weight of percentage gravel and tyre chips sample

	Weight (kg)						
No	100:0	80:20	60:40	50:50	40:60	20:80	0:100
A	0.659	0.532	0.543	0.514	0.544	0.355	0.206
B	14.880	14.880	14.880	14.880	14.880	14.880	14.880
C	15.400	15.310	15.280	15.230	15.180	15.080	15.030
D	0.162	0.162	0.162	0.162	0.162	0.162	0.162

$$Gs = \frac{A}{A-(C-D-B)} \qquad 4.4$$

4.4 Standard Proctor Test

Mixture of gravel and tyre chips were tested for its compaction properties. Several combination of gravel and tyre chips were used. The percentage combination used in this research are as follows: 100% gravel, 80% gravel, 60% gravel, 50% gravel, 40% gravel, 20% gravel and 100% tyre chips. Besides that, standard proctor test was also conducted on purely sand sample. Results of the standard proctor test conducted on sand is presented in the following paragraphs.

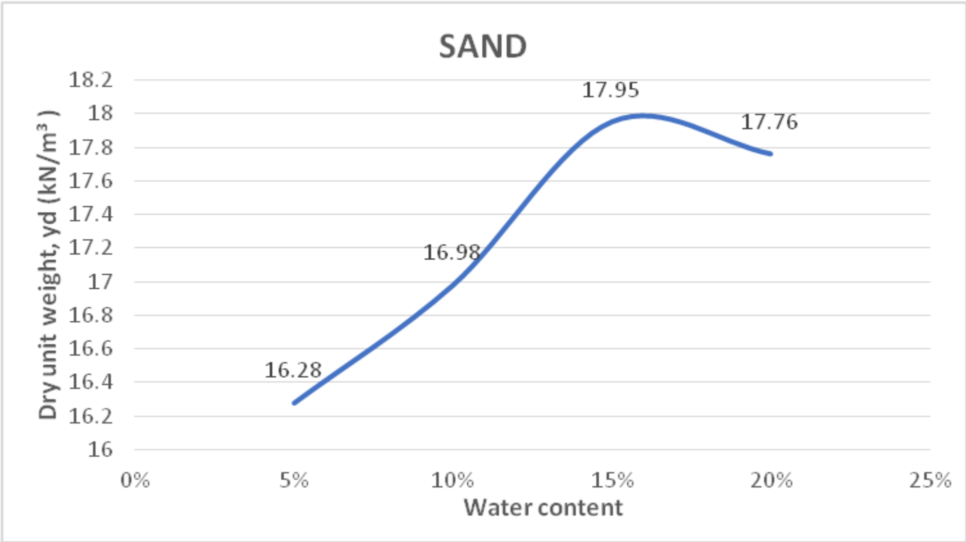

Figure 4.4 Compaction curve for sand.

From Figure 4.4, the optimum water content and the maximum dry unit weight of sand can be obtained. Optimum Moisture Content for sand is found to be 15% and its Maximum Dry Unit Weight is 17.95 kN/m^3.

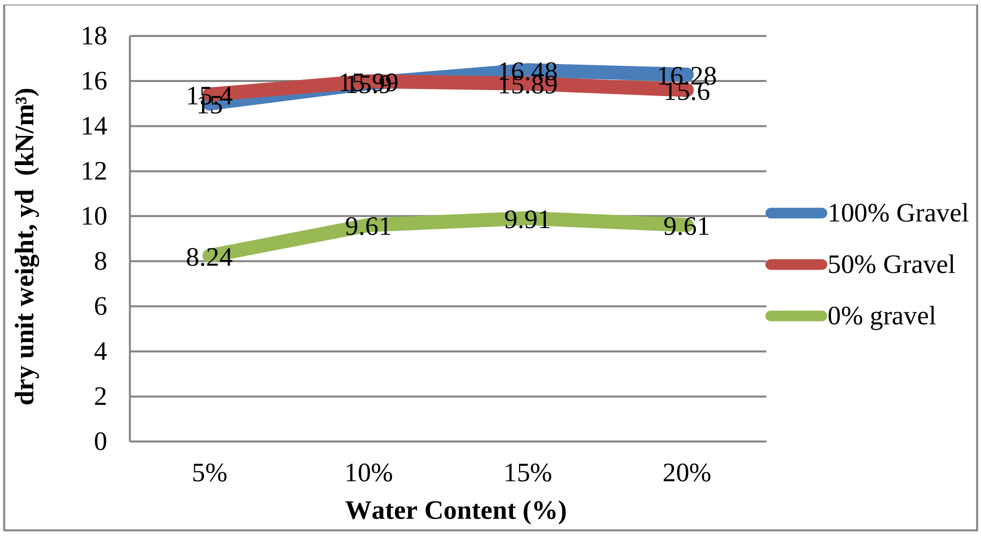

Figure 4.5 Compaction curve for gravel and tyre chips mixtures.

Table 4.5 Standard Proctor Test Results of each mixture sample

Parameter	100% gravel	50% gravel	0% gravel
Optimum Water Content, %	15	10	15
Maximum dry unit weight, (kN/m³)	16.48	15.99	9.91

Table 4.5 presents the result of Standard Proctor Test of each mixtures. The optimum water content for 100% and 0% gravel is found at 15%. However, for 10% gravel the optimum water content is at 10%.

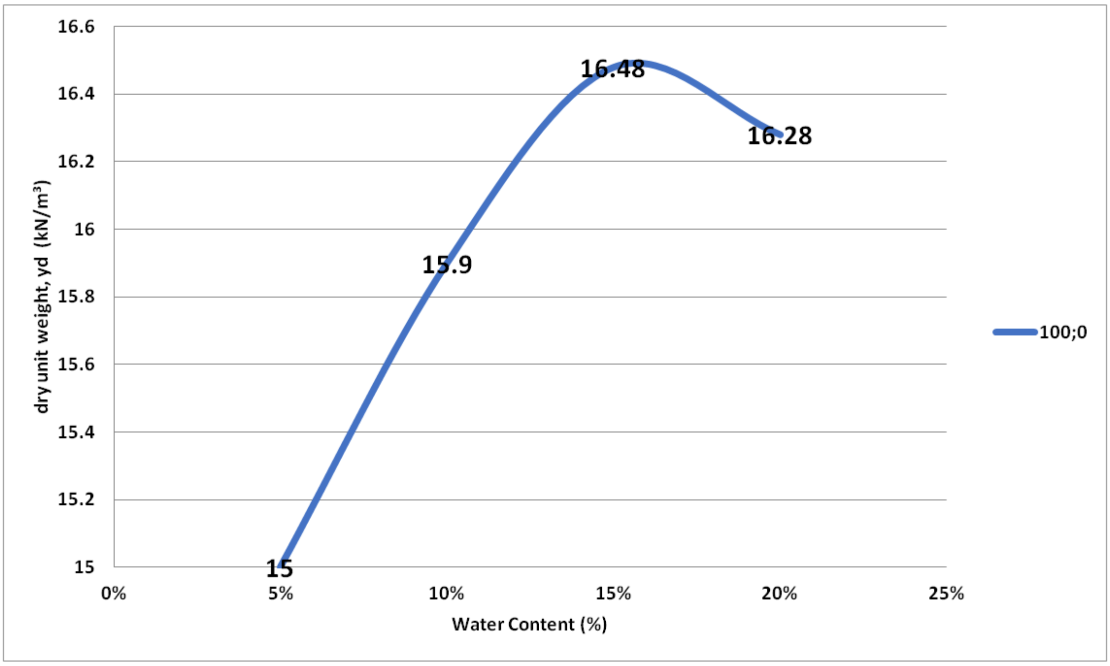

Figure 4.6 Compaction curve of 100% gravel and 0% tyre chips sample

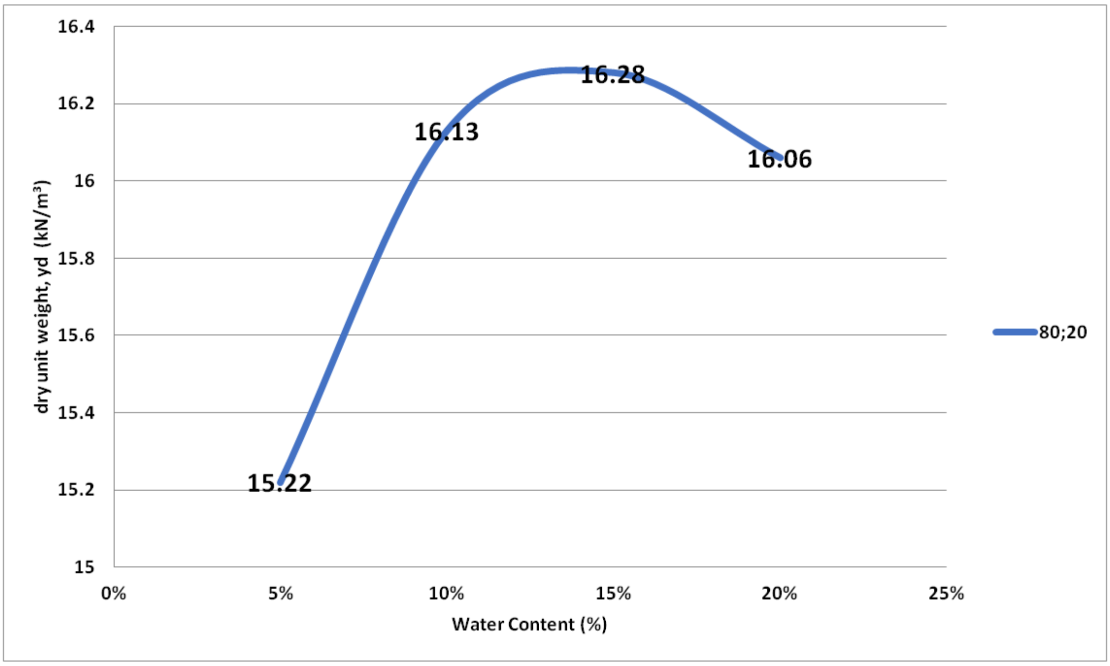

Figure 4.7 Compaction curve of 80% gravel and 20% tyre chips sample

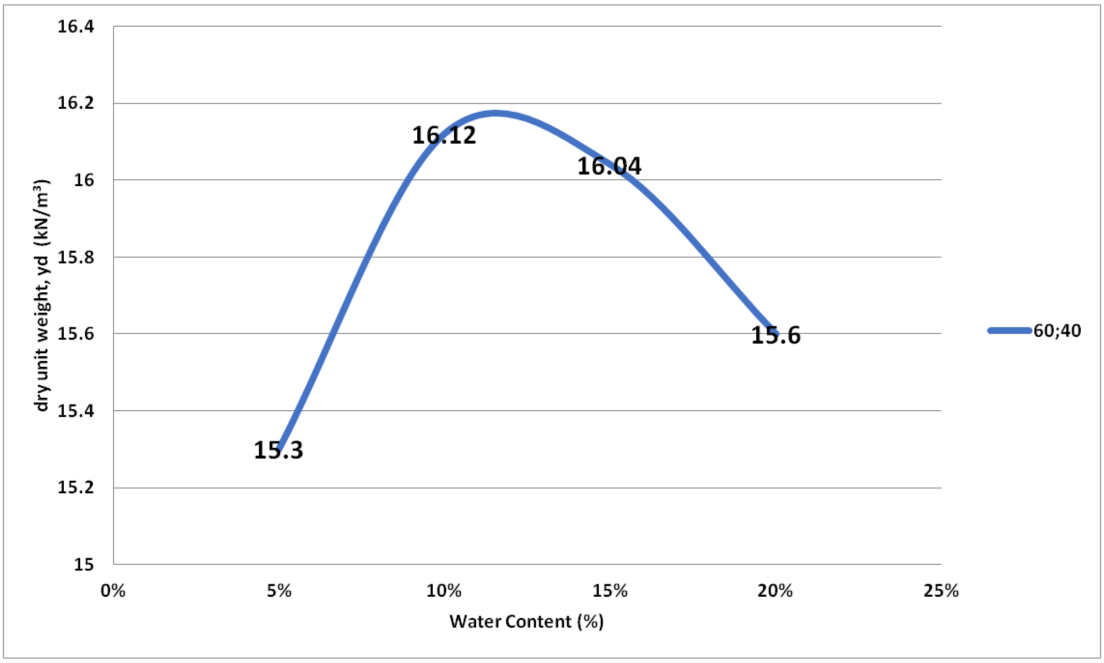

Figure 4.8 Compaction curve of 60% gravel and 40% tyre chips sample

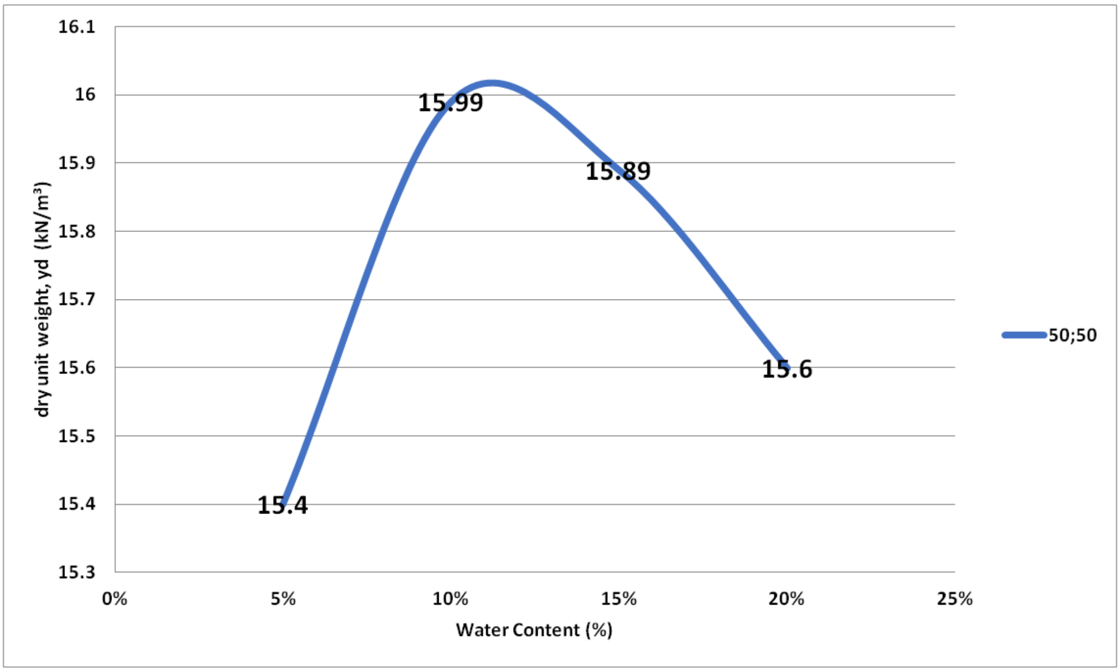

Figure 4.9 Compaction curve of 50% gravel and 50% tyre chips sample

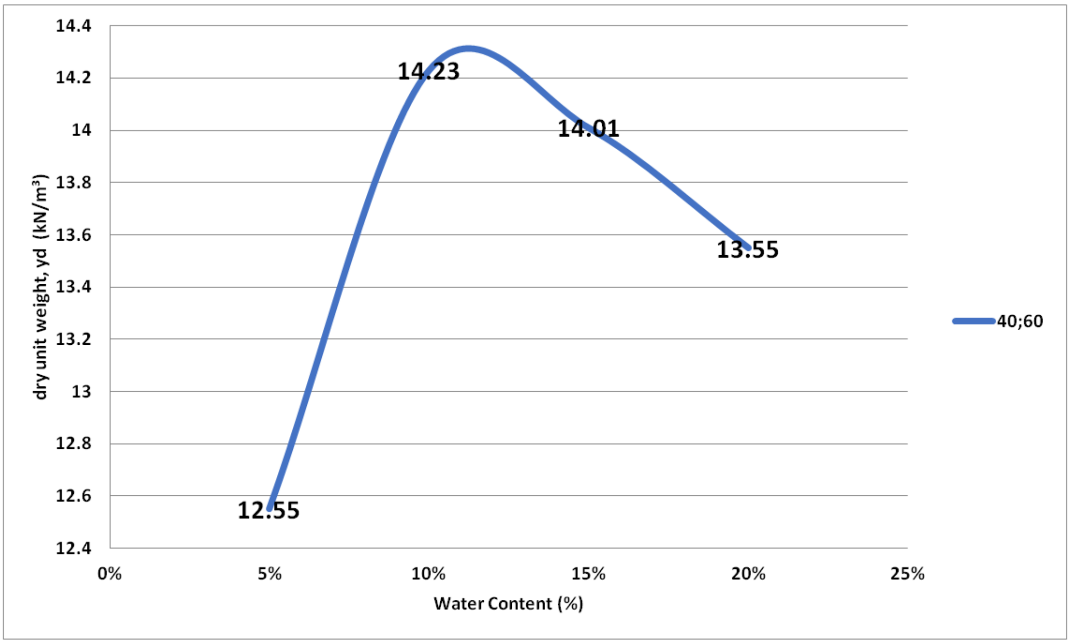

Figure 4.10 Compaction curve of 40% gravel and 60% tyre chips sample.

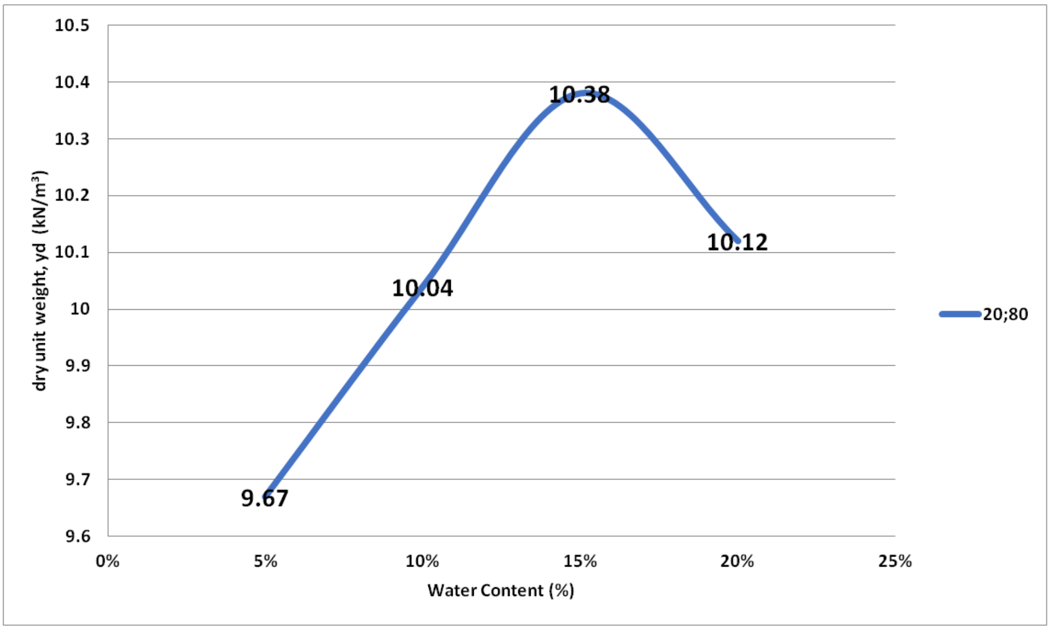

Figure 4.11 Compaction curve of 20% gravel and 80% tyre chips sample.

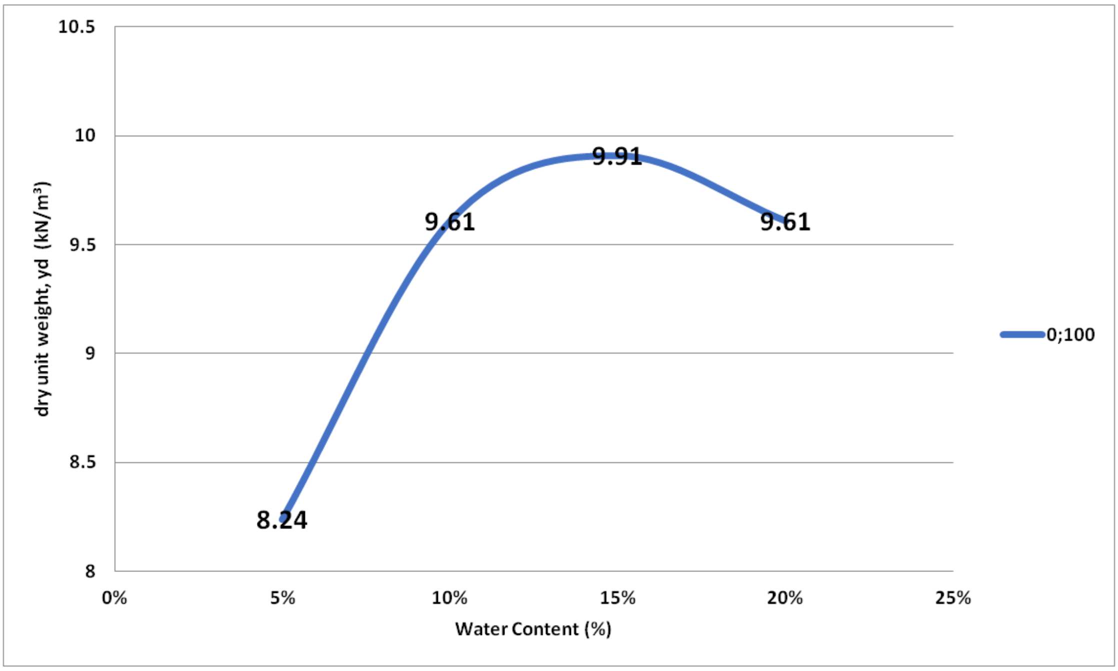

Figure 4.12 Compaction curve of 0% gravel and 100% tyre chips sample

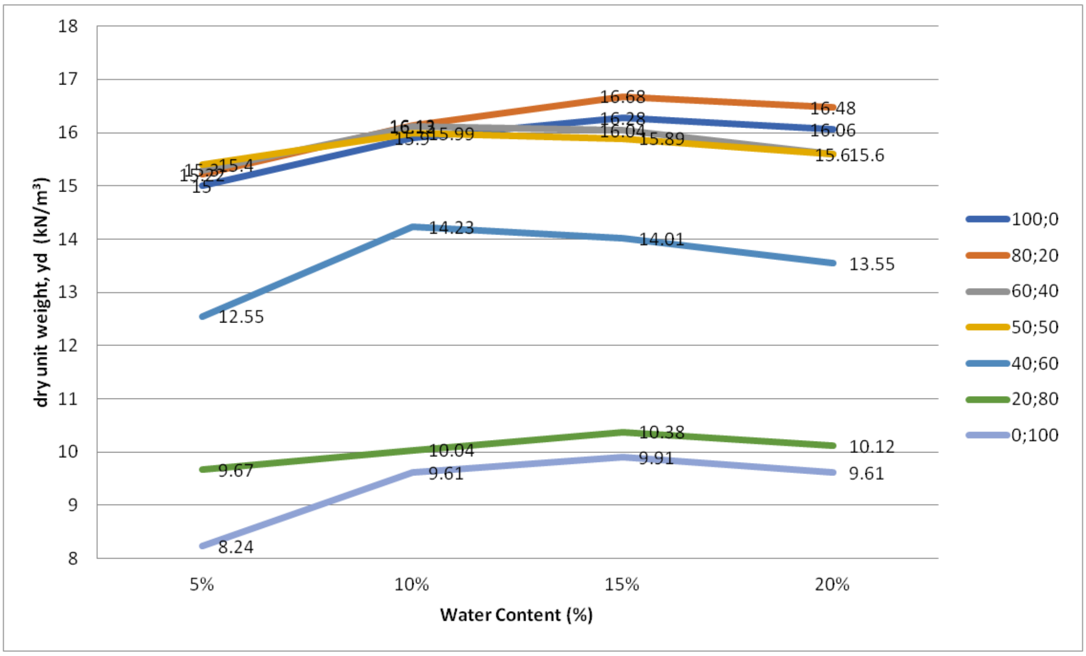

Figure 4.13 Compaction curve of all sample

4.5 Constant Head Permeability Test

Constant Head Permeability Test was conducted to determine the hydraulic conductivity of soil. The water supply at the inlet was adjusted in such way that difference of head between inlet and at the outlet remains constant during the test period. After a constant head achieved, water was collected in a graduated flask for a known duration. To determine the coefficient of permeability from data obtain during the test equation is used.

$$k = \frac{QL}{Aht} \tag{4.4}$$

Table 4.6 Shows the coefficient of permeability of each mixtures.

Gravel (%)	Tyre Chip (%)	Coefficient of Permeability, k (cm/s)
100	0	0.291
80	20	0.323
60	40	0.344
50	50	0.353
40	60	0.372
20	80	0.388
0	100	0.391

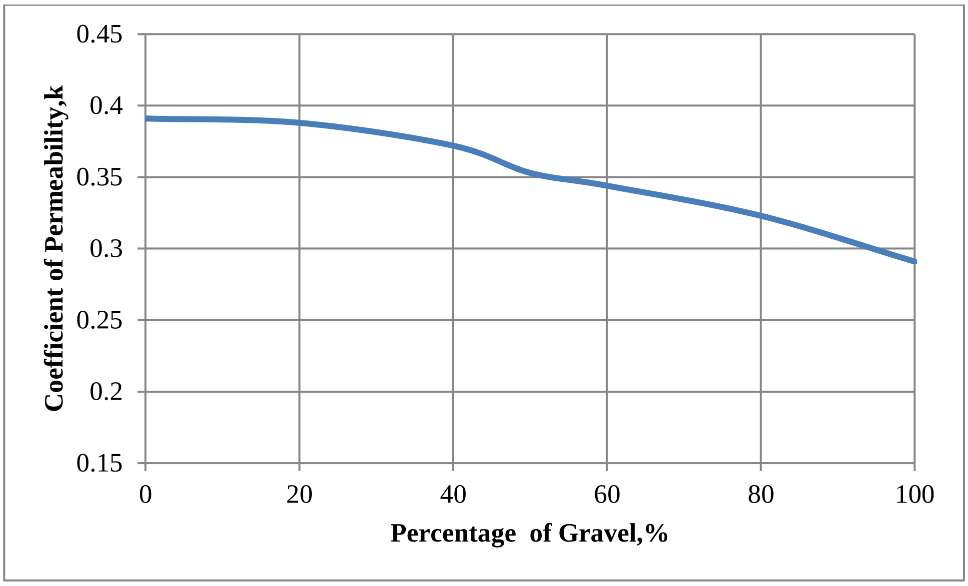

Figure 4.14 Coefficient of Permeability versus Percentage of gravel curve.

Based on coefficient of permeability curve Table 4.6, it shows that the coefficient of permeability is decreased when the percentage of gravel increased. Figure 4.14 is curve of coefficient of permeability versus percentage of gravel curve. It is based on data obtain in Table 4.6.

4.6 Model test

After preparation of material, laboratory test and preparation of apparatus for slope model testing complete, **t**here are two types of slope model that have been constructed in this study. The slope was built in a Perspex box under a sprinkler to simulate the rainfall. The first model involved the construction of slope with no retaining structure adjacent to the slope. While the other slope model was constructed with the presence of retaining wall next to the slope. To ensure the slope model same as the real situation, the real size gabion wall have been scaled down. After that, simulated rainfall was then subjected to both of the models and the movement of the wall are recorded. The slope was initially tested without the presence of gabion wall to know whether the slope's is fail or not due to the rainfall.

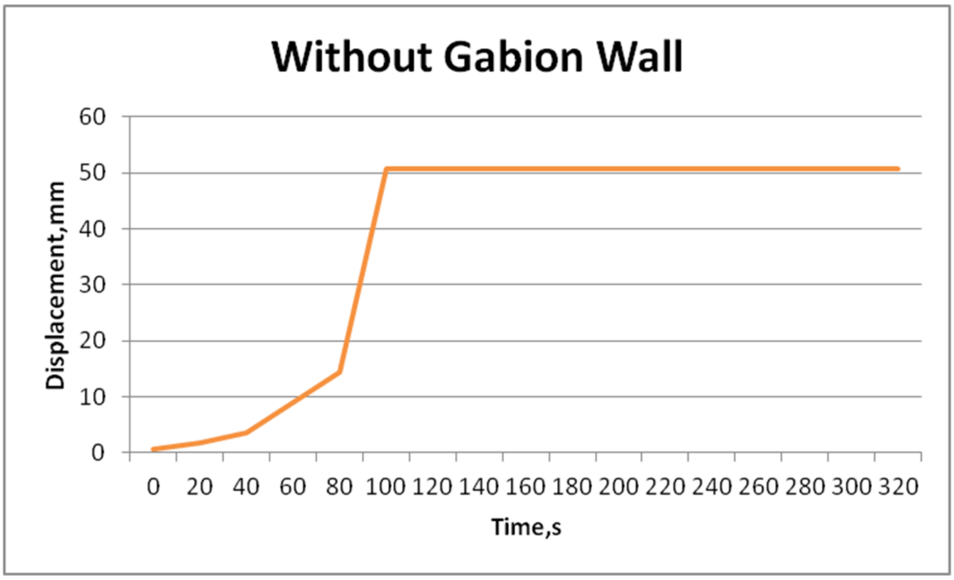

Figure 4.15 Graph of Displacement of slope without gabion wall.

Slope with 60° angle was tested and it is started to displaced after 20 seconds and the displacement was recorded as 0.78mm. The displacement of the slope continues gradually until 25.35mm at 100 seconds. The slope experienced a complete failure at 100 second. Figure 4.15 shows the variation displacement of the slope throughout the test.

Then, a critical slope at 60º slope's angle was developed again. Two layers of gabion wall was placed in front of the slope with the vertical arrangement as shown in Figure 3.2 to retain the slope from failure. The material inside the gabion was varied from gravel, tyre chips, and mixture of both with percentage of 50-50%. Based on the Figure 4.16, Figure 4.17, Figure 4.18, it is found that there is no displacement for gabion wall which supported the soil slope at all the cases. The slope collapse as shown in Figure 4.19 but the gabion wall was able to retained the soil. The same trend (no displacement of the gabion wall) also showed when 100% tyre chips gabion wall was used to support the slope at its toe.

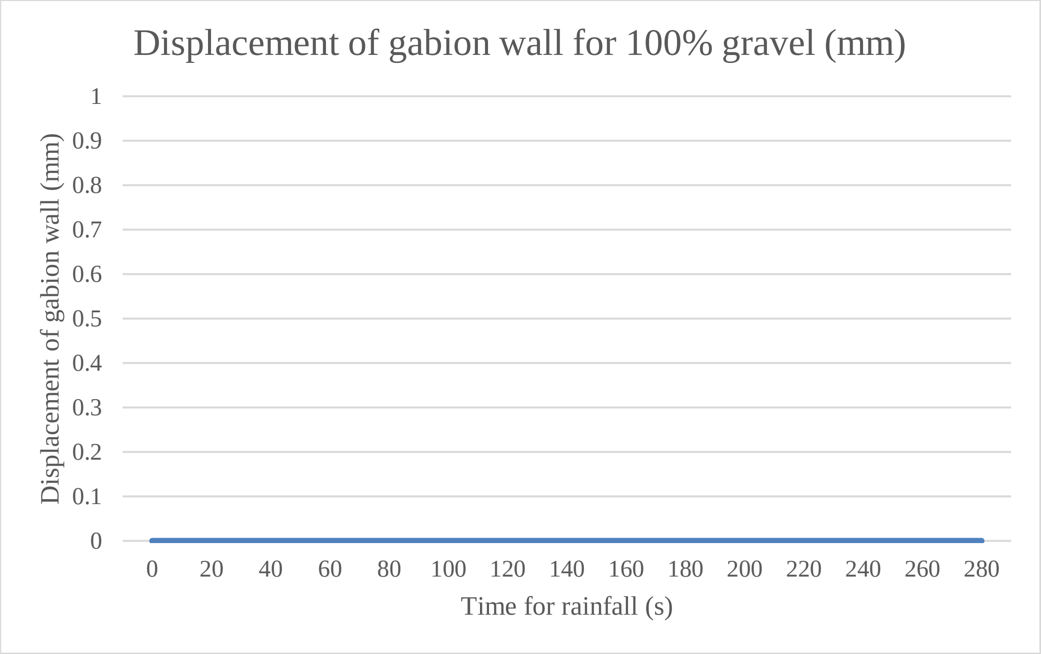

Figure 4.16 Displacement of gabion wall made of 100% gravel.

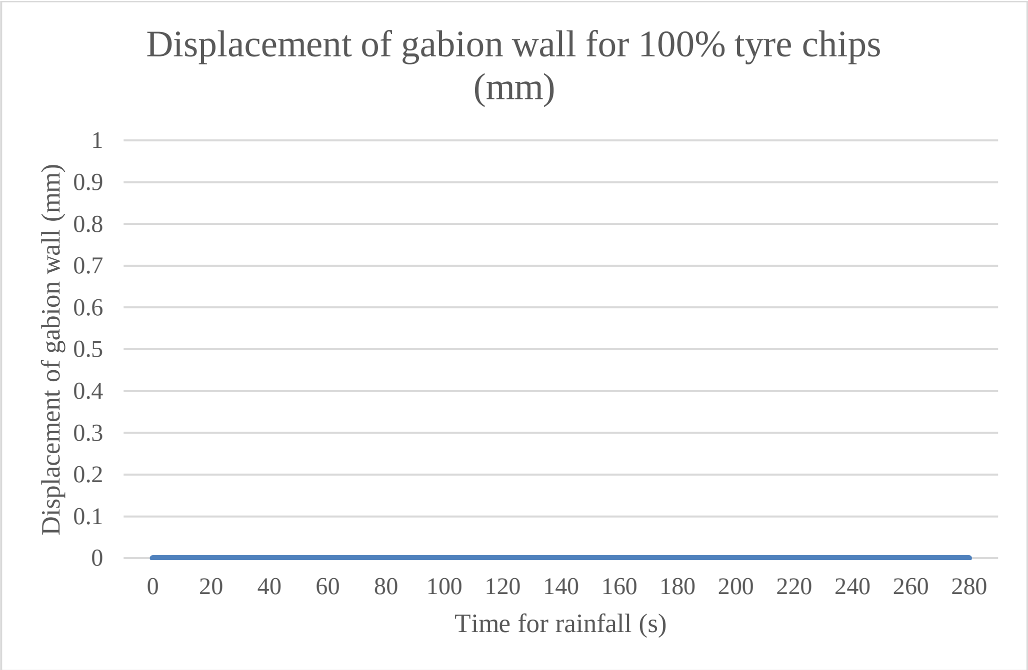

Figure 4.17 Displacement of gabion wall made of 100% tyre chips.

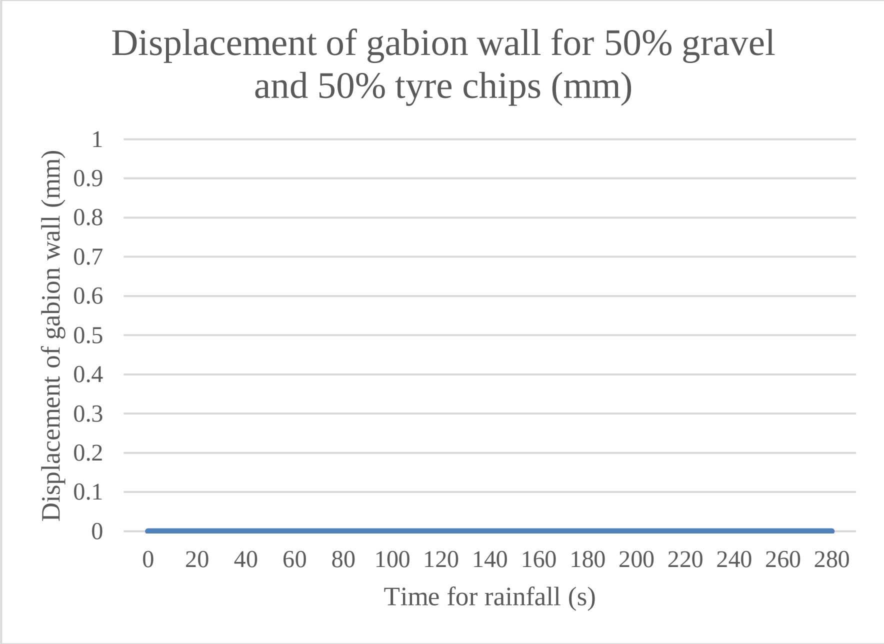

Figure 4.18 Displacement of gabion wall made of 50% gravel and 50% tyre chips.

Figure 4.19 Plan view of condition of the soil slope after subjected to rainfall.

After rainfall had stopped, the slope continues to failed but the failed soil was being retained by the gabion wall and still did not caused the gabion wall to displaced. The gravitational force of gabion wall is high and can withstand the load of the soil that is pushing the gabion wall.

CHAPTER 5

CONCLUSION

5.1 Introduction

This chapter discusses about laboratory test and model test result for achievement of the project objective. Problems regarding the stockpiling of waste tyres and slope instability leads to this research. Waste tyres are hard to decompose same as the gravel but tyres have its elasticity and have low specific gravity compare to gravel. Besides, common disaster that usually happen during monsoon season at the end of each year is slope failure. Slope failure case normally occurred after prolonged rainfall. When slope failure happened it can cause many losses and damages especially when the slope located near roads or residential area. It also caused the government to bear all maintenance cost and other costs to restore all the damages. Slope failure also have been acknowledged as one of the disaster that can lead to great losses and costs. Then, replacement of gravel with tyres products was studied and it reached its conclusion. After completing the testing and analyse the results, it is found that this study had achieved its objectives.

5.2 Conclusion

Based on the result obtained, it can be concluded that the basic properties of soil and tyre chips were succesfully determined. Several laboratory test that have been conducted which are Specific gravity test, Constant Head Test, Standard Proctor Test and Sieve Analysis. For Specific gravity test, it is found that the specific gravity value is decreases when percentage of gravel decreases while for Constant Head Test, it shows that the coefficient of permeability is decreases when the percentage of gravel increases. Moreover, in Standard Proctor Test, it is found that the optimum water content for 100% and 0% gravel is at 15%. However, for 50% gravel, the optimum water content is at 10% while for Sieve Analysis, the coefficient of uniformity, C_u of sand is 2.35 and coefficient of gradation, C_c is 1.15. For gravel, the value of the coefficient of uniformity, C_u is found to be 1.07 while coefficient of gradation, C_c is found to be 1.00. The coefficient of uniformity, C_u value for tyre chips is 0.99 and coefficient of gradation, C_c is 1.40.

Other than that, it is found that gabion wall made from 100% tyre chips is able to give sufficient support to retain the slope. The strength of the gabion wall is depends on the gravity force that is exerted. The higher the specific gravity of material in gabion wall, the higher the gravity force, and esulted to the stronger gabion walls. 100% gravel gabion wall may provide more support than 100% tyre chips but 100% tyre chips gabion wall was also found to be able to provide sufficient support for the slope. Therefore, replacing gravel with tyre chips and utilize it as material that made out gabion wall can be considered in a small scale project.

5.3 Suggestion and future study

Further study can be carry out in the future to obtain result that is more accurate by eliminating the weakness of this study that may observed. This study also need more time to ensure the models perfectly built. Some suggestions for the future study are listed as follows:

a. Run this test with more accurate model's dimension based on the real gabion wall and slope that is conventionally used.

b. The size of tyre chips can be cut into equivalent size with the gravel. For this study tyre chips with smaller size than gravel was used. This can affect the strength of the gabion wall when the materials that was used to fill gabion wall mixed with gravel and tyre chips. It is also need to consider the size of the material that is being replaced as a constant variable in this experiment.

c. Run this test with various critical slope angle. This approach is able to determine which slope's angle that cause the gabion wall to collapse or displaced. It is also can reveal the maximum slope's angle that this type of gabion wall and arrangement of gabion wall can support.

d. Try this test with various intensity of rainfall such as low intensity, medium intensity and high intensity as a manipulation variable. This can reveal which intensity can cause the retaining wall to collapse or displace. It also can show that the relation between the intensity of rainfall and the displacement of the gabion wall.

e. This study is based on intensity of rainfall at Kuantan. For further study, location can be change to so that different intensity of rainfall value is tested.

f. Adding more test to obtain other properties of material including testing to obtain shear strength parameters of the materials.

g. Key in the value from the properties of material test into a simulation software to understand the failure mechanism of the slope.

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APPENDIX A
LABORATORY WORK PERMIT

Project Risk Assessment Form
ATTACHMENT A

LABORATORY WORK PERMIT

ROOMS/LABS : GEOTECHNIC LABORATORY
PROJECT TITLE : INVESTIGATION OF STRENGTH CHARACTERISTIC OF GABION WALL MADE FROM GRAVEL MIXED WITH TYRE CHIPS
PROJECT SAFETY CLASSIFICATION: LOW
EXPIRY DATE: 25/5/18

EQUIPMENT AND ACTIVITIES PERMITTED DURING NORMAL WORKING HOURS	EQUIPMENT AND ACTIVITIES PERMITTED AFTER HOURS (ONLY ACTIVITIES WITH HAZARD RATING OF 5-6 ARE ALLOWED FOR AFTER HOURS ACCESS)
SIEVE ANALYSIS	
DIRECT SHEAR STRESS	
PROCTOR TEST	
CONSTANT HEAD TEST	

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Note: General requirements for working after hours in the lab:
1) Apply permission from the *FKASA Laboratory's* representative at least 3 days prior to date commencing.
2) Have emergency contact details with you

User/staff/student
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