`

EFFECTIVENESS OF TYRE CHIPS AS ALTERNATIVE MATERIAL IN INCLINED GABION WALL TO MITIGATE SLOPE FAILURE

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B. ENG(HONS.) CIVIL ENGINEERING

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JUNE 2018

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ABSTRAK

Kegagalan cerun adalah masalah biasa di negara-negara tropika seperti Malaysia, yang dipengaruhi oleh geografi tropika, profil cuaca dan kelembapan udara. Faktor utama kegagalan cerun adalah disebabkan oleh hujan lebat kerana lazimnya kegagalan cerun sering berlaku selepas hujan lebat. Tembok penahan adalah struktur yang dapat mengekalkan tanah di belakangnya dari menggeser atau mengikis. Jenis dinding penahan yang paling mudah ialah dinding gabion. Dinding gabion adalah dinding yang terbuat dari jaring dawai yang disusun diikat bersama dan diisi dengan kelikir. Walau bagaimanapun, penggunaan batu kelikir dalam tembok gabion perlu dikurangkan kerana penggalian batu kelikir berbahaya kepada persekitaran. Oleh itu, penyelesaian untuk mengurangkan penggunaan kelikir di tembok gabion adalah dengan menggabungkan kelikir dengan bahan lain. Tayar terpakai adalah bahan sesuai untuk digabungkan dengan kelikir bagi mengisi dinding gabion dengan nisbah peratusan tertentu. Dalam kajian ini, model cerun akan diuji dengan beberapa nisbah kelikir bercampur cip tayar yang akan diisi ke dinding gabion bagi menahan cerun pasir bersudut 60 ° yang di simulasi hujan buatan berintensiti 570mm/h. Dari hasil kajian, 50% Kelikir dicampur dengan 50% cip tayar sebagai bahan ganti untuk dinding gabion mampu menahan bagi mencegah kegagalan cerun bagi model berskala kecil kerana dari hasil kajian, berbezaan pergerakan dinding gabion 50% Kerikil dicampur 50% cip tayar dengan 100% kerikil hanya 6%.

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ABSTRACT

Slope failure is a common problem in tropical countries such as Malaysia, which is characterised by tropical region, weathering profile and a humid. The main factor of slope failure is cause by heavy rain because normally slides often occur after intense rainfall. A retaining wall is a structure that can retained soil behind it from sliding or eroded away. The most convenient type of retaining wall is gabion wall. A gabion wall is walls made of stacked wire meshes tied together and filled with gravel. However, the use of gravel in gabion needs to be decrease because the gravel quarrying is harmful to the environment .Thus; the solution to decrease usage of gravel in gabion wall is by combine the gravel with other material. Used tyres were chosen to combine with gravel that will fill up the gabion wall with certain percentage ratio. In this study by using slope model and simulation several of ratios that filled up in to gabion wall are tested against the sand slope with 60° angle that subjected artificial rainfall with intensity 570mm/h. From the result of the study, 50% Gravel mixed with 50% tyre chip as material for gabion wall is strength enough to prevent slope failure and provide support for vertical or near-vertical grade for small-scale model because the different between current practices by using 100% gravel is only 6%

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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

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LIST OF ABBREVIATIONS

NEM	North West Monsoon
SWM	South West Monsoon
OLR	Outgoing Longwave Radiation
PWD	Public Works Department
EPA	Environmental Protection Agency
WBCSD	The World Business Council for Sustainable Development

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Slope failure is a common problem in tropical countries such as Malaysia, which is characterised by tropical region, weathering profile and a humid. The main factor of slope failure is cause by heavy rain because normally slides often occur after intense rainfall. A few months ago, heavy rains over the past few days triggered a landslide on the Cameron Highlands-Sungai Koyan road at 2.30pm on Febuary 2018 but no loss of life or injury was reported, and that no vehicles were involved in the incident. Eventhogh no loss of life or injury the government need to spend lots of money to restore the damages. So, slope stability very important to decrease risk of injury and damages restoring cost Aside from assessing and monitoring existing slopes, whether man-made or natural, another important consideration when it comes to slope stability is proper slope design. Successful slope design requires the gathering of information regarding the site's geology and characteristics (e.g. the properties and status of rock mass, soil, and groundwater in and around the excavation), interpretation of this information, and the development a design that takes this information into account.. For this study, gabion types of retaining wall will be used. Gabion by definition is a cage filled with rocks, concrete, or sometimes sand and soil. A gabion wall is a retaining wall made of stacked stone-filled gabions tied together with wire. Gabion walls are usually angled back towards the slope, or stepped back with the slope, rather than stacked vertically. For this study, instead of stones only, a mixture of tyre chips and stones will be use to fill the gabion wall.

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Figure 1.1 Landslide at the Cameron Highlands-Sungai Koyan road

Source: m.thestar.com.my/

Figure 1.2 Landslide at the Cameron Highlands-Sungai Koyan road

Source: www.nst.com.my

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1.2 Problem Statement

Slope failure is a common phenomenon in tropical countries such as Malaysia, which is characterised by tropical region, weathering profile and a humid. The main factor of slope failure is cause by heavy rain because normally slides often occur after intense rainfall. This is because water is commonly the primary factor triggering a landslide. When storm water runoff saturates soils on steep slopes or when infiltration causes a rapid rise in ground water some slopes become unstable and fail. In addition, slope failure also due to uncontrolled development especially at hilly geographic area such as Cameron Highlands, Ulu Klang, and Serendah. The landslide tragedies have killed many people and also destroy the facilities such as buildings, roads, houses, bridges and others. This phenomenal also enforce the government to spend lots of money to restore the damages. As a result, preventing and reducing landslide effect can be solved by using retaining wall.

A retaining wall is a structure that can holds soil behind it from sliding or eroded away. There are many type of retaining wall structure. The most convenient type of retaining wall is gabion wall. A gabion wall is walls made of stacked wire mesh tied together and fill with gravel. To protect the all hill that has probability to fail around Malaysia, a lot of gravel required to fill up in gabion wall. However, application gravel in gabion needs to be decrease because the gravel quarrying is harmful to environment. For example, gravel quarries immediate ecological damage, destroy forest land and take away the habitats of animals. The gravel is typically produced through drilling and blasting the rock to make it smaller for specific uses. Through drilling and blasting rock, it will increase the noise pollution, air pollution, damage the habitat and biodiversity destruction. One of solution to decrease usage of gravel in gabion wall is by combine the gravel with other material.

Nowadays, dumping used tyres represent a serious environmental problem in Malaysia. The study shows that emissions from the burning of tyres are a serious threat to human health. The toxins released from tyre decomposition may cause irritation, respiratory and skin problems. Meanwhile, used tyre also become mosquito breeding places and spread dengue fever brought by Aedes mosquitoes which listed as the most frequent disease in Malaysia recently. Used tyres were chosen to combine with gravel

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that will fill up the gabion wall with certain percentage ratio. Used tyres will be cut into small piece before mix with gravel.

1.3 Objective of Study

The objective of this research is to identify the effectiveness of utilizing different material in gabion wall. Current practice which is 100% gravel as material in gabion wall were compared with other material. In this project several percentage ratio mixture between tyre chips and gravel are used as replacement material. Hence, there are following specific objective need to accomplish in order effectiveness of gabion wall made from gravel mixed with tyre chips is:

1. To determine the basic properties of tyre chips and soil used in the study.

2. To determine the effectiveness of tyre chips and gravel mixture as material in gabion wall to stabilize slopes.

1.4 Scope of Research

The study focus on making a slope model and laboratory tests, several types of laboratory tests were made in order to determine the basic properties of the soil. The types of laboratory test were conducted include sieve analysis, particle density test for sand, specific gravity test for gravel and tyre chips, standard proctor test and constant head permeability test. Next, one slope model without gabion wall and three slope model with gabion wall in different percentage of tyre chips is built according to dimension to scale. An artificial rainfall was simulated to the slope model. An experimental model was conducted in order to study the behaviour and movement of the slope under the influence of rainfall.

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CHAPTER 2

LITERATURE REVIEW

2.1 Malaysia's Climate/Weather

The mean monthly rainfall data for entire Peninsular Malaysia are presented in Figure. 2.1 findings by Moten (1993). The maximum rainfall was observed near the end of the year during the North West monsoon (NWM). A secondary maximum is found during the inter monsoon months (April or May). The highest average monthly rainfall of 314 mm is observed in December, equivalent to 14% of the average annual rain. The lowest mean monthly rainfall of 115 mm occurs in February, which contributes about 5% of the mean annual rainfall. It is observed that during the North East Monsoon (NEM) from November to March both the maximum and minimum monthly rainfall are observed. A relative high rainfall variation is observed during the NEM than the South West monsoon (SWM), which occurs from May to September.

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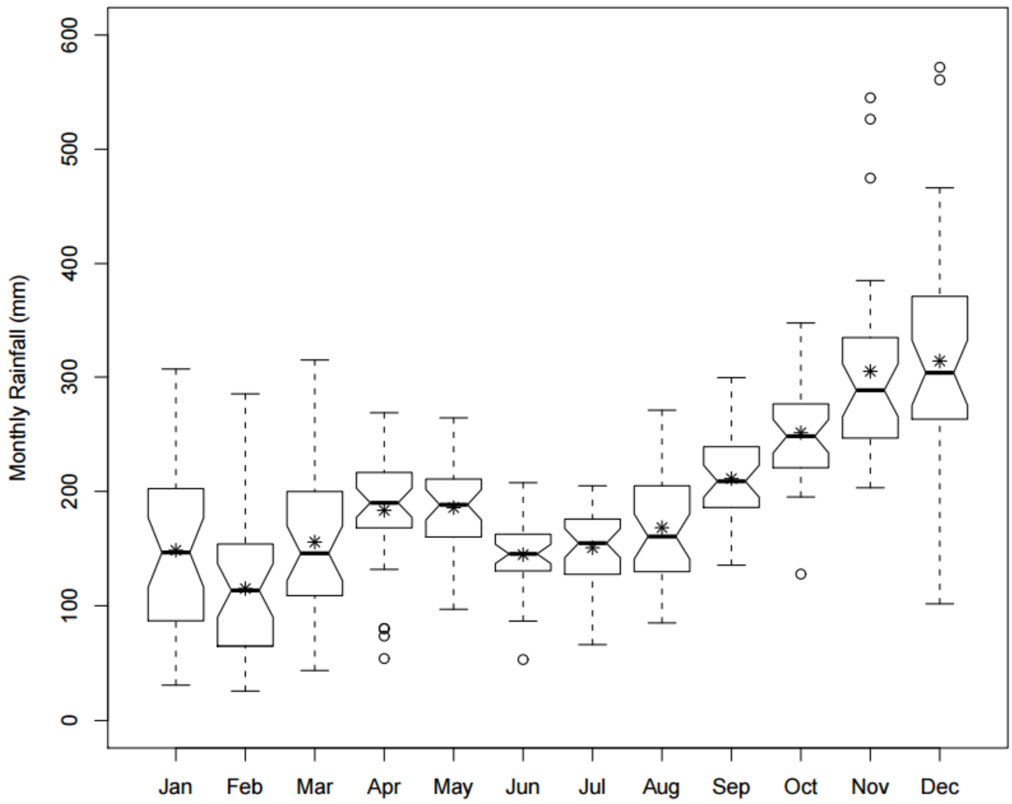

Figure 2.1 Box and whisker plot of areal average mean monthly rainfall (1971–2006) in Peninsular Malaysia.

Source: Wong et al.(2009)

The asterisk denotes the mean value, the solid line is the median, the height of the box is the difference between the third and first quartiles (IQR). Any data observation which lies 1.5 IQR lower than the first quartile or 1.5 IQR higher than the third quartile can consider an outlier in the statistical sense, indicated by open circles

The monsoon contributions to the annual rainfall in each region are shown in Table 2.1. The east coast region received 3124 mm of mean annual rainfall, 55% and 31% of which occurred during the NEM and SWM periods, respectively. The monsoons contribute 86% of the total annual rainfall in this region. During the NEM, the dry north-easterly wind becomes moist during the passage over the South China Sea. The interaction between with the land along the east coast area creates deep convection clouds and rainfall (Chang et al., 2005). The high rainfall in the east coast has also been explained from the low outgoing long wave radiation (OLR) over Peninsular Malaysia before and after the winter monsoon in the Northern Hemisphere (Murakami, 1980).

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During early winter (November–December), the OLR values are relatively low over the South China Sea, where equatorial disturbances frequently develop. During late winter (January–February), the disturbance activity becomes less pronounced, which is reflected by a relatively high OLR over the South China Sea (Murakami, 1980). Other 5 disturbances, such as the formation of the Borneo vortex and Madden Julian Oscillation are also believed to enhance low-level moisture convergence and organize deep convective rainfall (Cheang, 1977; Chang et al., 2005; Tangang et al., 2008) along the east coast. According to Ramage (1964), during the SWM, the strengthening of afternoon sea breezes in the opposite direction of the land winds deepens clouds and forces the convergence clouds drift landward, producing high downpour in the coastal zone in the late afternoon.

Table 2.1 Monsoons rainfall contributions in Paninsular Malaysia

Region (Malaysia)	**Annual Rainfall (mm)**	**NEM (Nor-Mar) Rainfall (mm)**	**SWM (May- Sep) Rainfall (mm)**	**Totoal Monsoon Rainfall (mm)**
East Coast	3124	1717	978	2696
Inland	2079	885	774	1659
West Malaysia	2311	937	866	1803
Peninsular	2334	1034	961	1894

Source: Malaysian Meteorological Department, (2009)

2.2 Introduction to Slope Failure

As stated by Samjwal (2006), slope failure is defined as the movement of a mass of rock, debris or earth down the slope, when the shear stress exceeds the shear strength of the material. The first outward sign of slope instability is usually a tension crack in the ground behind the crest of the slope, sometimes accompanied by slumping of the soil in front of the crack (Felix, 2003).

Extreme rainfall has caused slope failures in mountainous area worldwide. Participatory assessment revealed that heavy rainfall is a major triggering factor for a landslide. Increased pore pressure and seepage flow during periods of intense rainfall cause landslides and slope failures in general (Terzaghi, 1950). During rainfall, a wetting front moves down into the ground, resulting in an addition in water content and an increase in pore pressure. The increase in pore pressure results in a decrease in effective stress, slimming down the shear intensity of the soil and ultimately resulting in landslide/slope failure (Brand, 1981; Brenner, 1985).

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 (e.g., Duncan and Wright, 2005; Lu and Godt, 2013; Nash, 1987; Stead and Coggan, 2012).

Pore water in a soil affects the force balance in two ways. The added weight of pore water increases the weight of the soil mass, and thus the magnitude of both the driving and resisting forces. However, pore fluid pressure imparts a buoyancy force on the soil grains that acts upwards and perpendicular to the water table. If the water table is parallel to the slope, the buoyancy force counteracts the normal force and results in a reduced effective normal stress (Terzaghi, 1936, 1943)

2.3 Mode of Slope Failure

States of active and passive earth pressures are obtained when displacements within the soil have reached a critical value, which differs for different soil types Das(2009). Figure 2.2 shows three stages of earth pressures.

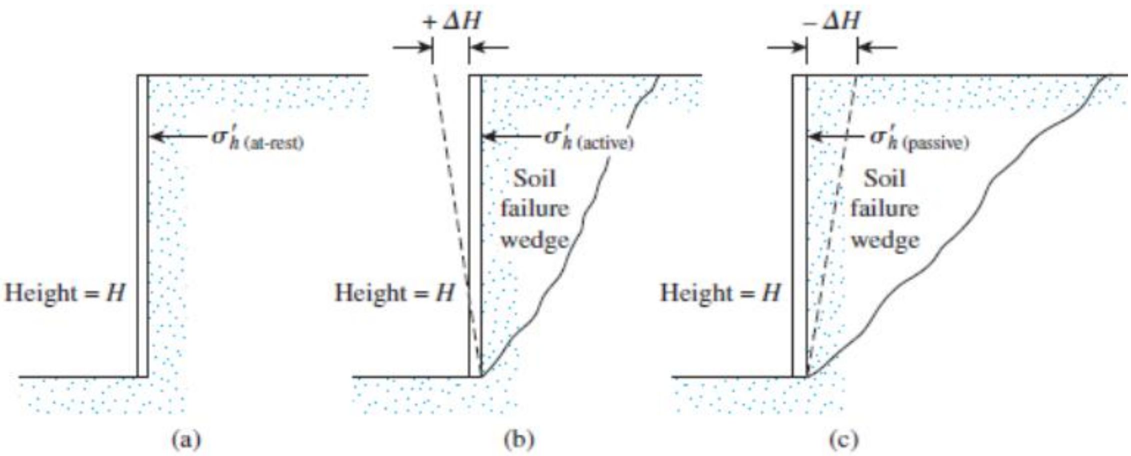

Figure 2.2 Passive and active earth pressure

Source: Das, (2009)

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Case (a) is achieved when retaining walls are restrained from moving by lateral earth pressure acting on the retaining wall. There are no deformations and displacements in this state. This state condition is typical obtained when stiff retaining walls are being installed, referred as at-rest earth pressure (Rnajan, 2000).

Case (b) is accomplished when retaining walls tilt away from the soil wedge (Das, 2009). A lateral stress reduction occurs when the retaining wall tilt away from its backfill until a minimum stress value is reached. This condition is named active earth pressure and depends on strength parameters within the soil. Notice, if a continuous wall movement directed away from the backfill occur, earth pressure will not change. Some part of the backfill is instead creating a triangular soil wedge behind the retaining wall, that will slide at a new failure surface (James, 2011). In that state plastic equilibrium will be generated (Das, 2009).

Case (c) is obtained when retaining walls are being pushed towards its backfill. Due to sufficient wall movement a soil wedge will reach failure. This condition is called passive earth pressure (Das, 2009).

According to Vernes (1978), there are six kinematically distinct types of slope movement which is fall, topple, slide, spread, flow and complex. Complex is combinimg the two terms given classifications such as Rock fall, Rock topple, Debris slide, Debris flow, Earth slide, Earth spread etc. The system of landslide classification devised by the late D.J. Varnes has become the most widely used system in the English language (Varnes 1954, 1978; Cruden and Varnes 1996).

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 (deep creep)	Debris flow (soil creep)	Earth flow
COMPLEX		Combination of two or more principal types of movement		

Figure 2.3. Types of landslide. Abbreviated version of Vernes' classification of slope movements

Source: Vernes (1978)

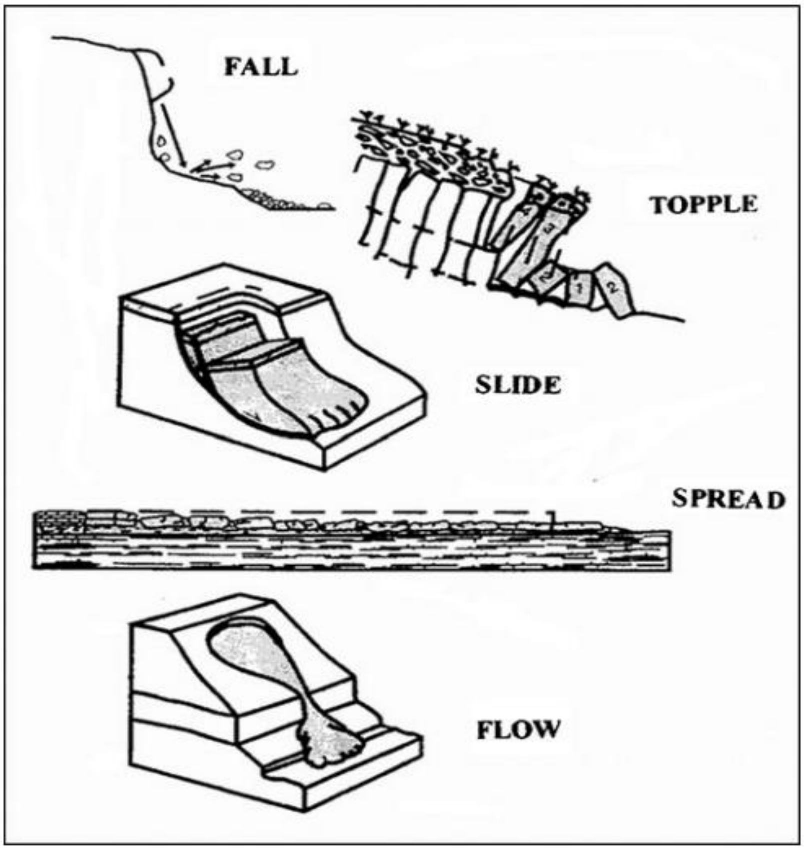

Figure 2.4 Type of slope movement

Source: Cruden and Vernes (1996)

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Figure 2.3 and 2.4 shows the type of landslide are based on Varnes (1978). Falls are abrupt movements of masses of geologic materials, such as rocks and boulders, that become detached from steep slopes or cliffs. Separation occurs along discontinuities such as fractures, joints, and bedding planes, and movement occurs by free-fall, bouncing, and rolling. Falls are strongly influenced by gravity, mechanical weathering, and the presence of interstitial water on Varnes (1987). Topples is Toppling failures are distinguished by the forward rotation of a unit or units about some pivotal point, below or low in the unit, under the actions of gravity and forces exerted by adjacent units or by fluids in cracks on Varnes (1987). Slide failure is although many types of mass movements are included in the general term "landslide," the more restrictive use of the term refers only to mass movements, where there is a distinct zone of weakness that separates the slide material from the more stable underlying material. The two major types of slides are rotational slides and translational slides. Rotational slide: This is a slide in which the surface of rupture is curved concavely upward and the slide movement is roughly rotated about an axis that is parallel to the ground surface and transverse across the slide). Translational slide: In this type of slide, the landslide mass moves along a roughly planar surface with little rotation or backward tilting. A block slide is a translational slide in which the moving mass consists of a single unit or a few closely related units that move down slope as a relatively coherent mass by Vernes (1987).

2.3.1 Fall Failure

Figure 2.5 show the free fall of earth material, as from a cliff, the free face of a slope. Typical geological conditions in which this type of failure may occur include thinly bedded shale and slate in which orthogonal jointing is not well developed. Generally, the basal plane of a flexural topple is not as well defined as a block topple. Sliding, excavation and erosion of the toe of the slope allows the toppling process to start and it retrogresses back into the rock mass with the formation of deep tension cracks that become narrower with depth. The lower portion of the slope is covered with disordered fallen blocks. Therefore, it is sometimes difficult to recognize a fall failure from the bottom of the slope. Rockfall is typically the result of frost wedging. Frost wedging is a process where water enters cracks in rocks, freezes, expands, and breaks the

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rock apart. Frost wedging results in a fan-shaped pile of rock fragments at the base of the slope. The rock fragments are called talus and the slope is referred to as a talus slope.

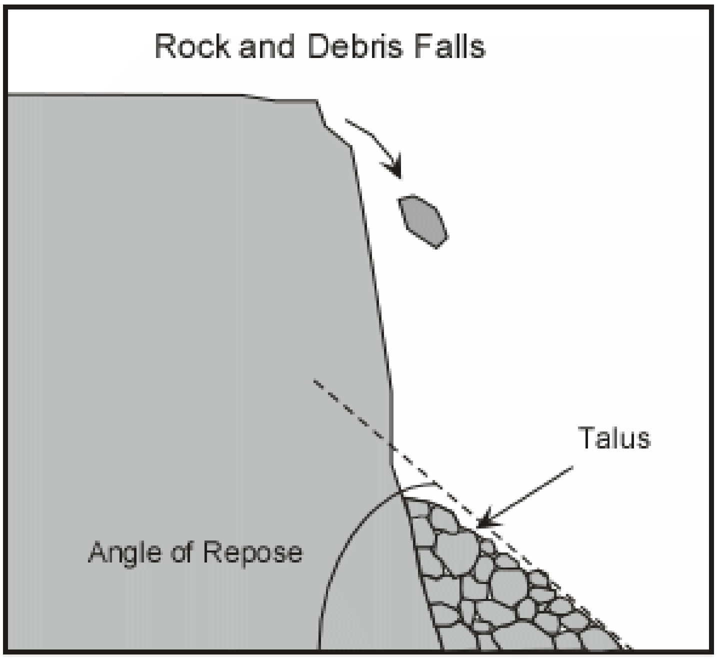

Figure 2.5 Fall Falling Slope Failure of slope

Source: www.tulane.edu/

2.3.2 Topple Failure

Topple failure of rock slope results when This happens when soil or rock cause it's rotation about an axis below the center of gravity of mass being displaced and rock mass slides along two intersecting discontinuities, both of which dip out of the cut slope at an oblique angle to the cut face, thus forming a wedge-shaped block. Topple failure can occur in rock mass with two or more sets of discontinuities whose lines of intersection are approximately perpendicular to the strike of the slope and dip towards the plane of the slope. This mode of failure requires that the dip angle of at least one joint intersect is greater than the friction angle of the joint surfaces and that the line of joint intersection intersects the plane of the slope. Depending upon the ratio between peak and residual shear strength, topple failure can occur rapidly, within seconds or minutes, or over a much longer time frame in the order of several months. The size of a topple failure can range from a few cubic meters to very large slides from which the potential for destruction can be enormous. The formation and occurrence of topple failures are dependent primarily on lithology and structure of the rock mass.

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Rock mass with well-defined orthogonal joint sets or cleavages in addition to inclined bedding or foliation are generally favourable situations for fall failure. Shale, thin-bedded siltstones, clay stones, limestones, and slaty lithologies tend to be more prone to wedge failure development than other rock types.

2.3.3 Slide Failure

Figure 2.6 show the downslope movement of a coherent block of earth material. This mode is recognize when the downward movement of soil mass occuring on surface rupture. A rock slope undergoes this mode of failure when combinations of discontinuities in the rock mass form blocks or wedges within the rock which are free to move. The pattern of the discontinuities may be comprised of a single discontinuity or a pair of discontinuities that intersect each other, or a combination of multiple discontinuities that are linked together to form a failure mode. A planar failure of rock slope occurs when a mass of rock in a slope slides down along a relatively planar failure surface. The failure surfaces are usually structural discontinuities such as bedding planes, faults, joints or the interface between bedrock and an overlying layer of weathered rock

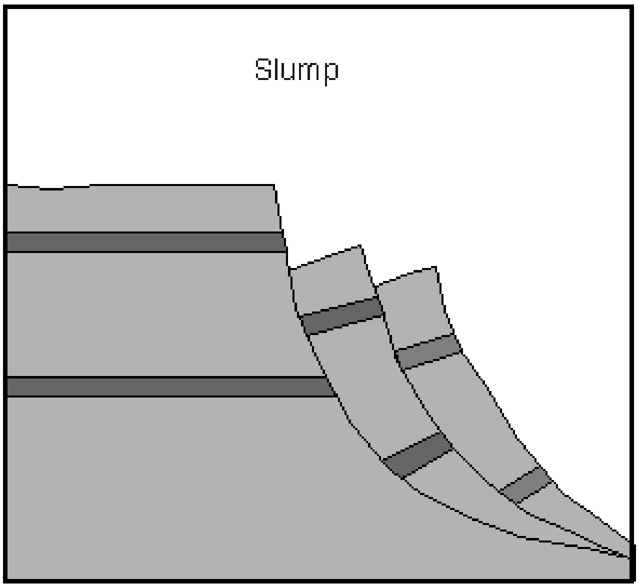

Figure 2.6 Slide failure of slope

Source: www.tulane.edu/

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2.3.4 Spread Failure

Figure 2.7 show the slope failure by lateral “spreading”. This type of failure is by translation. It cause by sudden movemeent of water bearing seams of sands or silts overlay by clays or loaded by fills (Braja M. Das,2009). Figure 2.7 show spread failure of slope.

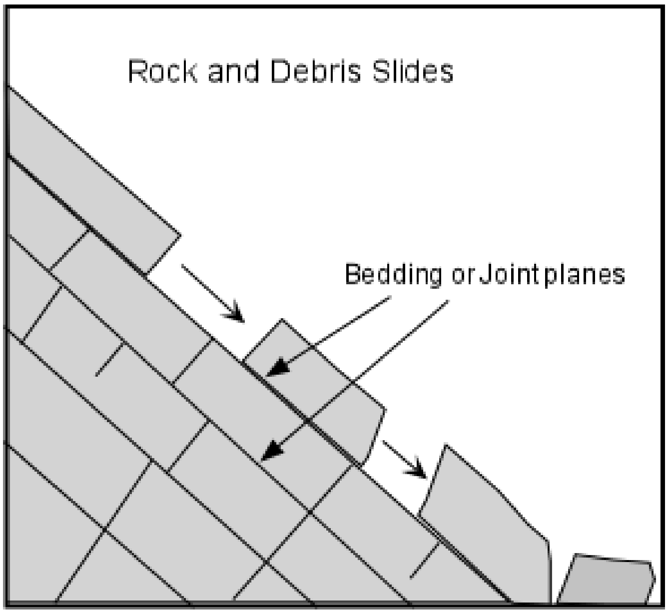

Figure 2.7 Spread slope failure of slope

Source: www.tulane.edu/

2.3.5 Flow Failure

Figure 2.8 show the flow type slope failure. Soil mass will move downward and flow like a viscous fluid. There are several type of flow which earthflows, mudflows, debris flow, and debris avalanches. Mixture of fine and coarse material with a variable quantity of water, that forms a muddy slurry which moves downslope, usually in surges (Carominas,1996). The common flow is Debris flows. Debris flows can result on the movement of coarse debris considerable distances from the source area. This movement is enhanced by high moisture contents that lubricate the flow. Three elements can be clearly distinguished in a debris flow: Firstly, the source area, where the scar is present, can have a linear or horseshoe shape, but is always shallow and the main track, always longer than wider. The depositional toe, where the previous structure of the debris is not recognisable. Although usually debris flows present a V shape on their track, leaving the coarser material on two lateral levées, this characteristic is not found at the Giant’s

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Causeway. Here debris tend to move by sliding over the slope surface, almost without dragging further material. As with ‘mudflows’, as the flows move downslope the material drains and the flow can develop into slide in which further movement is by plastic deformation.On the attached maps, rockfalls that move down along a gully and travel far away from their original scar, have also been reported as debris flow (Vernes,1978).

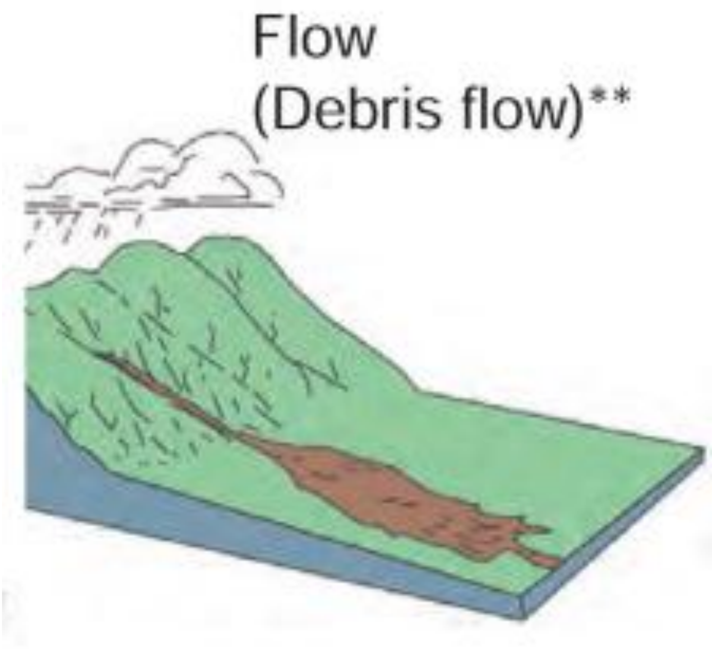

Figure 2.8 Example of debris flow type.
Source: Vernes, 1978

2.4 Cases of Slope Failure in Malaysia

Malaysia is a tropical country that experiences a lot of rainfall and most of the time this leads to landslides. Landslides commonly occur, especially in big cities where the development of hillside areas is uncontrollable and there are no strict regulations to guide the development. Mukhlisin (2010) stated that the Malaysia Public Works Department (PWD) has identified more than 100 hill slopes around Malaysia as risky areas. In Malaysia, most landslides occur on man-made slopes due to lack of maintenance, construction negligence and design errors. On top of that, the biggest cause triggering landslides in Malaysia is heavy rainfall, especially during the monsoon season when Malaysia receives very high rainfall. Jamaludin (2011) explains that

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shallow landslides are the most common landslide type to occur and are triggered due to heavy rainfall that lead to head loss in matrix suction areas in unsaturated areas.

According to M. Azmi (2011) the first recorded national landslide in Malaysia was in 1961. Although it was not the first one officially recorded, it was the official first after Malaysian independence was achieved in 1957. The tragedy occurred at Ringlet, Pahang and resulted in 16 deaths. After that event, an increasing number of deaths due to landslide tragedies have occurred. From 1973 to 2000, about 440 landslides have been recorded with almost 600 lives claimed due to landslide catastrophes. This is shown in Figure 2.10. It can be seen that fatalities have increased after the 1990s. This was the time when development of hilly terrain and slopes was significant due to urbanisation.

Figure 2.9 show the one of apartment was collapses due to the Highland Towers Tragedy on 11 December 1993, which claimed 48 lives that the government decided to set up several related agencies to form the special force to help mitigate the nation when disaster occurs. This was the time when not only the government, but also the public started to notice the importance of landslide catastrophes. Another record of the highest fatality for a single landslide event occurred on 26 December 1996 when the debris flow caused by Tropical Storm Gregg wiped out a few villages in Keningau, Sabah and claimed 302 lives.

Figure 2.9 One of apartment at Highland tower was collapses due to slope failure

Source: www.mstar.com.my

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Landslides do not only affect human lives but also the national economy. This can be seen through the losses of public infrastructure, such as road networks, and indirect losses, such as business trips and interrupted schedules. Therefore, a landslide early warning system together with probability assessment of future landslides is important not only to predict landslides but also to plan future land-use.

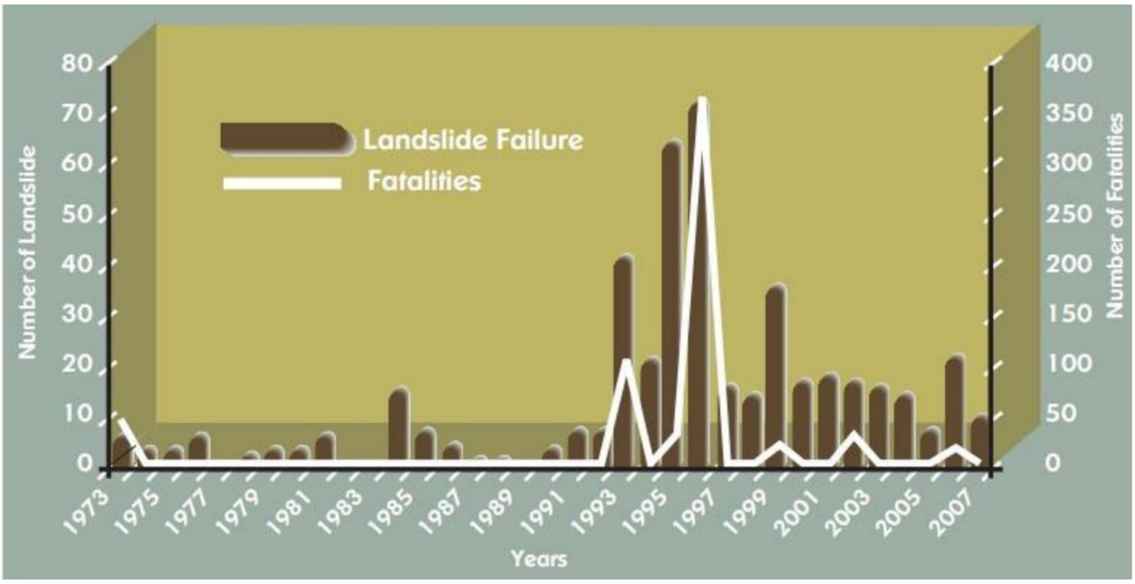

Figure 2.10 Reported landslides and fatalities 1973-2007

Source: National Slope Master Plan, Public Works Department Malaysia (2009)

2.5 Current Practice/Method to Ensure Stability of Slope

The analysis of these alternative remedial measures for soil slope problems requires experience and sound judgment on the part of the engineer. In evaluating the alternatives, the engineer will be influenced by a few factors such as the nature of failure, ground and groundwater conditions, site topography, environmental impact, availability of materials, labour and equipment, design life and maintenance requirements, adjacent and underground structures, confidence in design and construction, time constraints, and costs (Oliphant et al., 2000).

While designing any retaining walls, it is necessary to know how walls can fail hence, it becomes necessary to define failure. Failure mechanism could be sliding, tilting, bending, bearing or some other mechanism which is the result of the shear stresses being greater than the shear strength of the soil. The properly designed retaining wall will achieve equilibrium of the forces that are acted upon by the body

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forces related to the mass of the wall, soil pressures and other external forces under the static conditions, but during an earthquake, it may cause the permanent deformation of the wall due to violation of equilibrium from inertial forces and changes in soil strength (Kramer, 1996). This permanent deformation might cause a failure with one or more above discussed failure mechanisms.. In general, there are different types of retaining walls as shown in Figure 2.11 but in this section the three most common retaining walls; gravity wall, gabion wall and cantilever wall will be discussed, see Figure 2.11.

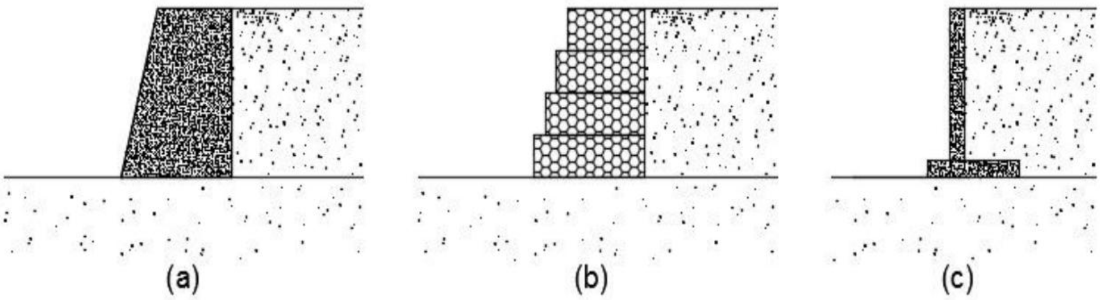

Figure 2.11 Retaining wall types (a) Gravity wall, (b) Gabion wall and (c) Cantilever
Source: Kramer(1996)

2.5.1 Gravity Wall

Gravity walls are the oldest and simplest type of retaining wall. Their movement occurs generally by rigid-body translation and/or rotation as these walls are thick and stiff enough that they do not bend (Kramer, 1996). They are generally built of stone or brick masonry or mass concrete and it resists movement due to the pressure from the soil by their self-weight (Murthy, 2002). The general failure mechanism of gravity walls such as sliding and/or overturning or gross instability are shown in Figure 2.12.

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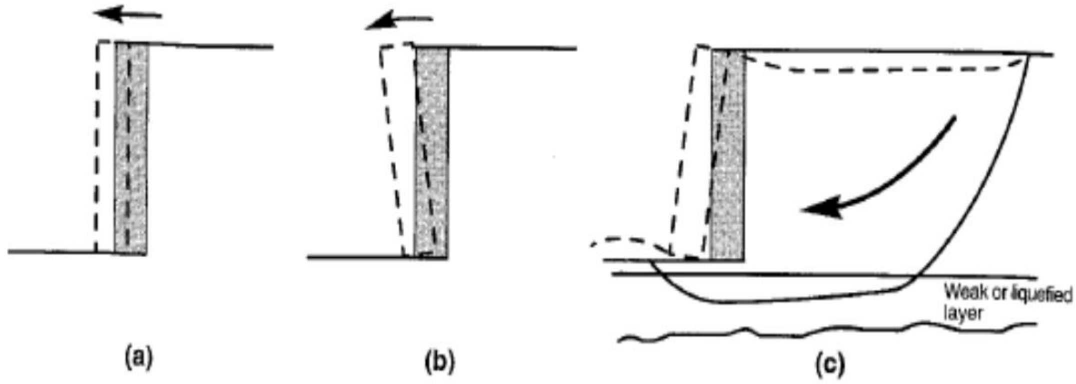

Figure 2.12 Typical failure mechanisms for a gravity walls: (a) sliding: (b) overturning: (c) gross instability failure

Source: Kramer (1996)

2.5.2 Gabion Walls

Gabion walls are rectangular cages made of zinc-coated steel wire mesh and filled with stones of appropriate size and necessary mechanical characteristics. The zinc coated wire helps to tie the individual units firmly so as to form a monolithic structure. The hexagonal double-twisted wire mesh is generally adopted. The gabion wall generally functions similar to the gravity wall without considering the contribution of the mesh which in addition provides resistance to tension and further enhances the safety factor (Agostini et al., 1987). Despite many advantages of gabion walls, failure might occur if the wall is subjected to a high magnitude of lateral forces which tends to cause side-shifting of the adjacent gabion units (Ramli et al., 2013).

Garg (1997) highlighted two innovative technologies for stabilisation of slopes. One was a reinforced gabion wall and the other was an anchored drum diaphragm wall implemented successfully in the Garhwal Himalaya during eighties to improve stability of slopes at comparatively lesser cost and time than conventional retaining walls. Ferriolo et a1. (1997) presented the details regarding the use of flexible gabion structures for landslide, road protection and river training works. The authors explained the phenomena of landslides and erosion as modification of equilibrium condition of soil at specific surfaces due to a natural configuration or due to a human activity. Gabion mattresses being flexible structures have added advantages in their use in these areas. It is also mentioned that the internal structure details of the gabions such as

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opening Size, double twist mesh, hexagonal shape, Wire diameter, extent of galvanisation, diaphragms and joint details play an important role in the functioning of the structure as a whole.

Bergado et al. (2001) conducted pullout tests on hexagonal wire mesh of gabions embedded in silty sand locally known as Ayuttaya sand to investigate the soil reinforcement interaction. Two types of hexagonal wire mesh were tested, namely: (a) galvanized (zinc-coated) which had smaller aperture (cell) dimension of 60 mm x 80 mm and (b) PVC coated which had a larger aperture (cell) dimension of 80 mm x 100 mm. The tests were conducted under normal pressures ranging from 35 to 91 kPa and the specimens were pulled at a rate of 1 mm/min. The total pullout resistance of hexagonal wire mesh reinforcement consists of two components, namely: friction and bearing resistance. It was seen that the bearing resistance is higher than the friction resistance for both types of reinforcement. Higher friction and bearing resistances \vere obtained with increasing normal pressures. The friction and bearing resistances mobilized on the galvanized ,rire mesh were greater than the PVC-coated wire mesh, due to higher friction coefficient as well as a greater number of transverse and longitudinal members (elements) per unit width in the former than the latter. The authors proposed an analytical method for predicting the pullout resistance and displacement relation using the basic soil and reinforcement properties which agreed reasonably well with the test results.

One of main advantages of gabion elements are flexibility gabion elements constitute a convenient solution for soils with a high settlement and swelling potential. Flexible gabion elements do not crack and are not affected by the earthquake such as gravity retaining walls. Next is esthetical: In architecture gabion elements are used for indoor and outdoor arrangements. Gabion elements have a natural outlook. Used of gabion wall also economical because shipping costs of gabion elements are lower due to the ease packing. Assembling the net mesh does not require qualified labor, and therefore, the labor costs are low. Filling material can easily be provided from a quarry close to worksite. Maintenance costs of gabion elements are extremely low. Gabion wall also eco-friendly because gabion elements are environmentally compatible. The gaps in the soil between filling materials allow the plantation to grow over time. Gabion elements are not affected by natural phenomena. Gabion elements do not

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require an additional drainage system because of the gaps between filling materials. Permeability of gabion elements is shown in Figure 2.13.

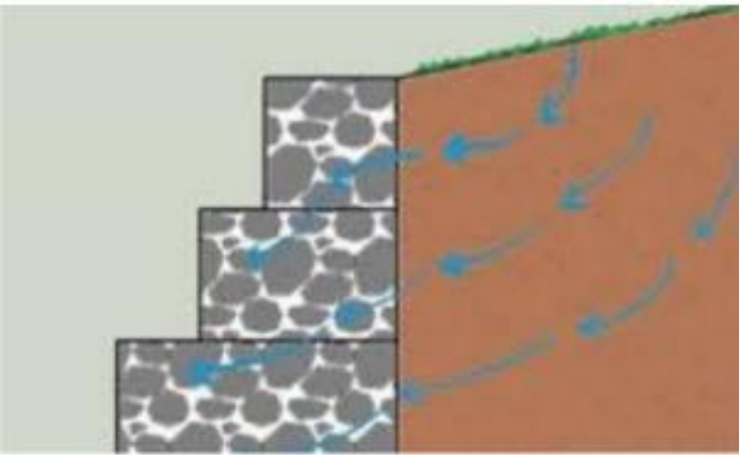

Figure 2.13 Permeability of gabion elements

Source: Kandaris, (1999)

2.5.3 Cantilever Walls

The cantilever wall generally consists of a vertical stem, and a base slab, made up of two distinct regions, viz. a heel slab and a toe slab. All three components behave like one-way cantilever slabs: the ‘stem’ acts as a vertical cantilever under the lateral earth pressure; the ‘heel slab’ and the ‘toe slab’ acts as a horizontal cantilever under the action of the resulting soil pressure. The reinforcement detailing is as given in Figure 2.14. The weight of the earth retained helps in maintaining the stability of the wall by Clayton, Milititsky and Woods, (1993).

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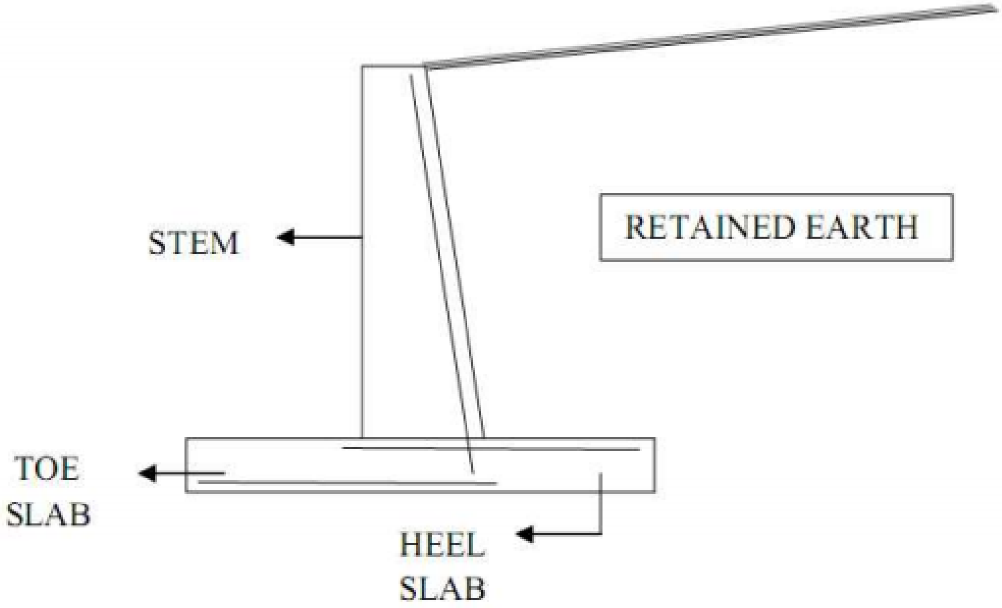

Figure 2.14 Cantilever retaining wall
Source: Clayton, Milititsky and Woods, (1993)

Figure 2.14.shown mechanisms structure of cantilever wall.Cantilever walls are generally considered advantageous over gravity walls as it is economic and easy to construct and install (Kloukinas et al., 2014). The stems of a cantilever walls are thinner and the base slab is the cantilever portion (Murthy, 2002). It utilizes the weight of the backfill soil over the footing slab to provide most of the resistance to the sliding and overturning and allows the construction of walls of considerable height (Kloukinas et al., 2014).

Figure 2.15 show the failure mechanisms of the cantilever walls are same as gravity walls and in addition there is a flexural failure mechanism as well. Soil pressures and bending moments in cantilever walls depend on the geometry, stiffness and strength of the soil-wall system and also the flexural failure may occur if the bending moment required for the equilibrium exceed the flexural strength of the wall (Kramer, 1996).

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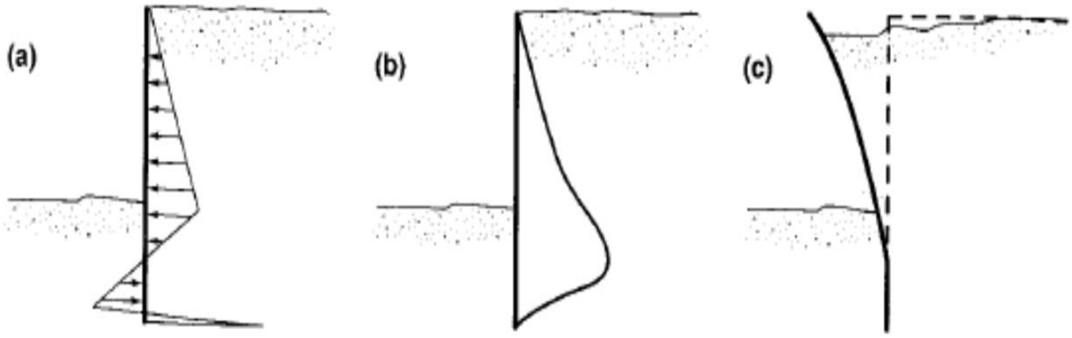

Figure 2.15 (a) Soil pressures: (b) bending moments, and (c) flexural failure mechanism for cantilever retaining wall.

Source: Kramer (1996)

2.6 Waste Tyres

Waste tyres, a by-product of modernization are non-biodegradable and non-hazardous waste that takes an extremely long time to disintegrate. Waste tyres are unique waste with a lot of potential for recycling, unfortunately, if left in the open environment or landfill they create many problems as they are bulky and occupy large volume of space, hardly compactable and resurface to the top after burial, create health problem as it becomes haven for rodents, mosquitoes, and other animals that carry diseases (Thiruvangodan, 2006; EPASA, 2010). Uncontrolled burn tyre in the environment produce thick soot and ash and emit hazardous chemicals such as polyaromatic hydrocarbons, lead, zinc, benzene and toluene where the immediate health effects of the exhausted smoke would be irritation to the skin, eyes, mucous membranes, respiratory effects, central nervous system depression and may activate cancer cell. (EPA, 1997).

Many developed countries have banned the disposal of waste tyre products and waste tyre itself from the landfill (Imperial Innovations Quelle, 2008; Dhir et. Al. 2001); as such, industries and researchers investigate ways to reclaimed its virgin components and recover energy and new materials from waste tyres through the highly technology oriented, expensive and requires excessive heat processes such as the de-vulcanization, pyrolysis, gasification and hydrogenation processes (Ramos et al, 2011; Aniza and Rao, 2012). Development of recycling huge amount of waste tyre is still extremely few in Malaysia. Previously, the government has encourage building

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artificial reef to raise fish in the sea however this practice was abandoned due to the leaching of zinc, benzothiazoles and a range of polyaromatic hydrocarbons released into the waters from the tyre that may restrained the growth of phytoplankton; in addition, the tyres, when not strongly bound to the seabed will float during tidal waves; scattered and littered the sea bed and beaches and may also damage coral reefs (CIWMB 1996, Dhir et al. 2001; Collins et al, 1995).

Furthermore, the proposal to have rubberized asphalt road surface utilizing tyre crumbs was also abandoned owing to the initial high construction cost (Thiruvangodan, 2006). At present, tyre manufacturers collect the waste tyres from tyre workshops for further recycling, thus collection is slow to reduce storing problems and transportation cost. Tyres have higher energy content compared to natural sources; therefore most of waste tyres are popularly used as alternative fuel to supplement heat energy to assist in the heating process of manufacturing cement and paper and thermal boilers to produce electricity (WBCSD, 2008; EPA, 1997); unfortunately, tyres can only supplement up to 20% of the fuel in controlled kiln to protect the environment from toxic gas emitted during burning and maintenance of the kiln itself (Dhir et. al. 2001, Aliapur 2011). With the increased of urbanization, waste tyres are being produced all over the world at an alarming rate, thus the needs for other type of recycling.

2.7 Tyres Recycling Activities

Recycling of waste tyres is a business like any production process where economic efficiency is central to sustainability (Sharma, et al., 2000). Environmental consideration is another integral factor, although it is not the sole driver of the initiative. Energy or resource economics might be the determinants of resource recycling. In the interest of the environment, governments are putting measures to integrate environmental management into the production process of all business initiatives (Scott, 1998). As a result, reuse and recycling of resources is not by choice but in the interest of environmental protection

2.7.1 Thermal Insulation Process

Many researchers have explored the potential use of waste tyre in cement mix due to the depletion of natural resources (Mavridou and Oikonomou 2011). In the attempts to replace aggregates in the mix for cement plaster/coating and structural

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concrete, the size and purity of tyre rubber influence the results of the research products. However, tyre rubber particles are not compatible with other substances in the cement mix; increment of rubber in the mixture increase the air content and disturb the water flow in the cement mixture thus preventing good hydration in some regions (Chou et al., 2007; Ganjian et al., 2009) and thereby reduce the concrete weight, compressive, tensile and flexural strength plus reduces further its density and static modulus elasticity (Nehdi and Khan, 2001; Mavroulidou and Figueiredo, 2010).

Khalitibas et al. (2011) revealed that the entrapment of air bubble or the hygroscopic nature of the rubber in the mix also promote corrosion to the rebar though the amount of fine rubber aggregate is only 10% of the sand aggregate weight; thus, this deem the rubber mix concrete cement is unsuitable for primary structure elements.

Thermal performance of rubberised concrete structure and cement mix have been known for quite sometimes but only recently this property is being explored quite rigorously (Yesilata et al. 2011). Many investigate the freezing and thawing test of cement plaster coating which success also varies depending on the various amount and size of rubber aggregates use and the type of cement use (Turgut and Yesilata 2009, Yesilata et al, 2009, Turgut and Yesilata 2008, Siddique and Naik 2004,).

In the freezing thawing tests, cement mix with tyre rubber powder of less than 20% showed more than 60% durability factors after 300 freezing and thawing cycles while this is not acceptable at all for coarse rubber tyre mix which are larger in size with non-uniform air entrapment distribution (Nehdi and Khan, 2001). Stankevicius et al. (2007) calculate the freezing and thawing resistance of the rubber powder mix cement plaster and the results showed that plaster with addition of fine rubber waste of 10% have the value of 7 – 8 times higher than typical plaster mix in preventing plaster crack during the freezing and thawing test.

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2.7.2 Waste Tyres in House Construction

Earth-sheltered houses pioneered by architect Michael Reynolds is an environmentally benign construction made from recycled and reclaimed materials (Freney, 2009, Hall 2009; Ip et al. 2005). One of the main feature of the house is the rammed earth tyre wall which act as retaining wall, load bearing wall and thermal mass to insulate against the cold winter and hot summer (Grindley and Hutchinson, 1996; Hall, 2008; Freney, 2009). The tyre wall is protected from water trickling down from the environment above to enhance its uses as thermal mass for better moderation of the indoor air (Ip etal., 2005) and prevent from off-gasing by adobe plaster wall (Freney2009).

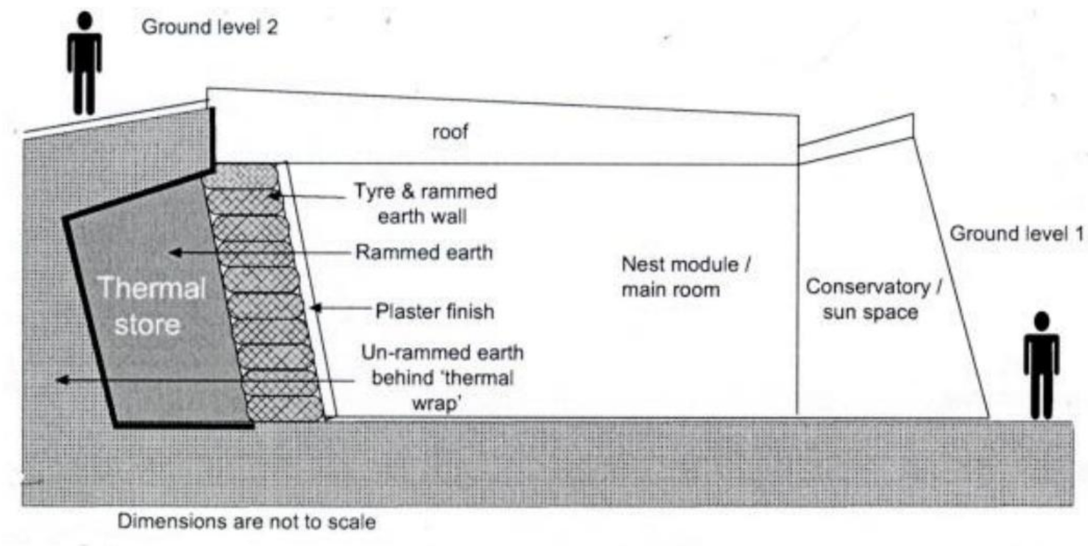

Figure 2.16 Typical 'Earthship' side view
Source: Raynolds, www.dreamgreenhomes.com.

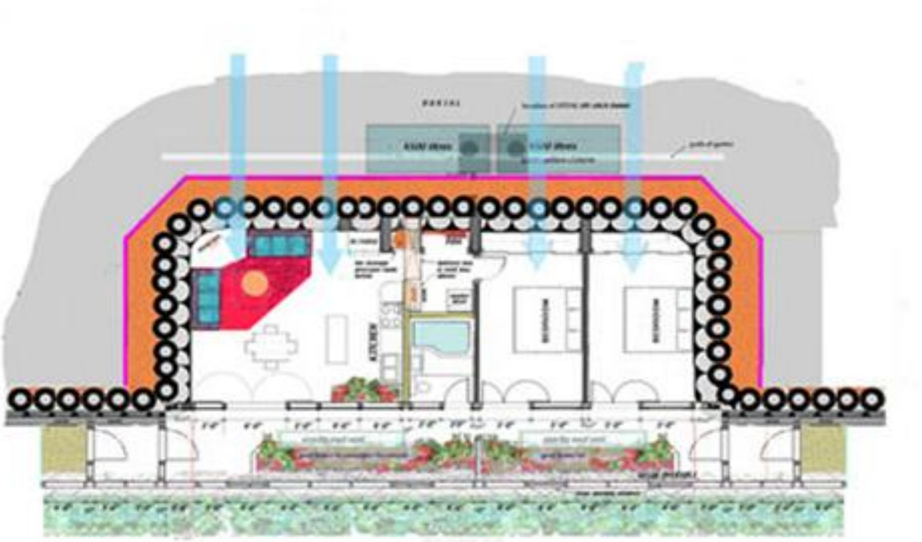

Figure. 2.17: Typical 'Earthship' floor plan.
Source: Reynolds, www.dreamgreenhomes.com

This indicates that the earth inside the tyre wall temperature is effected by its immediate surroundings; when the room heats up during the day it absorb the heat and becomes a heat sink, while at night it becomes a thermal mass and slowly release the heat to regulate the internal temperature (Ip et al., 2005, Ip and Miller, 2009; Grindley and Hutchinson, 1996). In another thermal insulation studies by Yesilata et al. (2011), a concrete structure with tyre rubber pieces in the center of the concrete floor and roof and crumb tyre concrete mix walls is able to moderate the room temperatures at an average of 12% improvement throughout a yearly weather fluctuation compared to structure without tyre rubber insulation; Figure 2.16 and 2.17 shows the illustrate a similar trend of heat sinks to the tyre wall in Earthship. Therefore, it can be summarized that tyre rubber is a good and cheap material for used as insulation materials in housing development, though more research is required to proof its performance.

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According to Calkin (2009), sustainable designs are green design which is supposed to be eco-friendly with a low carbon footprint and operate on low energy; some common principles are:

i. Use of low-impact materials in buildings - non-toxic, sustainably produced or recycled materials which require little energy to process.

ii. Energy efficiency or low energy building design to promote less energy usage during its lifetime for cooling or heating.

iii. Quality and durability buildings that will be longer-lasting, better-functioning and need little maintenance.

iv. Design for reuse and recycling.

v. Healthy Buildings: design with the aims to create buildings that are neither harmful to their occupants nor to the larger environment during and after construction. An important emphasis is on indoor environmental quality, especially indoor air quality.

Many Malaysian developers claimed their development are eco-friendly but in actual fact only the landscape design and road construction may be considered as eco-friendly; houses developed are still made from typical building materials and most of them are fully air-conditioned; solar panel and rainwater harvesting systems are an options to the house owners (www:spsetia.com, www:iskandarmalaysia.com). The Smart and Cool Home Developer tried to be a true eco-friendly developer by using a few techniques to cool down houses which include aerated concrete block wall, double glazing windows, Bernoulli effect ceiling design and embedded waste tyre foundation system; most of their houses are 100% air-conditioned free (Ismail and Rashid., 2011). However, night ventilation is encouraged to promote fresh air change. Interview with the developer revealed that underneath the slab of the entire exhibition house inclusive of the driveway, three layers of waste tyres are laid in between ground beams with a layer of damp proof membrane before the concrete slab. He claimed that the driveway surface temperature is cooler than any concrete surface placed directly on the ground.

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Initial visit to the house finds that the concrete driveway slab feels cool to the bare feet in a hot and sunny afternoon. To investigate this phenomena, two sample houses were selected for this purpose; Sample house 1 (H1) is the exhibition house itself in Tasek Kesuma, Beranang District, Selangor. At time of measurement, the house was under refurbishment and thus any readings in the interior of the house is not allowed. Sample house 2 is another detached house located in Bangi Golf Resort, Bangi District, Selangor where only two layers of tyres are laid under the exposed driveway, the porch and the interior of the house is free from any embedded tyre. Selection was made based on their locality and having two different tyre layers will enhance knowledge on the tyre performance as heat sinks. Many other houses built by this developer are located in Melaka and timing is crucial for this pilot study.

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CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter gives information about the methodology used in this study, such as the technical details of the laboratory test methods to determine the basic properties of materials such as soil, gravel, and tyre chips. The laboratory test such as sieve analysis, particle density test, specific gravity test (gravel and tyre chips), standard proctor test and constant head permeability test was conducted.

Besides that, gabion type of retaining wall was used to ensure the stability of slopes and to reduce soil erosion. A gabion wall is a retaining wall made of stacked stone-filled gabions tied together with wire. An experimental model of a slope with gabion wall was developed to simulate the behaviour of slope with and without the gabion wall. The model is then will be put under the influence of artificial rainfall. The effect of the rainfall and the movement of the slope as well as the displacement of the gabion wall was observed.

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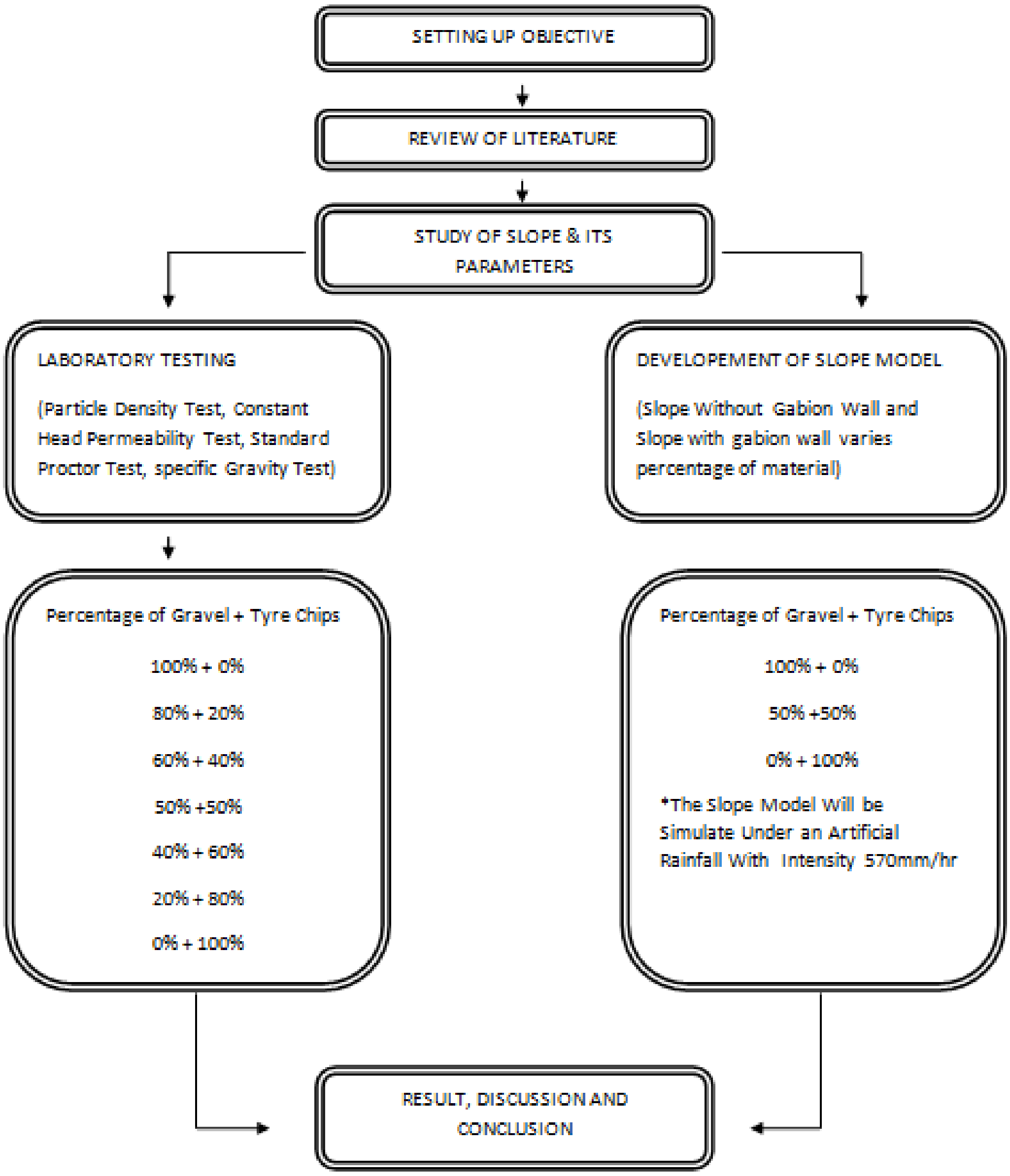
3.2 Research Flow Chart



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3.3 Laboratory Test

To obtain reliable information about the soil properties, a series of tests were performed to obtain basic properties of each material. The laboratory test will include sieve analysis, particle density test (Pycnometer), specific gravity test (gravel and tyre chips), standard proctor test and constant head test. Under provision of Geotechnical Laboratory of Universiti Malaysia Pahang.

3.3.1 Sieve Analysis

Sieve analysis is an analytical technique used to determine the particle size distribution of a granular material with macroscopic granular sizes. The technique involves the layering of sieves with different grades of sieve opening sizes. The finest sized sieve lies on the bottom of the stack with each layered sieve stacked above in order of increasing sieve size. When a granular material is added to the top and sifted, the particles of the material are separated into the final layer the particle could not pass.

Commercial sieve analysis weigh each individual sieve in the stack to determine the weight distribution of the particles. The base of the instrument is a shaker, which facilitates the filtering.

Sieve analysis is important for analysing materials because particle size distribution can affect a wide range of properties such as the strength of concrete, the solubility of a mixture, surface area properties and even their taste.

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3.3.2 Specific Gravity Test

The particle density test or specific gravity of fine aggregate is expressed as the ratio of the total mass (in grams) of solid particles to their total volume (cm³). The soil volume is determined by observing the displacement of a fluid with a known density and is dependent on the liquid completely surrounding each individual particle.

As shown in Equation **Error! Reference source not found.**, to determinate the particle density of soil.

$$Gs = \frac{W2 - W1}{(W4 - W1) - (W3 - W2)} \quad 3.1$$

Where W_1 = Mass of bottle + stopper

W_2 = Mass of bottle + stopper + dry soil

W_3 = Mass of bottle + stopper + soil + water

W_4 = Mass of bottle + stopper + water

Specific gravity test is used to determine specific gravity (relative density) and absorption of coarse aggregate. In this Project, seven samples are tested

Test sample is soaked in water for at least 24 ± 4 hours, after soaking process is complete remove the sample from water and wipe the outside surface of all particle by dampen cloth, by this way test sample change from fully saturation to saturation surface dry (SSD), measure the mass of SSD sample and record as (B), then submerge the sample in water and measure the mass in water and record as (C), place the test sample in oven till obtain a constant mass, after completely dry is obtain measure the mass of test sample and record as (A), then by using equations both specific gravity and absorption can be calculated.

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The specific gravity is calculated by using equation 3.2;

$$G_s = \frac{A}{(A)-(C-D-B)} \qquad 3.2$$

Where: A = Mass of sample

B = Mass of bowl + lid + water

C = Mass of sample + bowl + lid + water

D = Mass of cage

3.3.3 Standard Proctor Test

The Proctor compaction test is a laboratory method of experimentally determining the optimal moisture content at which a given soil type will become most dense and achieve its maximum dry density.

Compaction is the process of densification of soil by reducing air voids. The degree of compaction of a given soil is measured in terms of its dry density. The dry density is maximum at the optimum water content. A curve is drawn between the water content and the dry density to obtain the maximum dry density and the optimum water content.

Dry density of soil is calculated by using equation 3.3;

$$\gamma_d = \frac{\gamma}{1+\omega} \qquad 3.3$$

Where: γ = bulk density

ω = water content.

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3.3.4 Constant Head Permeability Test

The constant head permeability test is a common laboratory testing method used to determine the permeability of granular soils like sands and gravels containing little or no silt. This testing method is made for testing reconstituted or disturbed granular soil samples

The constant head permeability test involves the flow of water through a column of the cylindrical soil sample under the constant pressure difference. The test is carried out in the permeability cell, or permeameter, which can vary in size depending on the grain size of the tested material. The soil sample has a cylindrical form with its diameter being large enough in order to be representative of the tested soil. As a rule of thumb, the ratio of the cell diameter to the largest grain size diameter should be higher than 12 (Head 1982). The usual size of the cell often used for testing common sands is 75 mm diameter and 260 mm height between perforated plates.

The testing apparatus is equipped with an adjustable constant head reservoir and an outlet reservoir which allows maintaining a constant head during the test. Water used for testing is de-aired water at constant temperature. The permeability cell is also equipped with a loading piston that can be used to apply constant axial stress to the sample during the test. Before starting the flow measurements, however, the soil sample is saturated. During the test, the amount of water flowing through the soil column is measured for given time intervals.From equation 3.4, knowing the height of the soil sample column L, the sample cross section A, and the constant pressure difference Δh, the volume of passing water Q, and the time interval ΔT,

Coefficient of permeability, K can be calculated by using equation 3.4.

$$K = \frac{QL}{(A\,.\Delta h\,.\Delta t)} \qquad 3.4$$

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3.4 Preparation of Material

Before the slope model are developed the material such as tyre chips, gravel, aluminium wire perspex box are collected. For tyre chips, the recycled waste tyre are shaved into small piece from the manufacture are collected with size 6.30mm to 3.35mm.

Next, the gabion cage for the walls was made by aluminium wire and knitted using pliers into square shape scaled down ratio of 1m to 1cm from the actual dimension of wire mesh in field. The dimension of model size after scale down is 9 x 8 x 9 cm.

The frame that will hold the model of soil slope and gabion also was prepared. The frame was made from Perspex. The size of the Perspex frame is 51.5cm width, 103.5cm long and 35cm height. Figure 3.1 shows the size of the Perspex frame and the dimension of gabion that is used respectively.

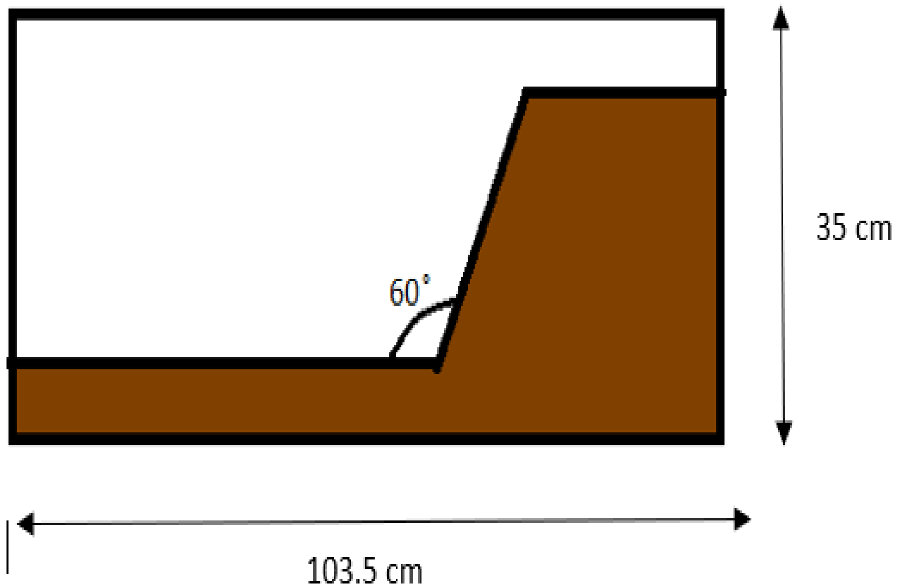

Figure 3.1 Size of perspex frame

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3.5 Development of Slope Model

Figure 3.2 shows the frame made of perspex is made to hold the slope with the gabion. The Perspex frame is made with dimension of 51.5cm width, 103.5cm long and 35cm height.

Figure 3.2 Perspex frame was filled with sand

Besides that, the gabion that was consisted of gravel, tyre chips and mixture of both is made. The gabion was made with a scaled down size from the actual size of gabion in the field. The ratio is 1cm to 1m. The size of the gabion that was being used for the model is 9cm x 9cm. Each slope model will use 10 gabion that was made up from 2 stacks of gabion. Each stack of gabion wall consists of 5 gabions.

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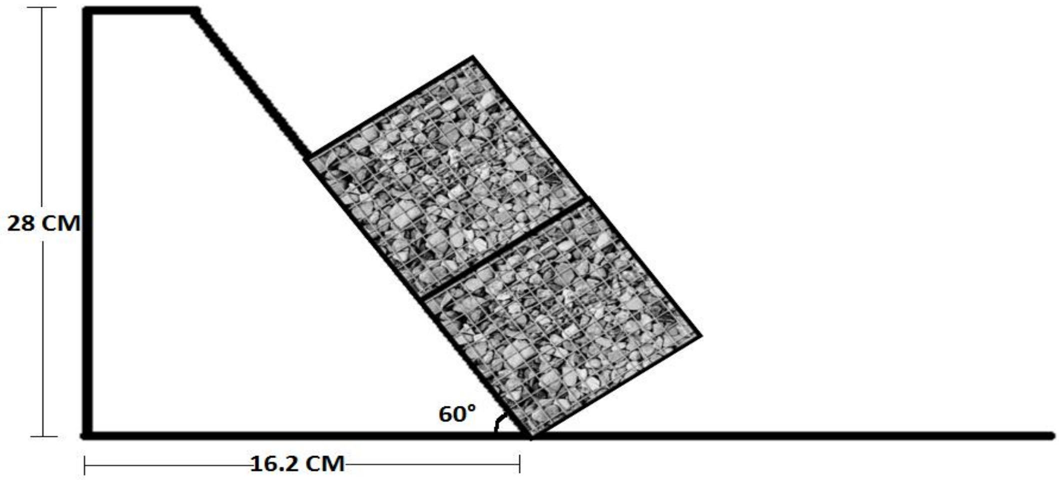

Figure 3.3 Inclined arrangement of gabion wall

Figure 3.3 shows the arrangement of gabion wall for model testing. The gabion wall is then will be arranged with inclined arrangement. The slope model is made with 60˚angle of critical. The sand is wetted with water first to make the sand damp. It was done in order to make the sand easier to be shape. The sand is then shaped into slope with 60˚of critical angles. Critical angle of slope the steepest angle of descent or dip relative to the horizontal plane to which a material can be piled without slumping. At this angle, the material on the slope face is on the verge of sliding. The slope is intentionally made to be with a critical angle as the slope is expected to fail under the influence of rainfall without any gabion wall to retain the slope.

Four models of slope was made. The first slope model is a slope without a gabion wall. After that, three slope model with three different percentage ratio of tyre chips and gravel. The percentage material in gabion wall that was tested is 100% gravel, 50% gravel mixed with 50% tyre chips and 100% tyre chips.The slope model is the exposed under the artificial rainfall with intensity of 570mm/hr. The 570mm/hr intensity of artificial rainfall was used because it was the maximum average intensity at Kuantan based on Figure 3.4. The constant variable in this model is the arrangement of gabion wall, angle of slope and also the rainfall intensity.

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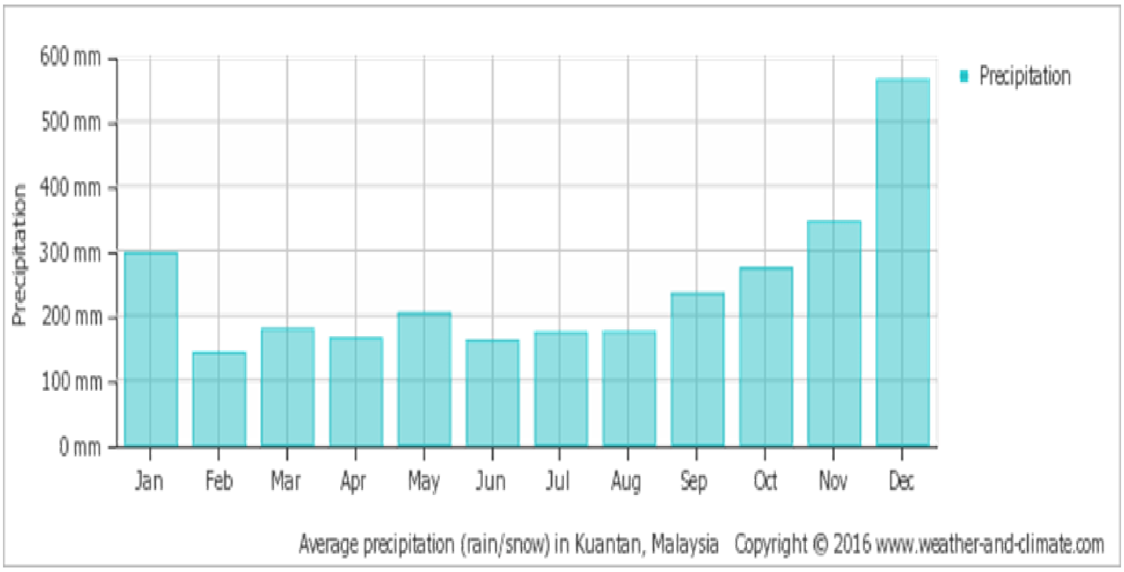

Figure 3.4 Average monthly precipitation in Kuantan, Malaysia

Source: www.weather-and–climate.com (2016)

3.6 Digital Transducer

Figure 3.5, 3.6 and 3.7 shows the tools for measure movement of gabion wall. A digital transducer was used in this project Digital transducer is a device that converts energy such as movement/displacement from one form to another, where electrical signals are converted to and from other physical quantities (energy, force, torque, light, motion, position, etc.). The process of converting one form of energy to another is known as transduction. The function of this device to measure the movement of gabion wall and movement of the slope. The data from transducer will be transfer to readout device and will be recorded every 20 seconds.

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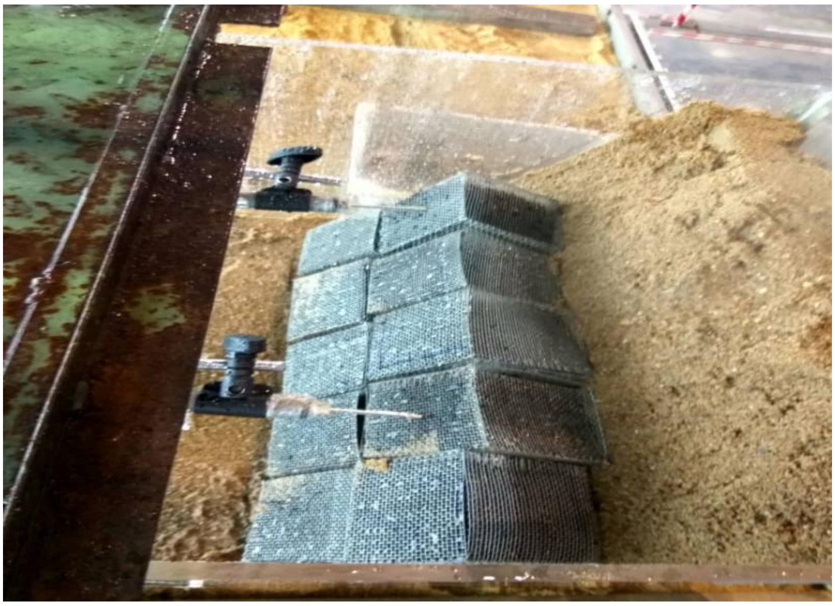

Figure 3.5 Digital transducer was used to measure the movement

Figure 3.6 Digital transducer must be 90° angle with the wall

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Figure 3.7 Output of readout Device

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CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter discuss about laboratory test and model test results for achievement of the research objective. Under the provision of Geotechnical Laboratory and Hydrology Laboratory of Universiti Malaysia Pahang, several soil testing were conducted to obtain reliable information about the soil properties of the material used in this research, which is the specific gravity, coefficient of permeability, optimum water content and maximum dry unit weight. The experiment setup to obtain those parameters are specific gravity test, constant head permeability test, standard proctor compaction test and sieve analysis test. For the model test, three different tests were conducted with different percentage of gravel and tyre chips in the gabion wall to observe the relationship between movement of gabion wall and time, when the slope model was subjected to artificial rainfall. The results obtained from all laboratory tests were tabulated. Graph and histogram are plotted by using Microsoft excel for the ease of understanding.

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4.2 Laboratory Test Results

4.2.1 Sieve Analysis

A sieve analysis is a practice or procedure are used to assess the particle size distribution of a granular material. The size distribution is often of critical importance to the way the material performs in use. A sieve analysis can be performed on any type of non-organic or organic granular materials including sands, crushed rock, clays, granite, coal, soils, a wide range of manufactured powders, grain and seeds, down to a minimum size depending on the exact method. Being such a simple technique of particle sizing, it is probably the most common. The suitability of a soil for a particular use in construction is often dependent on the distribution of gain sizes in the soil mass. There are two tests used to analyze the particle size distribution in a soil. One of these methods is by using sieves. The test is a fundamental requirement for identification and for specification compliance testing for soils.

From the particle size distribution plot, parameter such as the uniformity coefficient can be determined. The uniformity coefficient C_u is defined as the ratio of D_{60} by D_{10}. So when C_u is greater than 4 to 6, it has been classified as a well graded soil and when the Cu is less than 4, it can be considered to be poorly graded or uniformly graded. Uniformly graded in the sense that the soils have identical size of the particles. For example, Cu for desert sand will be approximately is equal to 1. Another coefficient that can be obtain from particle size distribution plot is coefficient of curvature, C_c. Coefficient of curvature, C_c can be calculate by using equation 4.1. For the soil to be well graded the value of coefficient of uniformity C_u has to be greater than 4 and C_c should be in the range of 1 to 3. So higher the value of C_u the larger the range of the particle sizes in the soil. So if the C_u value is high it indicates that the soil mass consists of different ranges of particle sizes.

The formula to determine uniformity coefficient C_u and coefficient of curvature,C_c are listed in equation 4.1 and equation 4.2

$$C_u = \frac{D_{30}}{D_{10}} \qquad 4.1$$

Soils with Cu≤ 4 are considered to be "poorly graded" or uniform.

Soils with Cu > 4 are considered to be well graded.

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$$C_u = \frac{{D_{30}}^2}{D_{60}\,D_{10}} \qquad 4.2$$

For well−graded soils, Cc~ 1

Figure 4.1, Figure 4.2, and Figure 4.3 show the value of the uniformity coefficient, C_u of sand is 2.35 and coefficient of gradation, C_c is 1.15. For the gravel the value of the uniformity coefficient, C_u is 1.07 and coefficient of gradation, C_c is 1.00. Next, the value of the uniformity coefficient, C_u of tyre chips is 1.40 and coefficient of gradation, C_c is 0.99. Therefore, the particle size distribution curve of gravel, sand and tyre chips is poorly graded soil because the graded soil has high proportion of the particle has a sizes within narrow limits.

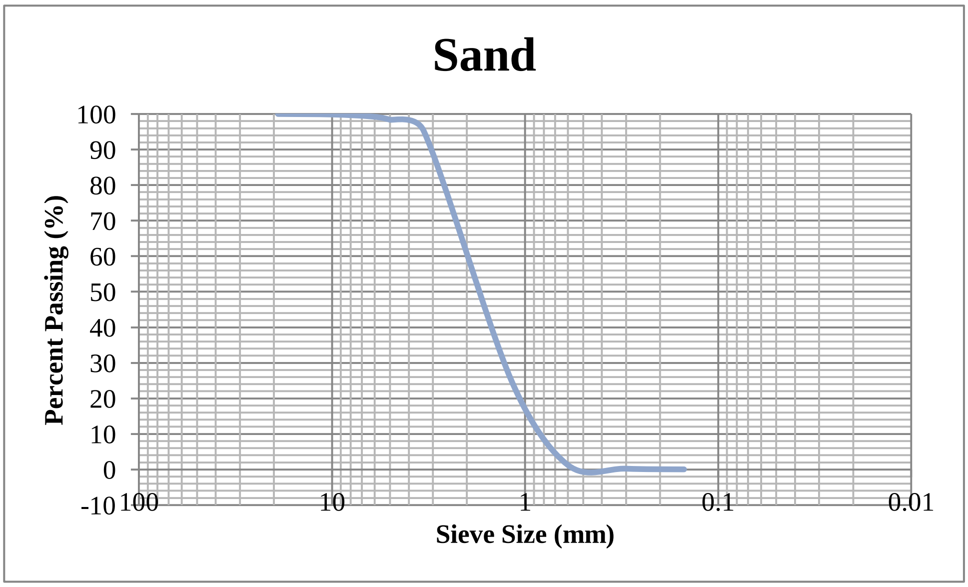

Figure 4.1 Particle Size Distribution Curve of Sand

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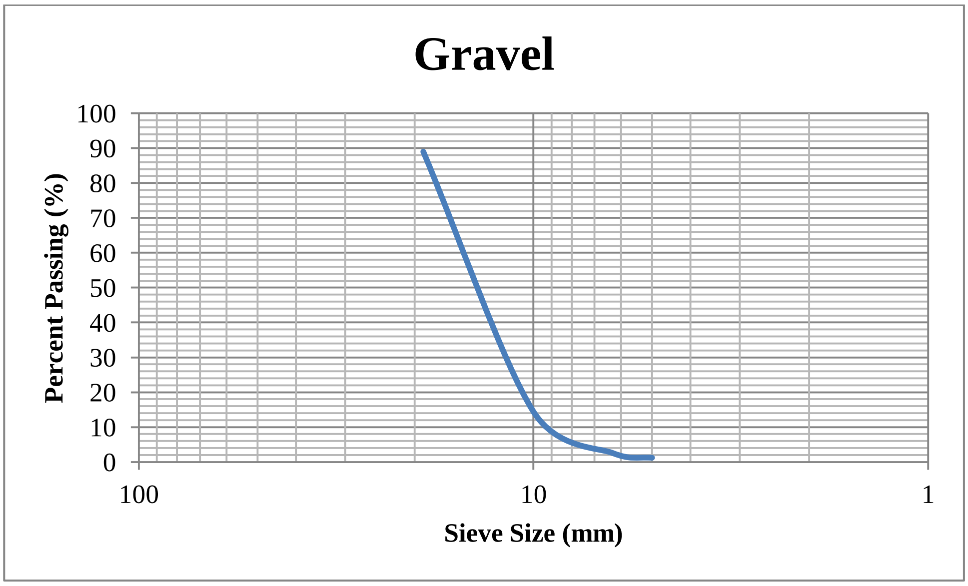

Figure 4.2 Particle Size Distribution Curve of Gravel

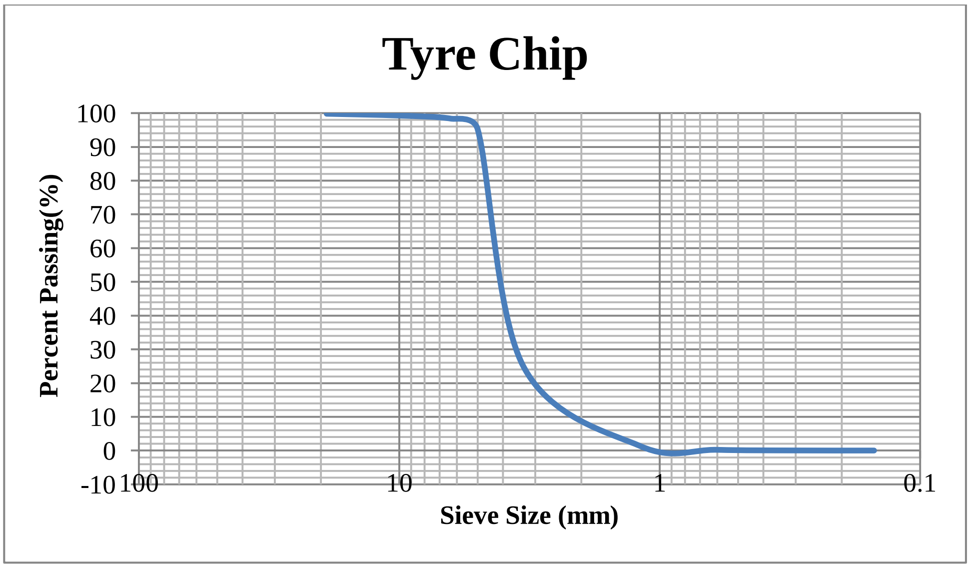

Figure 4.3 Particle Size Distribution Curve of Tyre Chips

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4.2.2 Particle Density Test and Specific Gravity Test

Particle density test is done to determine the specific gravity of soils consisting of clay, silt and sand-sized particles. This test used pycnometer which is a small gravity bottles that can only fit small sized particle. This test is done to obtain the specific gravity for sand sample only. Table 4.2 shows the calculation to obtained the data.

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 4.1 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	

Specific gravity test is done to obtained the specific gravity for coarse grain and bigger size particles. The specific gravity for gravel and tyre chips used can be obtained from this test. The result of specific gravity for seven samples with different percentage of mixture gravel and tyre chips obtained from specific gravity test was tabulated in Table 4.32. Each specific gravity obtained from equation 4.3.

Table 4.2 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

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Table 4.3: 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

Specific gravity of the samples is obtained by using equation 4.4

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

Table 4.4 shows the specific gravity of mixed gravel and tyre chip. The value of specific gravity is found to be decreased when the percentage of gravel decease. This is because the value of specific gravity of tyre chips is 0.96. Therefore, when percentage tyre chips increase the value of specific gravity of mixture decreased.

Table 4.4 Specific Gravity of each mixture sample

Gravel (%)	**Tyre Chips (%)**	**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

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4.2.3 Standard Proctor Test

The Proctor compaction test is a laboratory geotechnical testing method used to determine the soil compaction properties, specifically, to determine the optimum water content at which soil can reach its maximum dry density. Soil behaviour is highly depends on its initial water content and initial degree of saturation. In order to examine the effect of initial water content on the slope stability, four different initial water contents (5%, 10%, 15%, and 20%) were prepared before compaction took place. The right side of the peak point of the curve is called the 'wet side' which covers higher water content than the optimum moisture content with softer sample consistency. The dry (left) side of the optimum water content has lower water content than the 'optimum' with stiffer consistency.

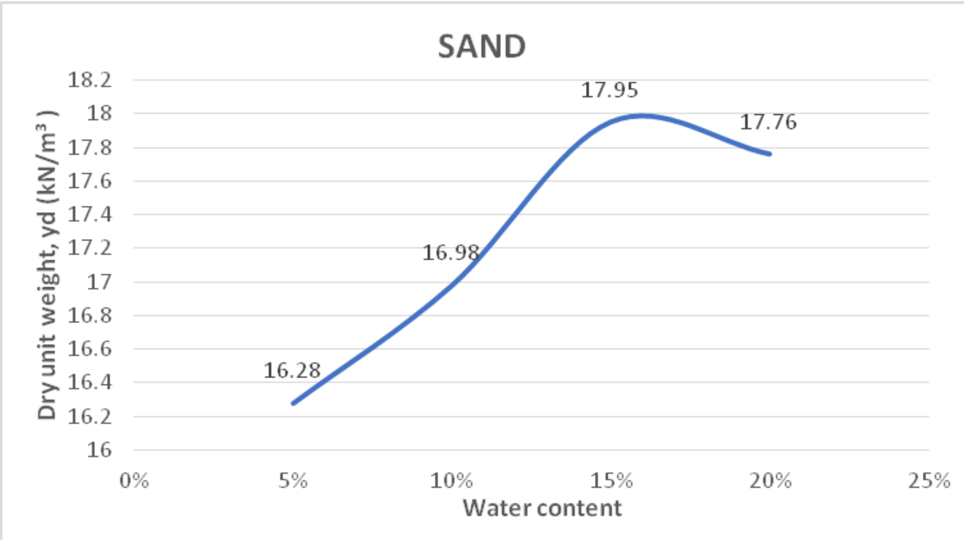

Figure 4.4 Compaction curve of sand

Figure 4.4 shows the dry unit weight of the sand obtained from various percent of water content tested during compaction test. The optimum moisture content was found to be 15% and the maximum dry unit weight was 17.95 kN/m^3. The main purpose of compacting soils is to reduce subsequent settlement under working loads and compaction also increases the shear strength of the soil, reduces voids ratio making it more difficult for water to flow through soil and prevent the built-up of large water pressures that cause soil to failure during rainfall.

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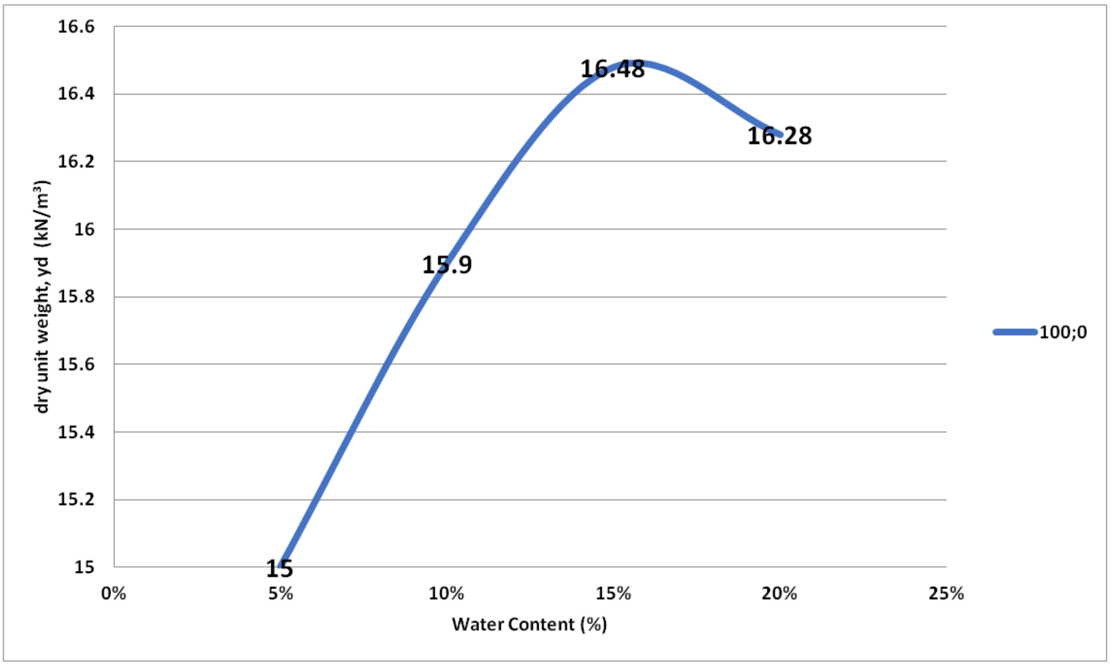

Figure 4.5 Compaction curve of 100% gravel and 0% tyre chips sample

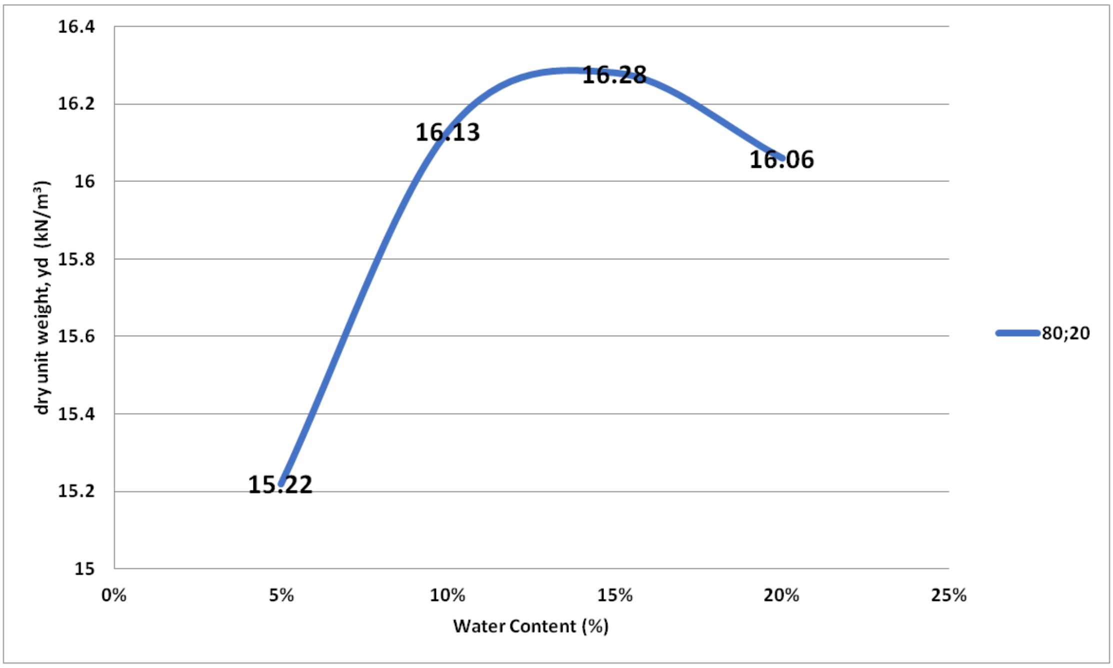

Figure 4.6 Compaction curve of 80% gravel and 20% tyre chips sample

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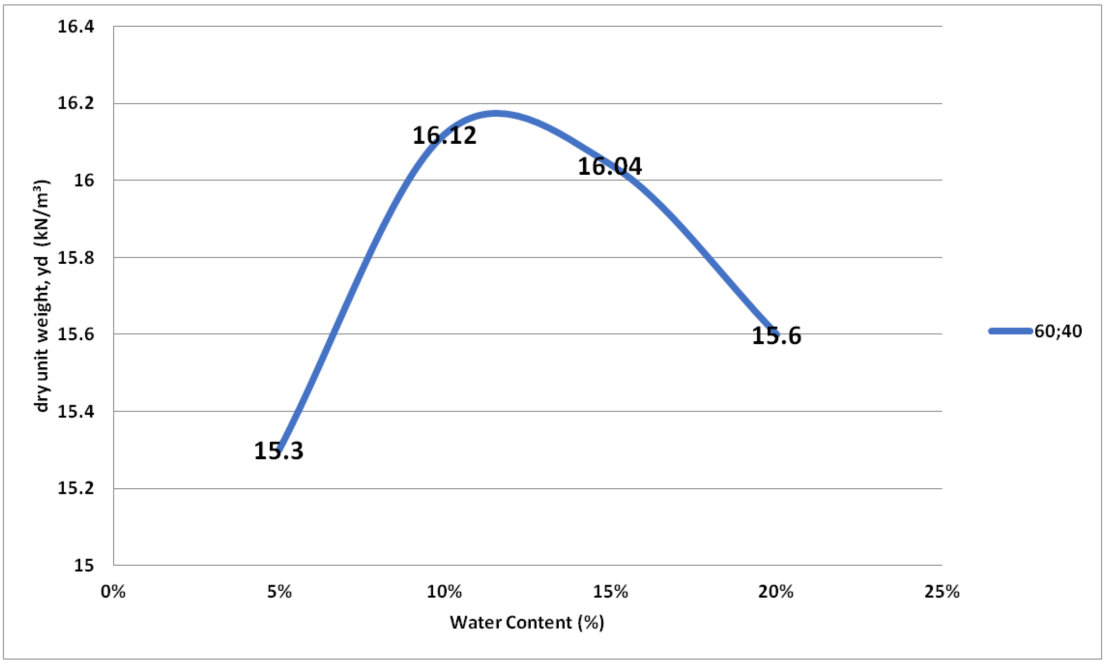

Figure 4.7 Compaction curve of 60% gravel and 40% tyre chips sample

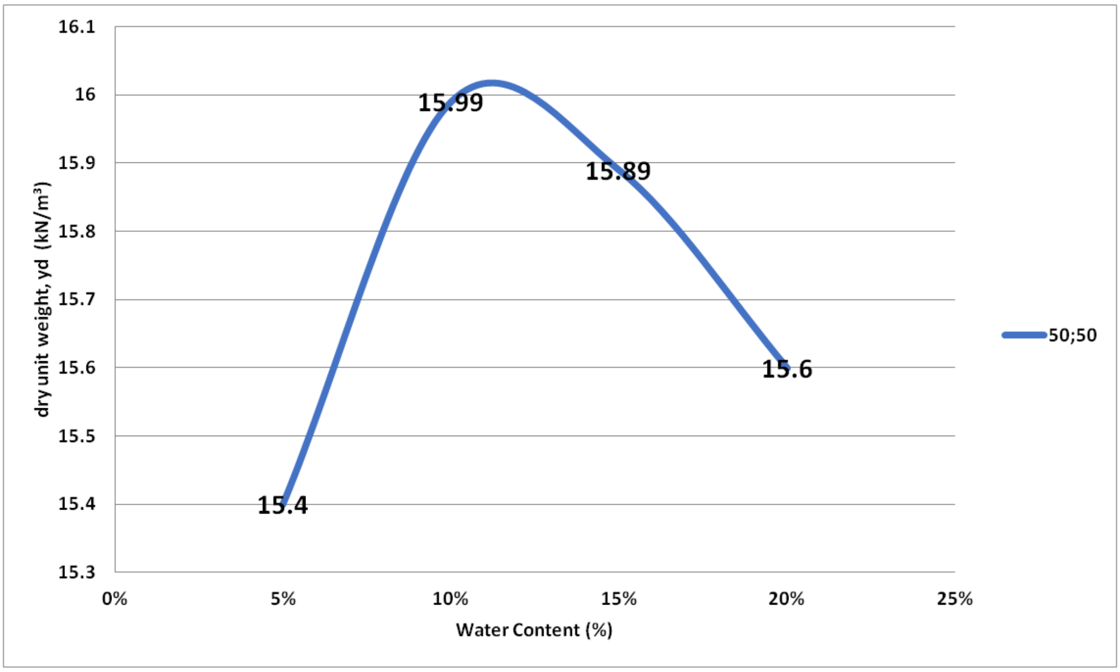

Figure 4.8 Compaction curve of 50% gravel and 50% tyre chips sample

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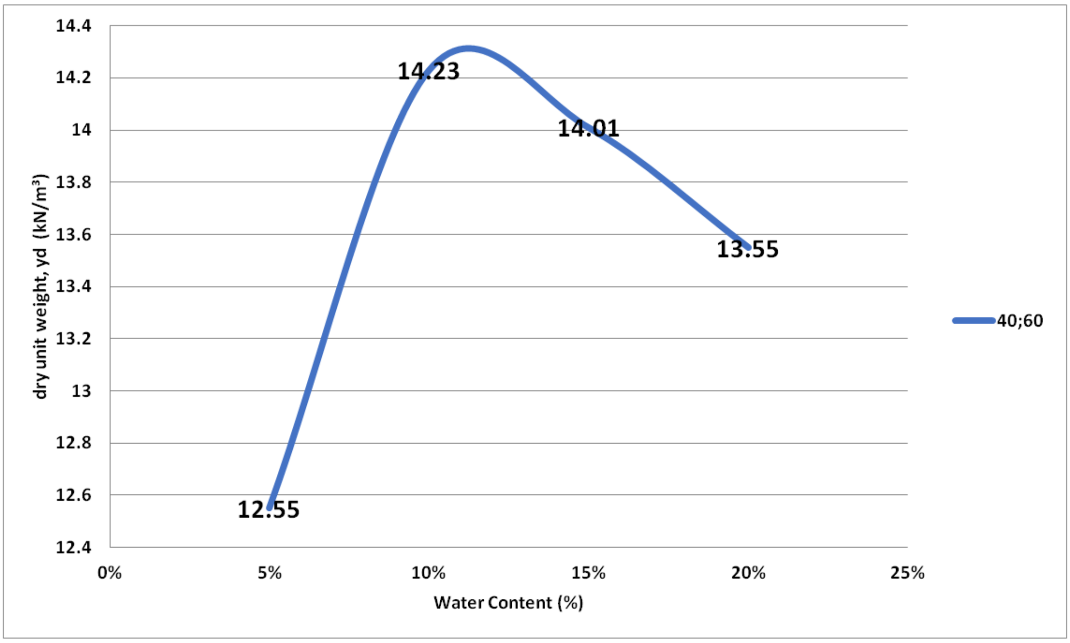

Figure 4.9 Compaction curve of 40% gravel and 60% tyre chips sample

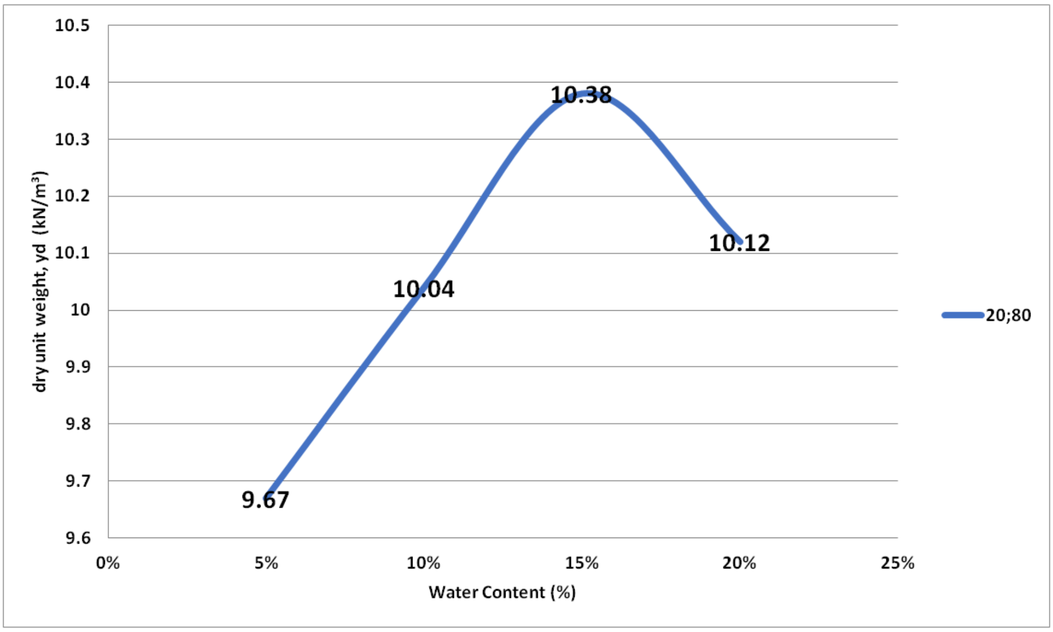

Figure 4.10 Compaction curve of 20% gravel and 80% tyre chips sample

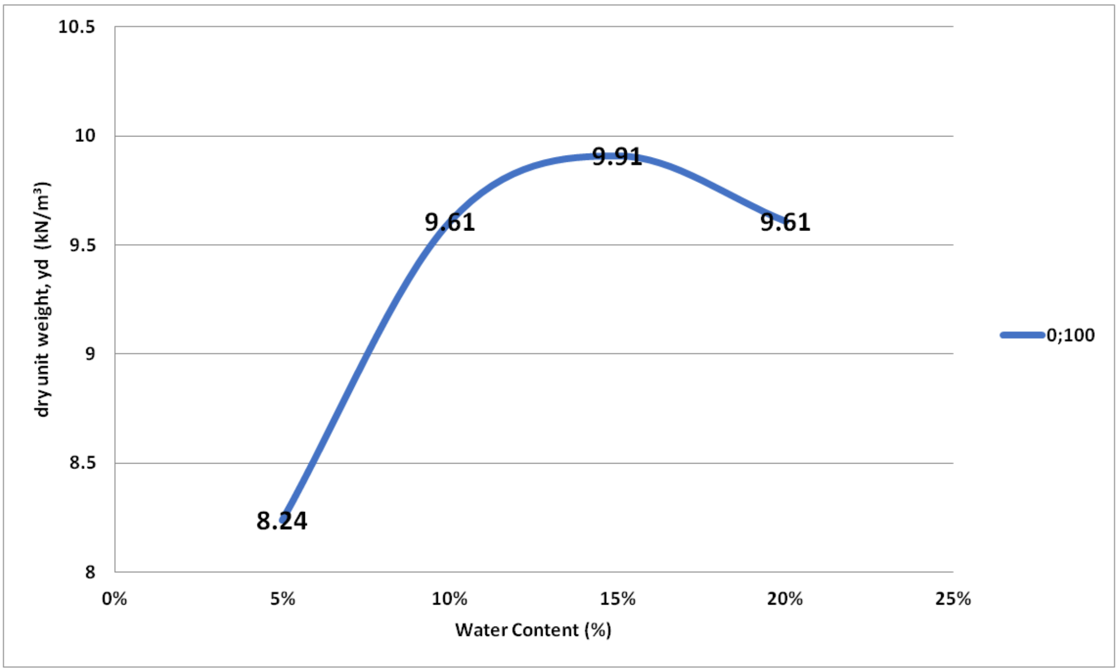

Figure 4.11 Compaction curve of 0% gravel and 100% tyre chips sample

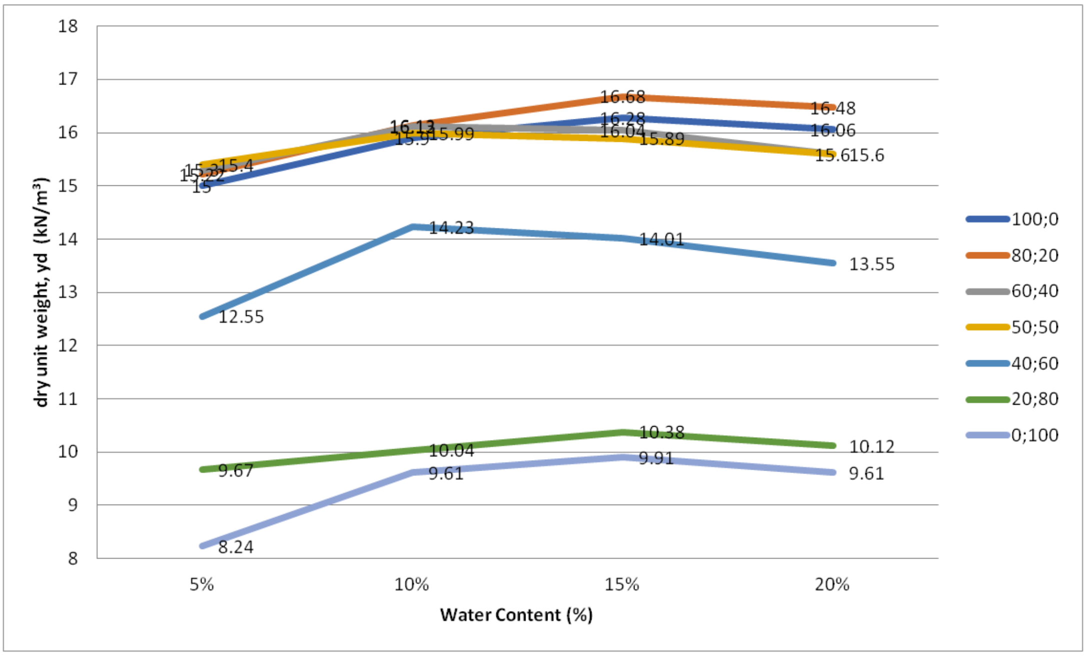

Figure 4.12 Compaction curve of all sample

Table 4.5 Optimun water contain and maximun dry unit weight.

	100:0	**80:20**	**60:40**	**50:50**	**40:60**	**20:80**	**0:100**
Optimum Water Content (%)	15	15	10	10	10	15	15
Maximum Dry Unit Weight (γ_d)	16.48	16.28	16.04	15.99	14.23	10.38	9.91

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Table 4.5 shows the result of compaction curve of seven materials that was used as material for constructing gabion wall. The optimum water content for 100%, 80%, 20% and 0% gravel is found to be 15%. While, for 60%, 50% and 40% of gravel, the optimum water content is 10%. From the results, it is also found that the maximum dry unit weight for the mixture is decrease when the percentage of gravel decrease.

4.2.4 Constant Head Permeability Test

Constant head permeability test was conducted to determine the coefficient of permeability of a soil. Coefficient of permeability is the rate of flow under laminar flow conditions through a unit cross sectional are of porous medium under unit hydraulic gradient is defined as coefficient of permeability.

Soils are permeable (water may flow through the soil) because the soil not only consist of solid particles, but also consist of interconnected pores network. The permeability of soil depends to several factors, such as soil type, grain size distribution and soil history. The permeability of the soil is characterized by the coefficient of permeability. The permeability test was conducted in this research to understand the relationship between permeability of material and percentage of gravel and tyre chips mixture.

Table 4.6 Coefficient of permeability for each mixture sample

Gravel (%)	Tyre Chips (%)	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

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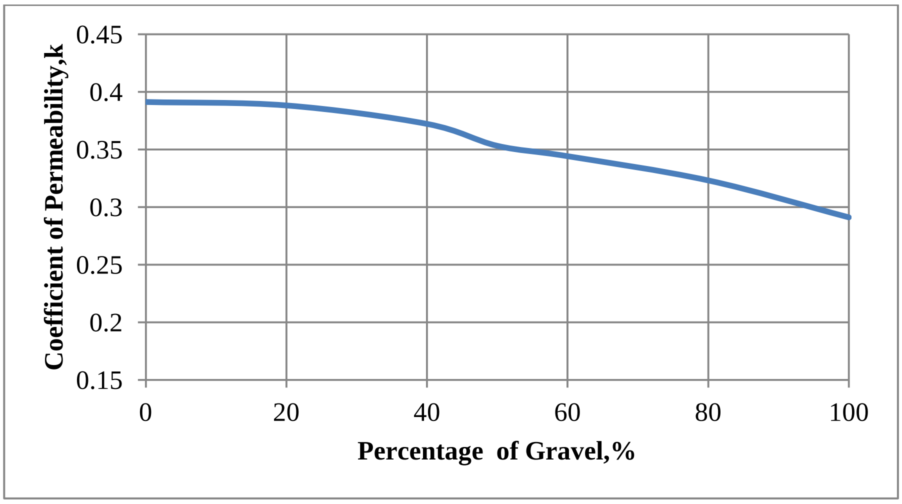

Figure 4.13 Coefficient of permeability against percentage of gravel

From Table 4.6 shows the coefficient of permeability of mixed gravel and tyre chips. The coefficient of permeability value is found to be decreased when the percentage of gravel increases. This is because when tyre chips added into the mixture, the permeability will be increased due to changes in properties such as properties of pore fluid, size and shape of particles, void ratio of tyre chips, adsorbed water of tyre chips, and degree of saturation of tyre chips.

4.3 Slope Model Result

The small-scale slope model was prepared in the model box size of 103.5 cm x 51.5 cm x 35 cm to observe the slope when artificial rainfall with intensity 570mm/h was subjected to the slope. The slope models are exposed to the artificial rainfall in 10 minutes. The movement and displacement of gabion wall were recorded by using digital transducer. The results provide an improved understanding of the behaviour and failure mechanism of an unsaturated soil slope subjected to external water level changes. The angle of slope fixed at 60° for each test. The size of gabions is scaled down with the dimensions 9 x 8 x 9 cm. Figure 4.8 shows the behaviour of the slope without gabion wall after being exposed to artificial rainfall under some time.

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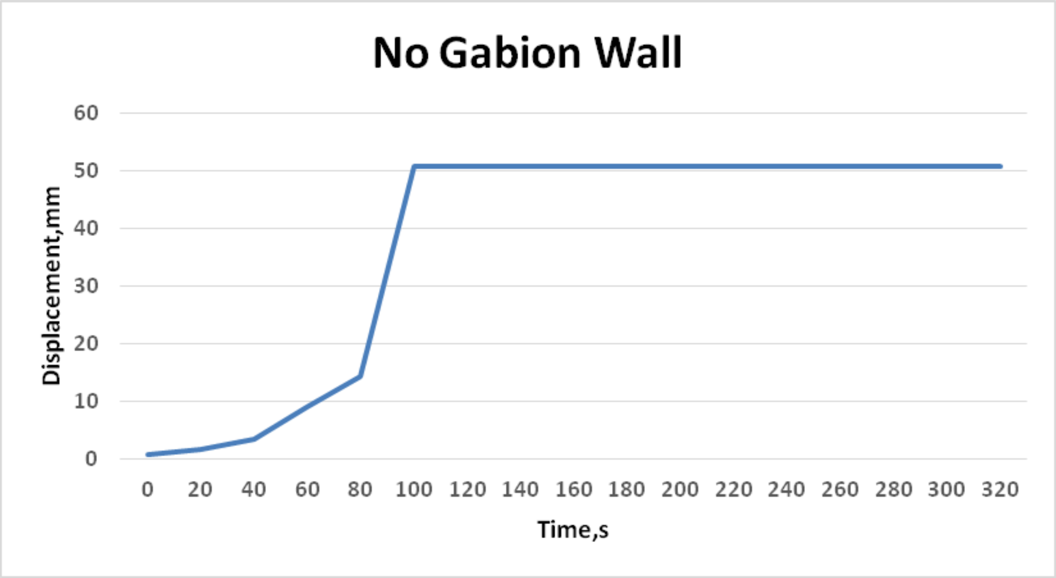

Figure 4.14 Displacement of slope without gabion wall

From Figure 4.14 it can be seen that the slope moves slowly in the first 60 seconds. In 60 to 80 seconds, the slope moves as much as 10 mm. The slope moves rapidly after 80 seconds and completely collapse after 120 seconds of being exposed to the rainfall. This means that it takes only 2 minutes for the slope with critical angle of 60º to collapse under the influence of rainfall without having any gabion wall to retain it.

The next slope model was developed with gabion wall to retain the slope at 60º of critical angle. There is two layers of gabion wall and is arranged with inclined arrangement in front of the slope to retain the slope from failure. The material inside the gabion is varies from gravel, tyre chips, and mixture of both with percentage of 50-50%. Based on the observation, the slope does not collapse even under the influence of rainfall but instead, only the top layer of the gabion is being settled into the soil slope. The movement of the settled gabion is recorded and is shown in Figure 4.15, 4.16 and 4.17 for each of the material used. Lastly, Figure 4.18 shows comparison of displacement of gabion wall for three type of samples.

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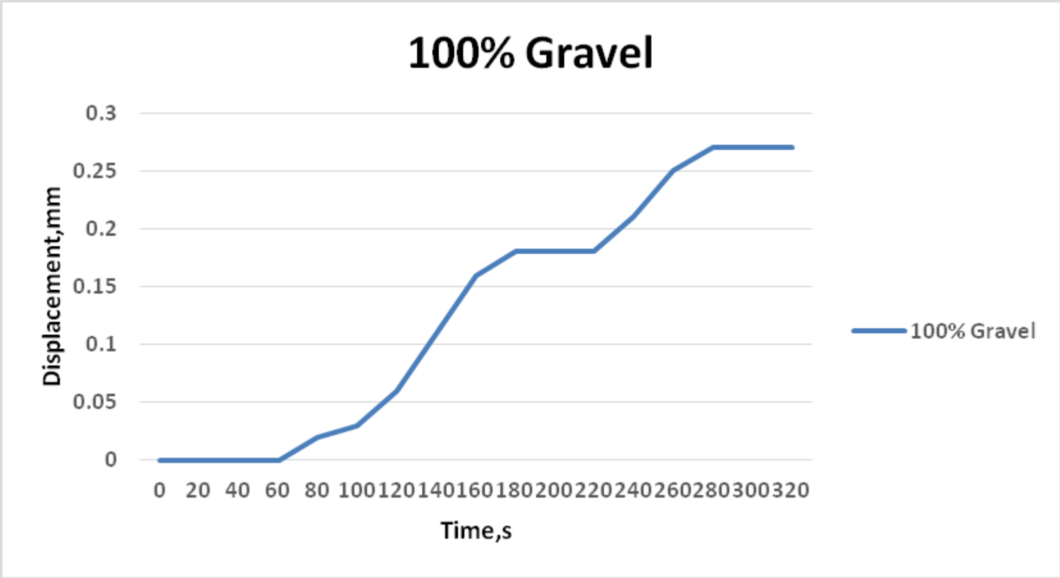

Figure 4.15 Displacement of gabion wall against time for 100% Gravel

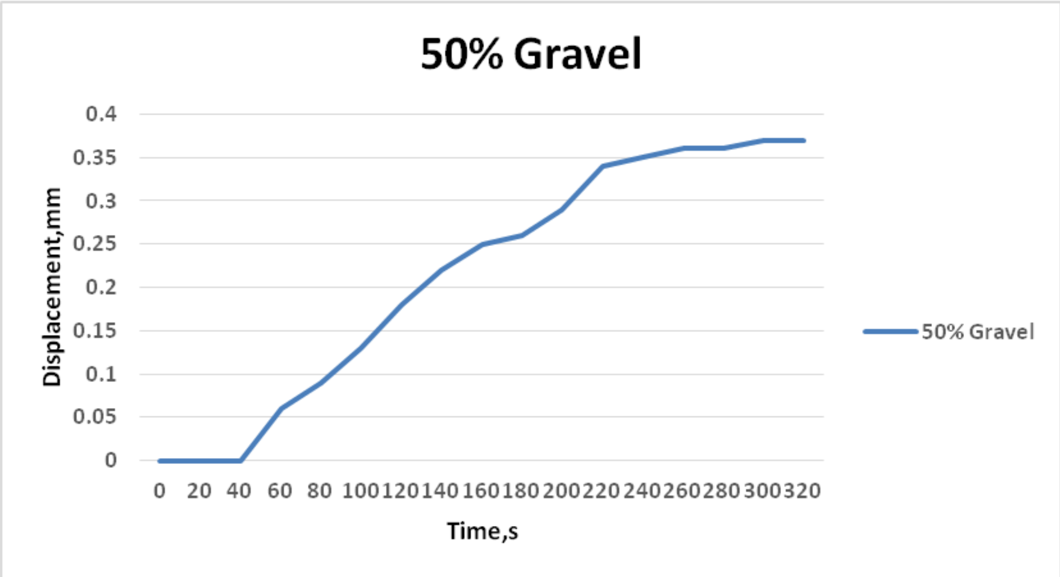

Figure 4.16 Displacement of gabion wall against time for 50% Gravel

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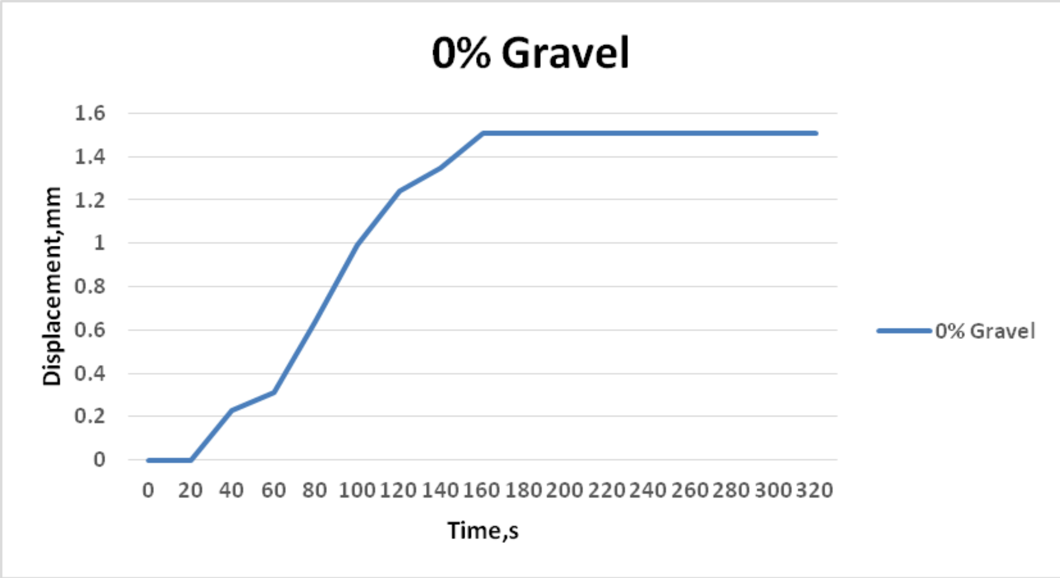

Figure 4.17 Displacement of gabion wall against time for 0% Gravel

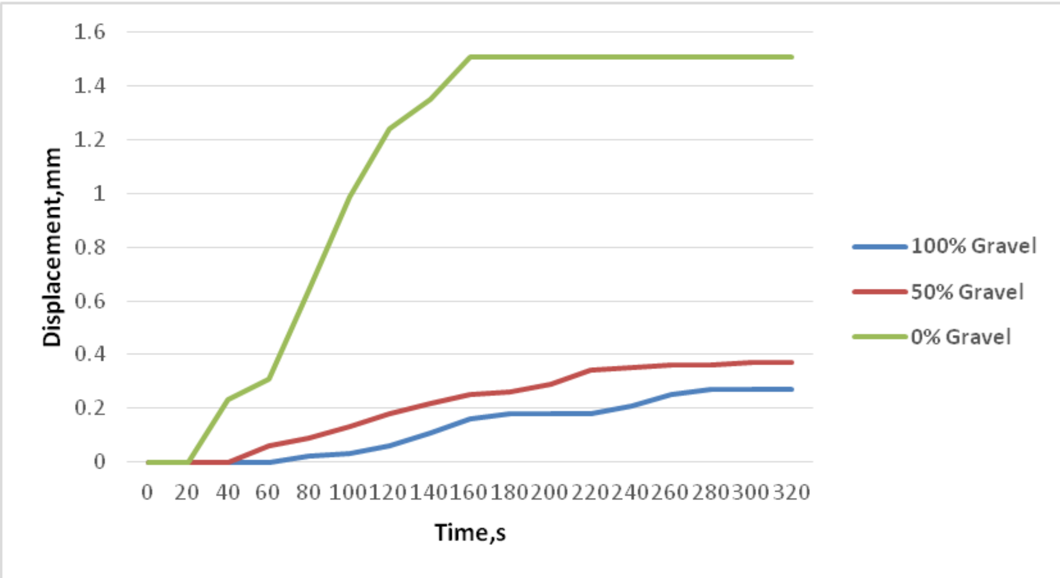

Figure 4.18 Displacement of gabion wall against time for three samples

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CHAPTER 5

CONCLUSION

5.1 Introduction

Gabion wall play an important role in the protection of structures from damage related to soil failure. However, application gravel in gabion needs to be limited because the gravel quarrying is harmful to environment. This is because, gravel quarries resulted to immediate ecological damage, destroy forest land and take away the habitats of animals. Thus, by utilizing tyre chips with gravel can decrease the demand of gravel for gabion wall and at the same time decrease quarries activities. From the model result, it is found that by combining tyre chips and gravel in gabion wall is effective to stabilize slope.

5.2 Conclusion

Several laboratory tests has been made for this study. The laboratory tests include sieve analysis, particle density test, specific gravity test, standard proctor test and constant head permeability test. From sieve analysis, the size of the material used has been obtained. The sizes for sand is range from 0.063 to 19 mm, 3.35 to 19mm for gravel, and 3.35 to 6.3 mm for tyre chips. Specific gravity for each material also has been obtained which 2.41 for sand, 2.17 for gravel, 0.96 for tyre chips and 1.58 for mixture of gravel and tyre chips. Standard proctor test results show the maximum dry unit weight for each material. Maximum dry unit weight for sand is 17.95 kN/m^3, 16.48 kN/m^3 for gravel, 9.91 kN/m^3 for tyre chips, and 15.99 kN/m^3 for mixture of gravel and tyre chips. Coefficient of permeability of each material was obtained from constant head permeability test. The coefficient of permeability for sand is 0.19, 0.29 for gravel, 0.39 for tyre chips and 0.35 for mixture of gravel and tyre chips. With all the results that

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has been obtained, the basic properties of each of the material used had been determined.

Besides that, based on the results and discussion gained from the previous chapter, there are several conclusions that can be drawn. Firstly, the slope model without gabion wall had been collapsed within 120 seconds which was expected as there was no gabion wall to retain the slope from failure. Next, the used of 50% Gravel mixed with 50% tyre chip as a replacement from 100% gravel for gabion wall is strong enough to prevent slope failure and provide support for vertical or near-vertical grade changes for small scale model. Moreover, the value of displacement of gabion wall of 100% gravel which is the current practice at Malaysia is slightly same with 50% Gravel mixed with 50% tyre chip with only 6% different.

Furthermore, stockpiling of tyres and conventionally dump had cause serious hazards and diseases, so by shredded used tyre into chips sizes, the stockpiling of waste tyres can be reduced. Tyre chips can be used as alternative material in gabion wall. The used of gravel in gabion also needs to be decrease because source of gravel may be limited someday and cause ecological damage due to quarries activities. Therefore, by changed 100% gravel to 50% gravel mixed with 50% tyre chips wall decrease used of gravel and effective to mitigate slope failure.

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5.3 Suggestions and Future Study

As mentioned in the first chapter, there are some limitations on this study. Therefore, further study should be carried out in the future to improve the results and also to understand the trends. Some recommendations to improve this research are listed as follows,

i. Slope model with varies critical angle should be developed. The critical angle of the slope that can be developed are 65º, 70º and 75º. The critical angle of the slope plays a major factor in slope stability as the higher the critical angle of a slope, the more likely for the slope to fail.

ii. Percentage of mixture in gabion walls for model test need to be more specific to obtain more accurate and reliable percentage of mixture. For example, in the future the combination percentage of material made up for gabion can be selected as 55% gravel with 45% tyre chips.

iii. Intensity of artificial rainfall for model test also need to consider other intensity at different location because in this study it only focused in Kuantan area. The rainfall intensity is different, depends on the location.

iv. Use larger scale, further study should be carried out future under a larger scale with real case scenario testing to test and analysis on the real performance and outcomes.

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APPENDIX A
LABORATORY WORK PERMIT

Project Risk Assessment Form
ATTACHMENT A

LABORATORY WORK PERMIT

ROOMS/LABS :
PROJECT TITLE : DEVELOPEMENT OF GABION WALL MADE OF RECYCLING MATERIAL (TYRE CHIP) TO MITIGATE SLOPE FAILURE
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	
SHEAR STENGTH TEST	
STANDARD PROCTOR TEST	
CONSTANT HEAD PERMEABILITY TEST	
SPECIFIC GRAVITY TEST	

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
Name : MUHAMAD WAFIY BIN IDZANI
Date : 6/3/18
Contact No: 011-26010868

Supervisor
Name :
Date
Contact No:

Assessor / Head of Laboratory
Name : YOUVENTHARAN A/L DURAISAMY
PENSYARAH
FAKULTI KEJURUTERAAN AWAM & SUMBER ALAM
UNIVERSITI MALAYSIA PAHANG
LEBUHRAYA TUN RAZAK, 26300 KUANTAN, PAHANG
TEL: 09-549 2284/2288 FAKS: 09-549 2299
Date :
Contact No:

Safety Representative
Name : HALIMAN RIDZUAN BIN MAT YATIN
PENOLONG PEGAWAI LATIHAN VOKASIONAL (DV29)
FAKULTI KEJURUTERAAN AWAM & SUMBER ALAM
UNIVERSITI MALAYSIA PAHANG
Date :
Contact No:
20/02/18

Faculty of Civil Engineering & Earth Resources   October 13rd, 2016   9