EFFECTIVENESS OF TYRE CHIPS AS ALTERNATIVE MATERIAL IN GABION WALL TO ENSURE SLOPE STABILITY

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Thesis submitted in fulfillment of the requirements
for the award of the
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Thank you.

ABSTRAK

Kegagalan cerun adalah bahaya geoteknikal yang serius di banyak negara di dunia termasuk Malaysia. Kegagalan cerun adalah satu fenomena dimana cerun runtuh secara tiba-tiba akibat lemahnya daya tahan diri bumi di bawah pengaruh hujan atau gempa bumi. Untuk projek ini, kestabilan cerun akan dikaji untuk mencegah kegagalan cerun berlaku. Langkah pencegahan perlu diambil untuk mengelakkan kemerosotan tanah daripada runtuh atau gagal. Untuk kajian ini, jenis dinding penahan gabion akan digunakan. Dinding gabion adalah tembok penahan yang terbuat dari batu yang disusun dan diikat bersama dengan dawai. Dinding Gabion biasanya bersudut ke arah cerun, atau disusun secara bertangga, dan bukan disusun secara menegak. Batu atau kerikil diklasifikasikan sebagai sumber yang tidak boleh diperbaharui yang akan terhad pada suatu masa akan datang pada masa akan datang. Untuk kajian ini, bukannya hanya batu, tetapi campuran batu dan serpihan tayar akan digunakan untuk mengisi dinding gabion. Model eksperimen dibangunkan untuk mensimulasikan tingkah laku cerun di bawah pengaruh hujan dengan sudut kritikal 60º. Berdasarkan analisis, dapat disimpulkan bahawa serpihan tayar adalah efektif sebagai bahan alternatif untuk dinding gabion bagi memastikan kestabilan cerun di bawah skala kecil.

ABSTRACT

Slope failure is a serious geotechnical hazard in many countries in the world including Malaysia. Slope failure is a phenomenon that a slope collapses abruptly due to weakened self-retainability of the earth under the influence of a rainfall or an earthquake. For this project, slope stability will be studied to prevent slope failure from happened. Preventive measure should be taken in order to prevent slope from collapse or fail. For this study, gabion types of retaining wall will be used. 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. Stones or gravel is classified as non-renewable resources which will be limited someday in the future. For this study, instead of gravel only, a mixture of tyre chips and stones will be use to fill the gabion wall. An experimental model is developed to simulate the behaviour of the slope under the influence of rainfall with a critical angle of 60º. Based on result analysis, it can be concluded that tyre chips is effective as alternate material for gabion wall to ensure slope stability under small scale.

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INTRODUCTION

1.1 Background of Study

Slope failure is a serious geotechnical hazard in many countries in the world including Malaysia. Slope failure is a phenomenon that a slope collapses abruptly due to weakened self-retainability of the earth under the influence of a rainfall or an earthquake. Slope failure, also referred to as mass wasting, is the downslope movement of rock debris and soil in response to gravitational stresses. Material is constantly moving downslope in response to gravity. Movement can be very, very slow, barely perceptible over many years or movement can be devastatingly rapid, apparent within minutes. Whether or not slope movement occurs depends on slope steepness and slope stability. For this project, slope stability will be studied to prevent slope failure from happened. Slope stability is the potential of soil covered slopes to withstand and undergo movement. Slope stability is based on the interplay between two types of forces, driving forces and resisting forces. Driving forces promote downslope movement of material, whereas resisting forces deter movement. So, when driving forces overcome resisting forces, the slope is unstable and results in slope failure. Preventive measure should be taken in order to prevent slope from collapse or fail. 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.

1.2 Problem Statement

In Malaysia, slope failure tragedy had happened so many times before and had caused so many death tragedies, injuries and property damages. As example, the biggest slope failure tragedy happened in 11 December 1993 at Taman Hillview, Ulu Klang, Selangor. The slope failed after prolong rainfall for about 2 weeks and had destroyed 3 blocks of apartment and 48 fatalities. Slope failure also cause a major money spending for the cost of repairing the damages and reparation for the victims.

Nowadays, almost all people in the world own vehicles which used tyres to move. Life expectancy for tyres is almost 2 or 3 years and need to be changed to a new one afterwards. Up to this century, stockpiling of used tyres have been a problem to the environment. The used tyres cannot be bury as tyres are difficult to compact and do not decompose easily. Not only do tyres take up valuable landfill space, but over time they tend to float to the top, working their way up through the waste and soil. Once they break through the surface, the landfill's cover is broken, exposing its contents to insects, rodents, and birds and allowing landfill gases to escape. Besides that, if the tyre is burned or happened to catch a fire, the fires are extremely dangerous and the most difficult problem associated with stockpiled waste tires. These fires are difficult to extinguish as the materials that make tyres good fuel unfortunately also makes tyre fires difficult to put out. Large tyre fires can burn for a long time, depleting firefighting resources. It will also cause air pollution as the hazardous compounds and potentially toxic gases are released in the thick black smoke produced by tire fires. It will also contaminate the ground as the oil and ash created during fires can contaminate the ground, endangering the ground and surface waters, In order to reduce the stockpiling of used tyres, this study proposed the use the tyres as one of the materials in the gabion wall and the effectiveness are studied.

Stones or gravel is classified as non-renewable resources which will be limited someday in the future. As a preventive measure, this study will propose to reduce the use of stones/gravel in the gabion wall. The effectiveness of this method also are studied.

1.3 Objectives of Study

There are two (2) objectives for this study:

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

- To determine the effectiveness of tyre chips and gravel mixture as material in gabion wall to stabilize slope

1.4 Scope of Study

For this project, several types of laboratory tests were conducted to determine the basic properties of the soil. The types of laboratory test that 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.

An experimental model was also developed to study the behaviour and movement of the slope under the influence of rainfall.

CHAPTER 2

LITERATURE REVIEW

2.1 Malaysia’s Climate / Weather

Malaysia is a country in South-East Asia and consist of peninsular Malaysia and east Malaysia. Malaysia is located near the equator which makes it climate equatorial, hot and humid throughout the year. Peninsular Malaysia and east Malaysia experienced different climate as peninsular Malaysia is directly affected by wind from the mainland while east Malaysia experienced maritime weather.

Malaysia experienced two monsoon winds seasons which is the Southwest Monsoon and the Northwest Monsoon. Southwest Monsoon usually commenced in the later half of May or early June and ends in September. The Southwest Monsoon is the drier season throughout the country except for the state of Sabah in East Malaysia. During this season, most states experience monthly minimum rainfall. This monsoon season can be characterized by relatively stable atmospheric conditions in the equatorial region (Chew, 2013). The wind flow is generally light, below 15 knots.

On the other hand, Northeast Monsoon usually commenced in early November and ends in March. The northeast monsoon is the major rainy season in the country. Monsoon weather systems that develop in conjunction with cold air outbreaks from Siberia produce heavy rains that often cause severe floods along the east coast states of Kelantan, Terengganu, Pahang and East Johor in Peninsular Malaysia, and in the state of Sarawak in East Malaysia (Chew, 2013). The wind flow is steady easterly or northeasterly with 10 to 30 knots of wind prevail. The direction of winds in Northeast Monsoon and Southeast Monsoon season is shown in Figure 2.1.

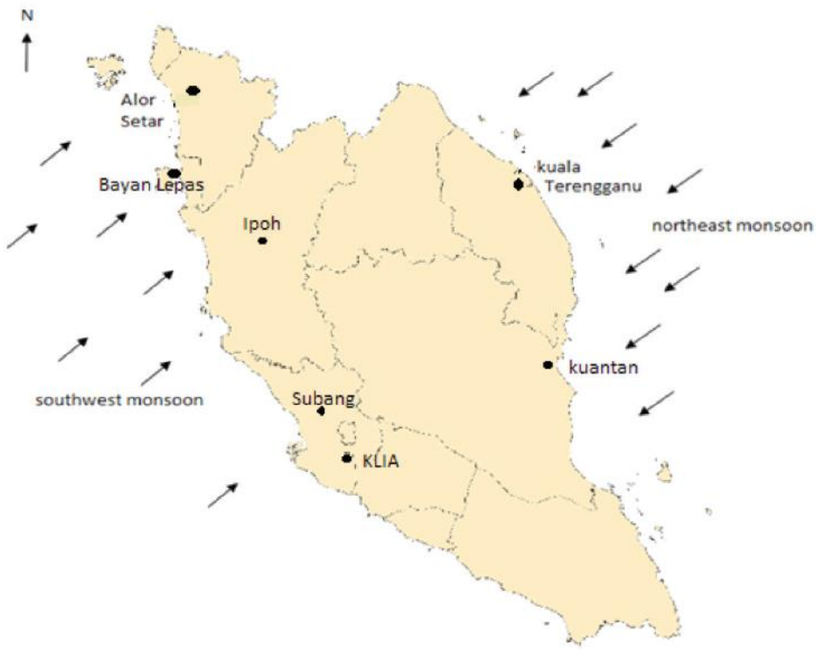

Figure 2.1 Direction of wind in Monsoon season (Hassan, S.F, 2015)

As mentioned earlier, northeast monsoon brings more rain in Malaysia compared to any other seasons, it is not surprising that the highest average rainfall is recorded during that period of time.

Based on the Figure 2.2, the highest rainfall is recorded at the end of the year which October recorded 294.8 mm, November 317mm, December 301.6mm which is in the period of northeast monsoon season.

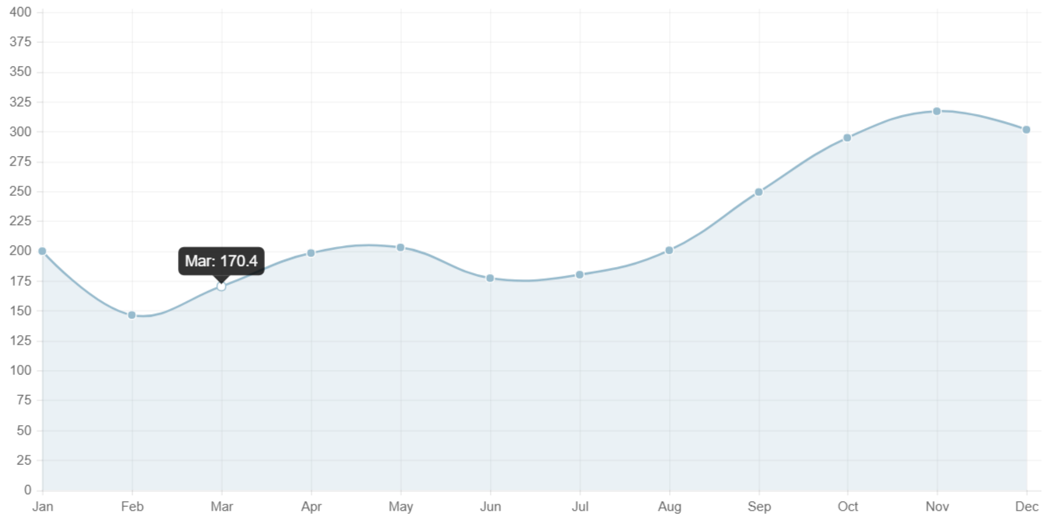

Figure 2.2 Malaysia Annual Average Rainfall Graph (mm)

Source: **(**https://www.travelonline.com/malaysia/weather.html , 2016**)**

2.2 Introduction to Slope Failure

Slope failure can be defined as a phenomenon that a slope collapse unexpectedly or the downslope movement of soil in response to gravitational stresses. Material is constantly moving downslope in response to gravity. Movement can be very slow, barely perceptible over many years or, movement can be devastatingly rapid, apparent within minutes. Whether or not slope movement occurs depends on slope steepness and slope stability (Hughes, 2003).

Slope failure happened when the slope driving forces is greater than the slope resisting forces. Driving forces promote downslope movement of soil from the slope while resisting forces deter the movement of the soil. When driving forces overcome the resisting forces, the slope is unstable and cannot retain itself and results in slope failure. The most driving forces of slope movement is gravity which affected by slope angle, climate, slope material and water. Resisting forces acts oppositely from driving forces. The resistance to downslope movement is dependent on the shear strength of the slope material. The shear strength is a function of cohesion (ability of particles to attract and hold each other together) and internal friction (friction between grains within a material) (Hughes, 2003).

There are several factors that contributed to the slope failure, but they are more likely to occur in certain season if triggered by weather events. For example, rainfall has been the biggest contributor to slope failure. As addition, our country receives annual rainfall about 2000 to 3000 mm per year. Long period of rainfall may saturate, soften and erode the soils. When water enters into the existing cracks, the underlying soil layers may be weakened and lead to slope failure. When rainwater infiltrates a soil profile that is initially in an unsaturated state, a decrease in negative pore pressure (or matric suction) occurs. This causes a decrease in the effective normal stress acting along the potential failure plane, which in turn diminishes the available shear strength to a point where equilibrium can no longer be sustained in the slope (Orense, 2004).

2.3 Mode of Slope Failure

Slope failures are major natural hazards that occur in many areas throughout the world. Slopes expose two or more free surfaces because of geometry. Plane, wedge, toppling, rockfall and rotational (circular/non-circular) types of failure are common in slopes as shown in Figure 2.3. The types of slope failure are primarily controlled by material properties, water content and foundation strength.

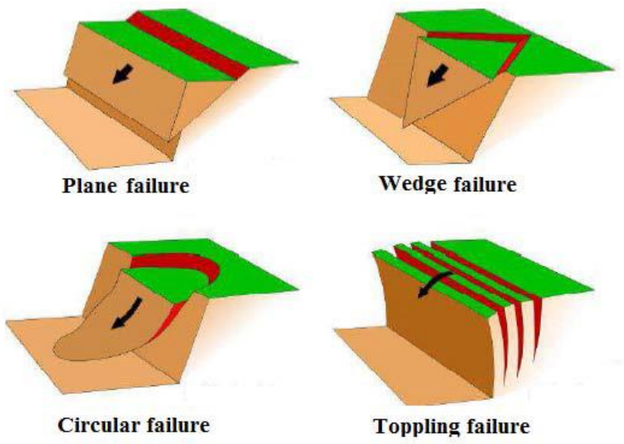

Figure 2.3 Common type of slope failure

Source: (http://content.inflibnet.ac.in/data-server/eacharya-documents/53e0c6cbe413016f234436e8_INFIEP_3/3/ET/3-3-ET-V1-S1__03_types_of_slope_failure.pdf)

2.3.1 Plane failure

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.

2.3.2 Wedge Failure

Wedge failure of rock slope results when 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. Wedge 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, wedge 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 wedge 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 wedge failures are dependent primarily on lithology and structure of the rock mass.

Rock mass with well-defined orthogonal joint sets or cleavages in addition to inclined bedding or foliation are generally favorable situations for wedge failure. Shale, thin-bedded siltstones, clay stones, limestones, and slaty lithologies tend to be more prone to wedge failure development than other rock types. The necessary structural conditions for this failure are summarized as follows:

• The trend of the line of intersection must approximate the dip direction of the slope face.

• The plunge of the line of intersection must be less than the dip of the slope face. The line of intersection under this condition is said to daylight on the slope.

• The plunge of the line of intersection must be greater than the angle of friction of the surface.

2.3.3 Toppling failure

Toppling failures occur when columns of rock, formed by steeply dipping discontinuities in the rock rotates about an essentially fixed point at or near the base of the slope followed by slippage between the layers. The centre of gravity of the column or slab must fall outside the dimension of its base in toppling failure. Jointed rock mass closely spaced and steeply dipping discontinuity sets that dip away from the slope surface are necessary prerequisites for toppling failure. The removal of overburden and the confining rock, as is the case in mining excavations, can result in a partial relief of the constraining stresses within the rock structure, resulting in a toppling failure. This type of slope failure may be further categorized depend on the mode such as flexural toppling, block toppling, and block flexural toppling.

2.3.3.1 Block toppling

Block toppling occurs when individual columns in a strong rock are formed by a set of discontinuities dipping steeply into the face. A second set of widely spaced orthogonal joints defines the column height. The short columns forming the toe of the slope are pushed forward by the loads from the longer overturning columns behind. This sliding of the toe allows further toppling to develop higher up the slope. The base of the failure generally consists of a stepped surface rising from one cross joint to the next. Typical geological conditions, in which this type of failure may occur, are bedded sandstone and columnar basalt in which orthogonal jointing is well developed.

2.3.3.2 Flexural toppling

The process of flexural toppling is a continuous column of rock separated by well developed, steeply dipping discontinuities, breaking in flexure as they bend forward. 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 toppling failure from the bottom of the slope.

2.3.4 Rockfalls

In rockfalls, a rock mass of any size is detached from a steep slope or cliff along a surface on which little or no shear displacement takes place, and descends mostly through the air either by free fall, leaping, bouncing, or rolling. It is generally initiated by some climatic or biological event that causes a change in the forces acting on a rock. These events may include pore pressure increase due to rainfall infiltration, erosion of surrounding material during heavy rain storms, freeze-thaw processes in cold climates, chemical degradation or weathering of the rock, root growth or leverage by roots moving in high winds etc. In an active construction environment, the potential for mechanical initiation of a rockfall may probably be one or two orders of magnitude higher than the climatic and biological initiating events described above.

Movements are very rapid to extremely rapid. Rock fall may involve a single rock or a mass of rocks, and the falling rocks can dislodge other rocks as they collide with the cliff. Rockfalls are a major hazard in rock cuts for highways and railways in mountainous terrain. Once movement of a rock perched on the top of a slope has been initiated, the most important factor controlling its fall trajectory is the geometry of the slope. In particular, dip slope face, such as those created by the sheet joints in granites are important, because they impart a horizontal component to the path taken by a rock after it bounces on the slope or rolls off the slope.

2.3.5 Rotational Failure

In rotational slips the shape of the failure surface in section may be a circular arc or a non-circular curve. In general, circular slips are associated with homogeneous soil conditions and non-circular slips with non-homogeneous conditions. Translational and compound slips occur where the form of the failure surface is influenced by the presence of an adjacent stratum of significantly different strength. Translational slips tend to occur where the adjacent stratum is at a relatively shallow depth below the surface of the slope where the failure surface tends to be plane and roughly parallel to the slope. Compound slips usually occurs where the adjacent stratum is at greater depth, the failure surface consisting of curved and plane sections.

The sliding of material along a curved surface called a rotational slide. These are of two types of rotational slides which is circular and non-circular. While failures of this type do not necessarily occur along a purely circular arc, some form of curved failure surface is normally apparent. Circular shear failures are influenced by the size and the mechanical properties of the particles in the soil or the rock mass. This failure can occur in rock structures that exhibit no plane of weakness and may not be associated with any underlying critical discontinuity.

A circular failure occurs when the individual particles in soil or rock mass are very small as compared to the size of the slope. The broken rock in a fill tends to behave as soil and fail in a circular mode, when the slope dimension is substantially greater than the dimension of the rock fragments. Highly weathered rocks, and rocks with closely spaced, randomly oriented discontinuities such as rapidly cooled basalts also tend to fail in this manner. If soil conditions are not homogeneous or if geologic anomalies exist, slope failures may occur on non-circular shear surfaces. For these conditions, non-circular failure surfaces should be analysed.

2.4 Cases of Slope Failure in Malaysia

Malaysia as a developing country has went through a rapid infrastructure development for the past decade due to the population growth. Many buildings and houses have to be built even at the risky area such as hillside area or mountainous region. In order to cope with the population growth, engineers have to come out with the project at the mountainous region. As a consequence, slope stability issues have been the main threat in construction industry affected by the nature topography of Malaysia (Aminudin, 2009). JKR showed that with increased developments that have went into the hillside areas over the past decades, Malaysia had experienced frequent slope failure tragedies which had caused severe damages and inconvenient to the public. From 1973 onwards, a considerable number of landslides was reported in the local newspapers. Figure 2.4 which shows reported landslides and fatalities from 1973 to 2007, indicates an increase in the number of fatalities with an increase in the number of landslides (National Slope Master Plan, 2009).

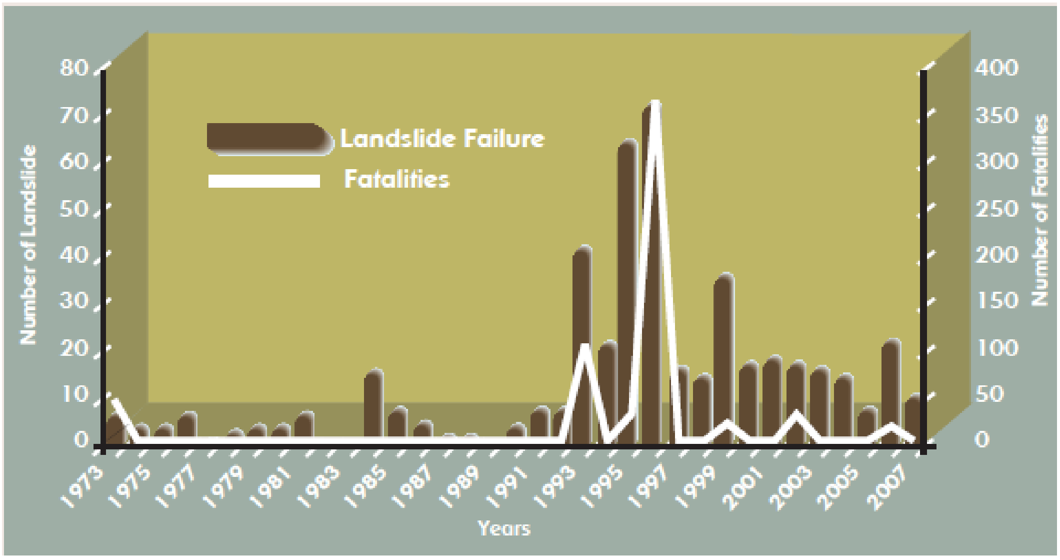

Figure 2.4 Reported landslides and fatalities (1973-2007)
Source: JKR, National Slope Master Plan (2009)

In this country, most cases of slope failure involved hillside areas and caused deaths, injuries and property damages. The most tragic slope failure/landslide happened in 1993 when the Highland Towers collapse in Kuala Lumpur, Malaysia. The tragedy resulted in 48 deaths. The failure of retaining walls under heavy rains was a contributing factor, causing a landslide that led to the building’s collapse. Heavy rain on December 11, 1993 had caused retrogressive landslides behind Block 1, which consequently induced the instability of the rail pile foundation, which was not designed for lateral loading. (Kazmi et. al, 2017). Figure 2.5 shown the image of one of the apartment blocks that collapse in the Highland Tower tragedy.

Figure 2.5 Highland tower collapse.
Source: (http://images.says.com/uploads/story/cover_image/13730/f718.jpg)

2.5 Current Practice / Method to Ensure Stability of Slope

Slope failure tragedies have been so common in Malaysia. Preventive measures should be taken to ensure slope stability in order to prevent this kind of deathly tragedy from happening again. There are many methods that can be used to ensure slope stability. A few of the methods that will discussed in this chapter are:

- Drainage and water control
- Soil nailing
- Geo-synthetic reinforcement
- Retaining wall

2.5.1 Drainage and water control

The presence of water in the slope may come from two source which is surface water (rainfall) and groundwater. High amount of rainfall may increase the pore pressures of the soil in the slope and may cause the slope to fail. Besides that, a rise in groundwater level also often cause the slope to fail. Water can be control through installation of surface drainage and sub-surface drainage within the area of potentially unstable slope. Drainage systems are the most common method in stabilizing slope. This is because a large volume of ground can be stabilized at a very low cost.

2.5.1.1 Surface drainage

Surface drains are used to direct water away from the head and toe of cut slopes and potentially unstable slope. Besides that, surface drains also can reduce infiltration and erosion in and along a potentially unstable slope. Surface water allowed to flow down a slope or to pond on benches of a slope can infiltrate into the ground along discontinuities and thereby cause an increase in the driving forces on an unstable area through a build-up in pore pressure. Grading and shaping are major considerations in the control of surface water. Surface water can be controlled through a combination of topographic shaping and runoff control structures (Glover et al. 1978). Topographic shaping is used to control the rate and direction of surface water flow by manipulating the gradient, length, and shape of the slope. Grading benches to divert water away from the slope face and off the bench. Flatten the gradient of the slope to encourage sheet runoff as opposed to channel flow. Surface runoff is usually collected in permanent facilities such as V- or U- shaped concrete lined or semi-circular corrugated steel pipe channels and diverted away from the slide mass.

In climates experiencing intense rainfall that can rapidly saturate the slope and cause surface erosion, it is beneficial to construct drains both behind the crest and on benches on the face to intercept the water for stability (Government of Hong Kong, 2000). These drains are lined with masonry or concrete to prevent the collected water from infiltrating the slope and are dimensioned to carry the expected peak design flows. The drains are also interconnected so that the water is discharged to the storm drain system or nearby water courses (Wyllie, 2004).

2.5.1.2 Sub-surface drainage

The main functions of sub-surface drains are to remove sub-surface water directly from an unstable slope, to redirect adjacent groundwater sources away from the subject property and to reduce hydrostatic pressure beneath and adjacent to engineered structures. Control of sub-surface drainage is generally attained by installing a network of horizontal and/or vertical sub-surface drains. Figure 2.6 illustrate how sub-surface drainage works.

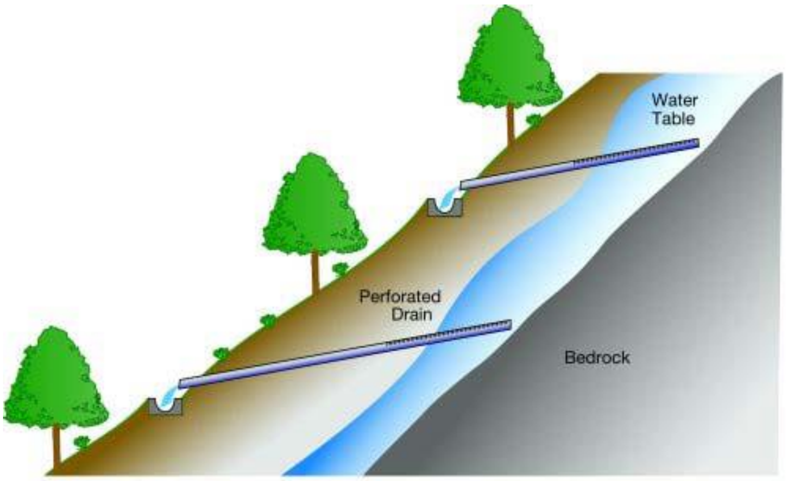

Figure 2.6 Sub-surface drainage.
Source: (http://www.sigra.com.au)

2.5.2 Soil nailing

Soil nailing is a method to treat unstable natural soil slopes. Soil nailing is a technique in which soil slopes are passively reinforced by the insertion of relatively slender elements – normally steel reinforcing bars. Such structural element which provides load transfer to the ground in excavation reinforcement application is called nail (Figure 2.7) (Prashant, 2010). It is a soil reinforcement technique that places closely spaced metal bars or rods into soil to increase the strength of the soil mass by resisting against tensile, shear, and bending stresses imposed by slope movements. Soil nails are either installed in drilled bore holes or secured with grout, or they are driven into the ground. The soil nails are generally attached to concrete facing located at the surface of the structure (figure 2.8). This method allowed in-situ strengthening on existing slope surface with minimum excavation and backfilling, particularly very suitable for uphill widening, thus environmental friendly. Besides that, soil nailing also can be used for strengthening of either natural slope, natural or man-made cut slopes (Shaw-Shong, 2005). Figure 2.9 shows the application of soil nailing in the field.

Figure 2.7 Soil nail with centralizers.

Source: (http://www.williamsform.com/Ground_Anchors/Soil_Nails_Soil_Nailing/soil_nail_soil_nailing.html)

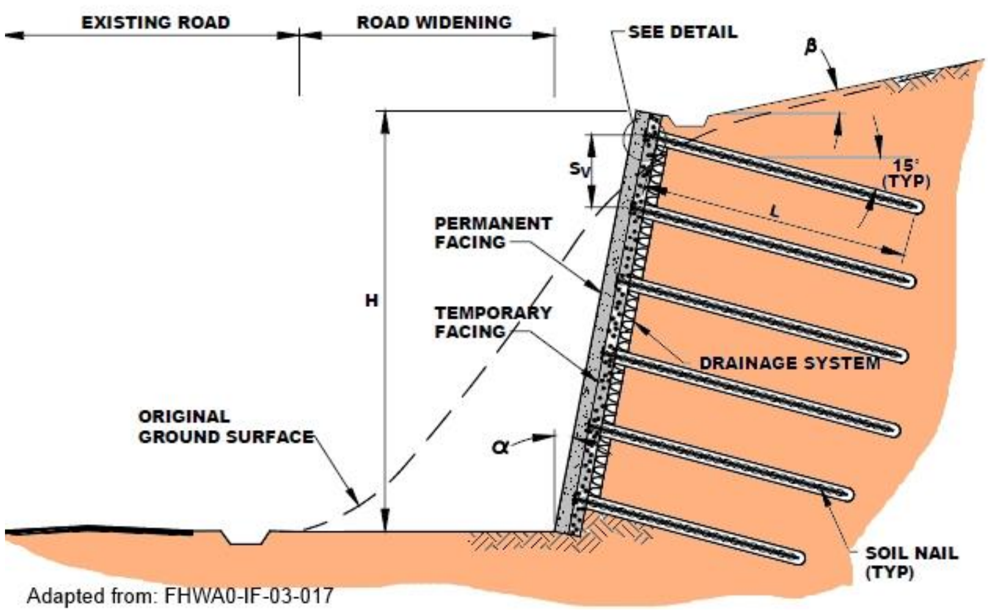

Figure 2.8 Application of soil nail for reinforcing the slope.

Source: (http://www.deepexcavation.com/en/soil-nail-wall)

Figure 2.9 Application of soil nailing in the field.

Source: (http://www.systemdrillers.com/)

2.5.3 Geosynthetics reinforcement

Geosynthetics are porous, flexible, man-made fabrics with function to reinforce and increase the stability of structures such as earth fills, and thereby allow steeper cut slopes and less grading in hillside terrain. Reinforced soil vertical walls generally provide vertical grade separations at a lower cost than traditional concrete walls. Geosynthetic inclusions within a soil mass can provide a reinforcement function by developing tensile forces which contribute to the stability of the geo-synthetic-soil composite (a reinforced soil structure). Design and construction of stable slopes and retaining structures within space constrains are aspects of major economic significance in geotechnical engineering projects (Zornberg, 2007). Geo-synthetics and Geo-synthetics -related materials are generally classified on the basis of their manufacturing process. Geo-synthetics can be knitting, woven, non-woven or composite. Related Geo-synthetics products in use are webs, mats, nets, grids, plastic sheets or composite structure. Geo-synthetics have been used for filtration, drainage, separation, reinforcement, fluid barrier and protection.

Geo-synthetics are classified into the following:

- **i)** **Geotextiles:** geotextiles are permeable fabrics which used in civil engineering purposes that have the ability to separate, filter, reinforce, protect, or drain. It is commonly used to improve soils. Depending on the type of application, geotextiles can be open mesh type, warp-knitted structure, or with a closed fabric surface, such as a non-woven.
- **ii)** **Geogrids:** These are relatively stiff net-like materials with large open spaces between the ribs that make up the structure. They can be used to reinforce aggregate layers in pavements and for construction of geo-cells for improvement of bearing capacity. Geogrids are formed by a regular network of tensile elements with apertures of sufficient size to interlock with surrounding fill material.
- **iii)** **Geomembranes:** A continuous membrane—type liner composed of asphaltic, polymeric materials with sufficiently low permeability so as to control fluid migration. Geomembranes are low permeability geosynthetics used as fluid barriers.

2.5.4 Retaining wall

Retaining wall are structures usually provided at the toe of a slope to stabilize it from slide, overturn or collapse. Wisconsin Department of Transportation (WISDOT) in WISDOT Bridge Manual, 2015 states that retaining walls are used to provide lateral resistance for a mass of earth or other material to accommodate a transportation facility. These walls are used in a variety of applications including right-of-way restrictions, protection of existing structures that must remain in place, grade separations, new highway embankment construction, roadway widening, stabilization of slopes, protection of environmentally sensitive areas, staging, and temporary support including excavation or underwater construction support, etc. The types of retaining walls that are commonly used are; gravity wall, cantilever retaining wall, sheet piling retaining wall, anchored retaining wall, and gabion.

The most important consideration in proper design and installation of retaining walls is to recognize and counteract the fact that the retained material is attempting to move forward and downslope due to gravity. This creates lateral earth pressure behind the wall which depends on the angle of internal friction and the cohesive strength of the retained material, as well as the direction and magnitude of movement the retaining structure undergoes.

Lateral earth pressures are zero at the top of the wall and in homogenous ground increase proportionally to a maximum value at the lowest depth. Earth pressure can push the wall forward or overturn it if not properly considered. Also, any groundwater behind the wall that is not dissipated by a drainage system causes hydrostatic pressure on the wall. Unless the wall is designed to retain water, it is important to have proper drainage behind the wall in order to limit the pressure to the wall's design value. Drainage materials will reduce or eliminate the hydrostatic pressure and improve the stability of the material behind the wall.

2.5.4.1 Gravity wall

As shown in Figure 2.10, a gravity wall is typically made of stone, brick masonry or concrete and relies on its huge weight for stability. Gravity is able to hold back the earth or soil, due to its construction. For this purpose, the mass of the structure must be sufficient to develop enough frictional resistance to sliding, and the base or footing of the structure must be wide enough to develop sufficient moment to resist overturning earth forces.

The thickness of the wall at the base exceeds that at the top. Construction of gravity walls demands a high quantity of building materials. That is the reason why these walls are difficult to build and get more cumbersome as they get higher.

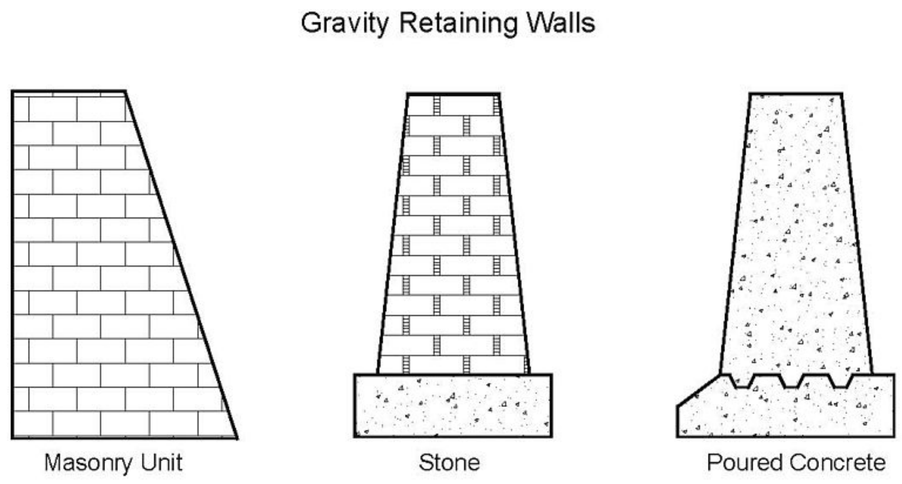

Figure 2.10 Gravity walls with different type of material.
Source: (https://commons.wikimedia.org/wiki/File:Gravity_Walls.jpg)

2.5.4.2 Cantilever Retaining Wall

Cantilever walls are made from a relatively thin stem of steel-reinforced, cast-in-place concrete or mortared masonry (often in shape of and inverted T) (Ahmad, 2007). It means that the walls transform horizontal pressures from behind the wall into vertical pressures on the ground below. The footer of cantilever walls should be wide enough to prevent the wall from tipping. The thickness of not only the footer but also that of the wall is important. The wall is built with steel-reinforcement in both the footing and wall structures. Figure 2.11 shows the cross-section view of a cantilever wall.

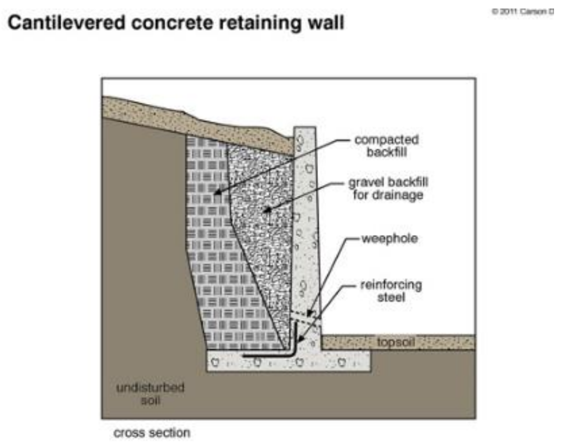

Figure 2.11 Cross section view of a Cantilever wall.

Source: (http://www.ashireporter.org/HomeInspection/Articles/Retaining-Walls/2159#RetainingWalls-1947.jpg)

2.5.4.3 Sheet Piling Retaining Walls

Sheet piling retaining walls are utilized for areas having soft soils and tight spaces. Materials such as steel, vinyl or wood planks go into the making of these types of retaining walls. The statistics of the walls include one-third portion above the ground and the rest (two-third) below ground level. A cable or a rod is used as a tie-back anchor to the walls. The rods are placed at a distance and tied to the back of the walls. Proper drainage has to be ensured during construction of such walls to encounter hydrostatic pressure which may cause instability within the walls. Figure 2.12 shows the view of a sheet piling wall in the soil.

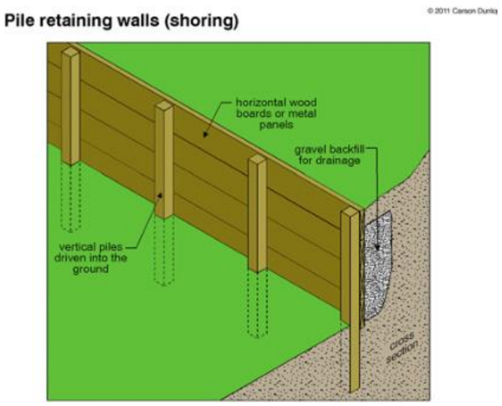

Figure 2.12 Sheet piling wall in the soil.

Source: (http://www.ashireporter.org/HomeInspection/Articles/Retaining-Walls/2159#RetainingWalls-1947.jpg)

2.5.4.4 Gabion

Gabions are cages, cylinders, or boxes filled with soil or sand that are used in civil engineering and road wall particularly in hilly region. For dams or foundation construction, cylindrical metal structures are used. Gabions are multi-celled, welded wire or rectangular wire mesh boxes, which are then rock-filled, and used for construction of erosion control structures and to stabilize steep slopes as shown in Figure 2.13. Their applications include:

- Retaining walls,
- Bridge abutments,
- Wing walls,
- Culvert headwalls,
- Outlet aprons,
- Shore and beach protection walls, and
- Temporary check dams.

Figure 2.13 Application of gabion wall at cut slope.
Source: (https://www.gabionsupply.com/retaining-walls.html)

2.6 Waste Tyres

Wastes generally are inevitable products that are generated by every living organism. This extends from the simple unicellular organism such as *Amoeba Proteus* to the complex multi-cellular organism such as man (Mahlangu, 2009). Nowadays, with increase in population, the volume of wastes generated also increases. The industrial era brought about tremendous improvement in the standard of living of man. This was also accompanied by the introduction of different kinds of waste materials, some of which are detrimental to our lives and the environment. These wastes are in the form of solid wastes e.g. waste tyres, broken glasses, spent nuclear fuels, plastics; liquid wastes e.g. leachates, general chemical and gaseous wastes such as methane emitted from landfills, carbon-monoxide etc. Waste tyres has been classified or defined as tyres that are bald and worn down to the tread belt or have bulges or sidewall damage and are not suitable to be re-treaded as a result of long use (Adhikari and Maiti, 2000).

Waste tyres are bulky and difficult to dispose. Their nature does not allow compression or folding in order to reduce the space occupied during disposal at landfills and they also do not degrade easily (Adhikari and Maiti, 2000; Weng and Chang, 2001). In addition, when whole waste tyres are land filled, they trap air in their curvatures with possibility of migrating to the top of the landfill, hence breaking the sanitary cap and creating further problems (Van Beukering and Jassen, 2001).

Shredding of the waste tyres before disposal has been suggested and tried for size reduction before disposal. The high operational costs of this process made it an unattractive option. Subsequently, many landfills around the world stopped accepting waste tyres due to the aforementioned problem of size among others where the land becomes filled quickly (ANZECC,1994 and ASTMC, 1994). This situation eventually leads to waste tyres becoming litters in the environment.

Presently, waste tyres in the country could be regarded as constituting a menace to human and environmental health (Human, 2005). They are found in illegal dumpsites across the country which harbour storm or rain water and thus constitute breeding haven for mosquitoes. They are burn for the generation of heat by people in rural areas, low income residential areas and informal settlements. It is widely known that such action will lead to the release of noxious gases such as the NOx, SOx, COx, dioxins etc into the atmosphere causing the atmospheric pollution (Mahlangu, 2009).

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. Consequently, recycling of any material in a sustainable manner requires the critical consideration of:

- Economic growth and
- Environmental protection

One of the fastest growing markets in the United States is the use of waste tyres in civil engineering applications (STMR, 1994). The process can be called physical application because the waste tyre does not undergo any chemical process where the structure (thermosetting materials) is broken down. The waste tyre can be used whole or chipped in the following applications:

- Clean fill, gravel and sand. (Waste tyres are used as they are without physical or chemical processing). In this regard, waste tyres are used as light weight back fill, as road embankment fill, as leachate collection system and as septic field drainage material.
- Artificial reefs.
- Floating breakwaters.
- Erosion control.
- Silage production. Here tyres are used to hold plastic sheeting.
- Landscaping. There is some use of waste tyres as a base for landscaping in raised garden beds and cascading rock gardens.

CHAPTER 3

METHODOLOGY

3.1 Introduction

For this study, several types of laboratory test were conducted to determine the basic properties of the soil, and tyre chips. The laboratory test that were conducted are sieve analysis, particle density test, specific gravity test (gravel and tyre chips), standard proctor test and constant head permeability test.

Besides that, gabion type of retaining wall was used to ensure the stability of slope 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 are developed to simulate the behaviour of slope with and without the gabion wall. The model is then 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 will be observed. Figure 3.1 shows the flowchart of this study.

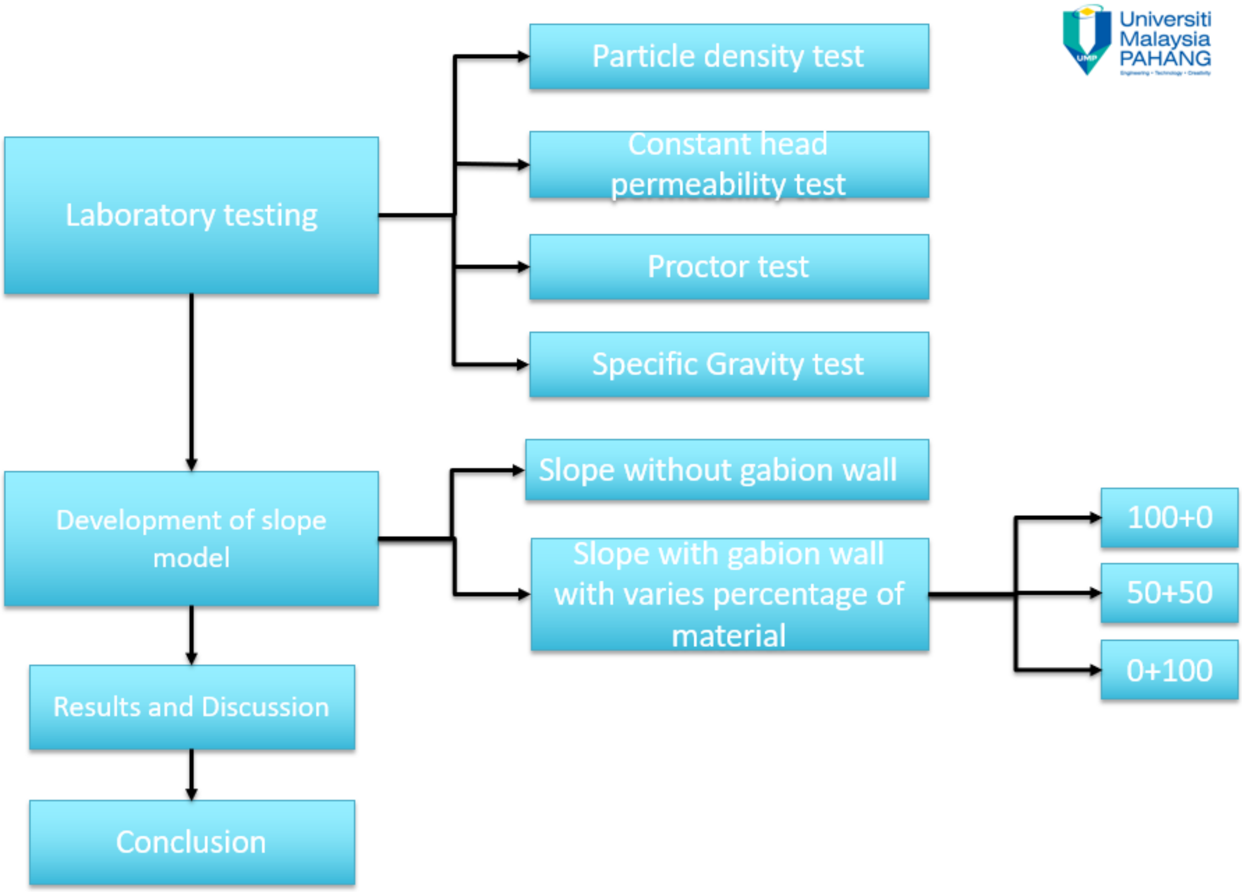

Figure 3.1 Methodology flow chart

3.2 Laboratory Test (Sand, Gravel, Tyres)

Several laboratory tests were conducted to know the basic properties of each material. The laboratory test includes sieve analysis, particle density test (Pycnometer), specific gravity test (gravel and tyre chips), standard proctor test and constant head test.

3.2.1 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 analysers 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.

3.2.2 Particle Density Test (Pycnometer)

The particle density test or specific gravity of soil is expressed as the ratio of the total mass (in grams) of solid particles to their total volume (cm^3). 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.

Equation 3.1 used to determine particle density (Dp);

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

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

3.2.3 Specific Gravity Test (Gravel and Tyre Chips)

Specific gravity test is used to determine specific gravity (relative density) and absorption of coarse aggregate.

Test sample was soaked in water for at least 24 ± 4 hours, after soaking process is completed, sample are removed from water and the outside surface is wiped from all particle by dampen cloth. By this way, test sample change from fully saturation to saturation surface dry (SSD). The mass of SSD sample is measured and recorded as (B). the sample is then submerged in water and the mass in water is measured and recorded as (c). The test sample placed in oven till obtain a constant mass. The completely dry sample is measured to obtain the mass of test sample and recorded as (A). Then both specific gravity and absorption can be calculated by using equation.

The specific gravity is calculated by using equation 3.2;

$$\text{Specific Gravity, Gs} = A/ A- (C-D-B) \qquad 3.2$$

Where A = Mass of sample

B = Mass of bowl + lid + water

C = Mass of sample + bowl + lid + water

D = Mass of cage

3.2.4 Standard Proctor Test

Standard proctor test was carried out to determine compaction of soil to understand compaction characteristics of different soils with change in moisture content.

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;

$$Yd = \frac{Yt}{1+w} \qquad 3.3$$

Where Y_t = bulk density

w = water content

A series of samples of the soil are compacted at different water contents, and a curve is drawn with axes of dry density and water content. The resulting plot usually has a distinct peak as shown. Such inverted "V" curves are obtained for cohesive soils (or soils with fines) and are known as compaction curves (Figure 3.2).

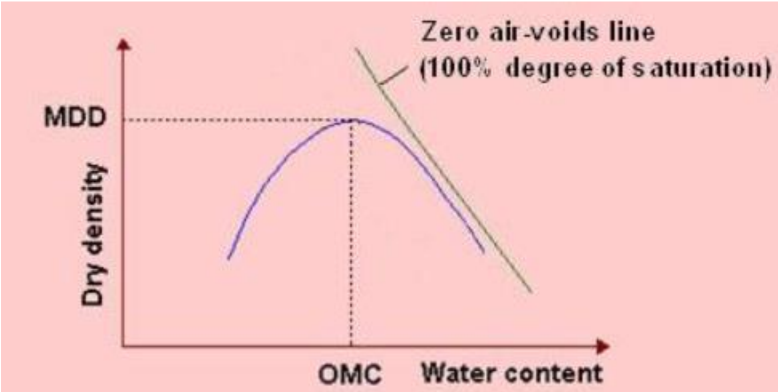

Figure 3.2 Compaction curve

3.2.5 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 flow of water through a column of 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 a 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.

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 can be calculated by using equation 3.4

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

3.3 Preparation of Material

For this study, a model of a slope and gabion filled with mixture of gravel and tyre chips are developed.

Used tyres were collected and shredded to chips size. Then, the tyres chips were filled in the gabion's cage.

Gabion are made of a cage or wire mesh filled with gravel and for this study it was mixed with tyre chips. The wire mesh was made by using aluminium wire and was knitted using plier with scaled down ratio of 1cm to 1m from the actual dimension of wire mesh in the field.

The frame that held the model of soil slope and gabion also were prepared. The frame was made from Perspex. The size of the Perspex frame was 51.5cm width, 103.5cm long and 35cm height. Figure 3.3 and Figure 3.4 shows the size of the Perspex frame and the dimension of gabion that was used respectively.

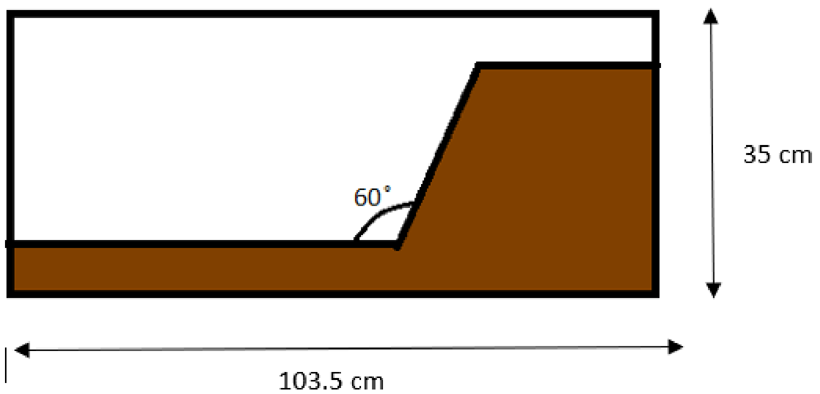

Figure 3.3 Cross section of the Perspex frame

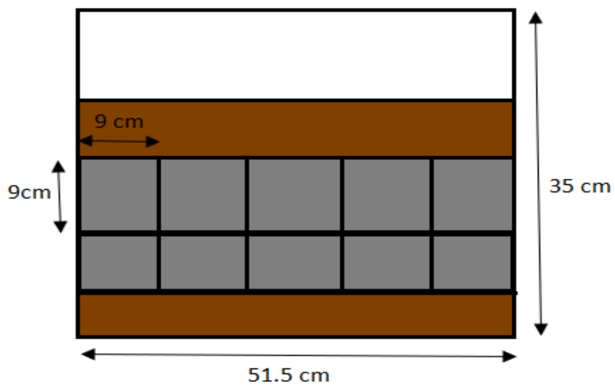

Figure 3.4 Front view of the gabion wall and the Perspex frame

3.4 Development of Slope Model

The frame made of Perspex was made first hand it held the slope and the gabion. The Perspex frame was made with dimension of 51.5cm width, 103.5cm long and 35cm height.

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

The slope model was made with 60˚ angle of critical. The sand was wetted with water first to make the sand damp. It was done in order to make the sand easier to be shape. The sand was then shaped into slope with 60˚of critical angle. 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 was 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.

Two models of slope were made. The first slope model was a slope without gabion wall. The slope model was the exposed under the rainfall with intensity of 570mm/hr. The second slope model was a slope with gabion wall with terrace arrangement. The material of the gabion wall was the manipulative factor as the materials were varied from gravel to tyre chips and the mixture of 50-50% percentage of both material. The constant variable for this model is the arrangement of gabion wall and also the rainfall intensity.

Figure 3.5 shows the slope model with the arrangement of gabion wall that had been developed.

Figure 3.5 Arrangement of gabion wall at slope model

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

Several laboratory test that includes particle density test, specific gravity test, standard proctor test and constant head permeability test had been conducted. The results of each of the test for each of the material used had been obtained and recorded.

Besides that, two models of slope had been developed. The first slope model is without gabion wall and the second slope model is with gabion wall but with varies materials. Both of the model is exposed to the artificial rainfall. The behaviour of the slope model under the influence of rainfall had been observed and the data had been recorded.

4.2 Laboratory Test Results

4.2.1 Sieve Analysis

The objective of sieve is to obtain the particle size distribution and the grading curve for a given soil sample. As for this study, the soil sample is sand, gravel and tyre chips.

For sieve analysis, the mass retained on the first sieve is subtracted from the initial mass (m_1) to give the mass passing the first sieve. The mass retained on each subsequent sieve is subtracted from the mass passing the previous sieve to give the mass passing each sieve. Each mass passing is the expressed as a percentage of the initial mass. The process is summarized as in Table 4.1. Each mass retained is subtracted from the mass passing the previous sieve.

Table 4.1 Calculation for sieve analysis

Mass Passing	**% Passing**
m_1	100
$m_1 - m_{s1} = a$	(a/m1) x 100
$a - m_{s2} = b$	(b/m1) x 100
$b - m_{s3} = c$	(c/m1) x 100
$d - m_{s4} = d$	(d/m1) x 100

Figure 4.1 shows that the sieve analysis results for sand sample shows that the sand sample is well graded. The size distribution of sand sample is range from 0.063 – 19 mm.

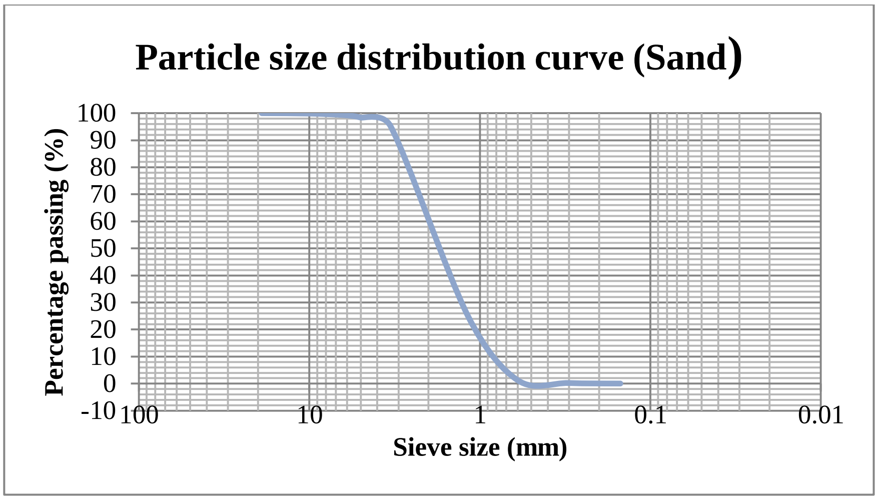

Figure 4.1 Particle size distribution curve for sand

Figure 4.2 shows the particle distribution curve for gravel. From the particle distribution curve, the size for the gravel used can be obtained. The size for the gravel used range from 3.35 – 19 mm.

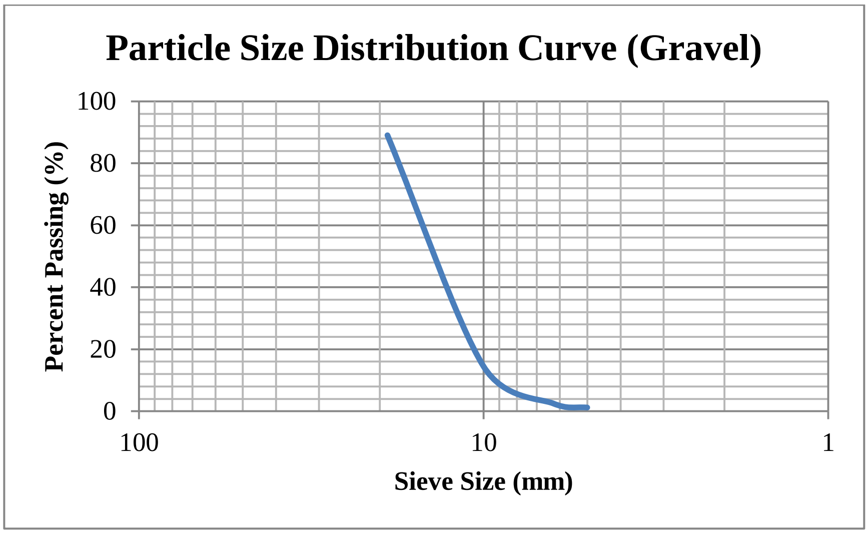

Figure 4.2 Particle size distribution curve for gravel

Figure 4.3 shows the particle size distribution curve for tyre chips that is being used. The particle size distribution curve shows that the curve for tyre chips is uniform. The size of tyre chips used range from 3.35 – 6.3 mm.

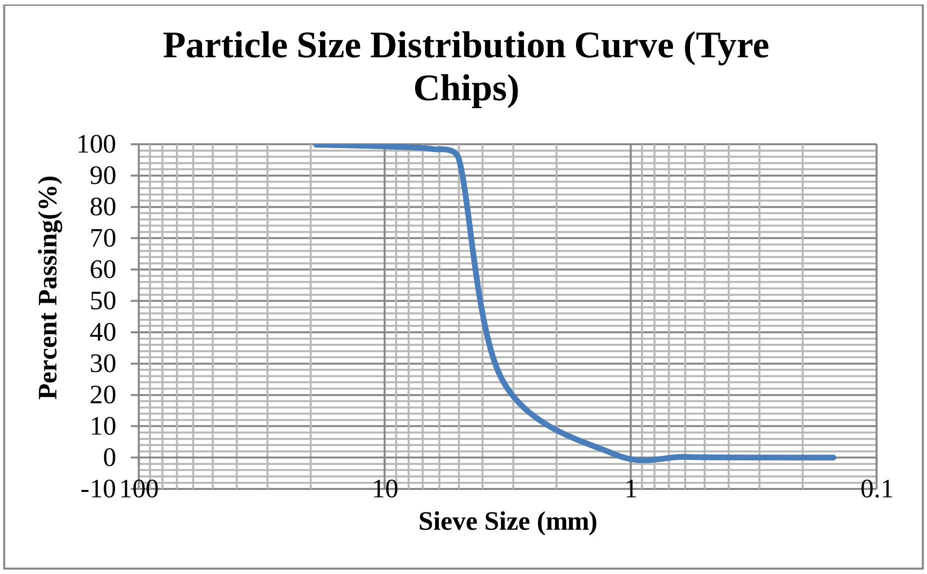

Figure 4.3 Particle size distribution curve for tyre chips

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 4.1.

$$Gs = \frac{W2-W1}{(W4-W1)-(W3-W2)} \qquad 4.1$$

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	36.3
Mass of bottle + stopper + dry soil (w2)	g	41.95	42.18	46.3
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	10	10
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		2.3753	2.39234	2.47525
Average specific gravity			2.414296311	

Specific gravity test was 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.

Specific gravity of tyre chips is obtained by using equation 4.2;

$$\text{Specific Gravity, } G_s = A / A - (C-D-B) \qquad 4.2$$

Where A = Mass of sample

B = Mass of bowl + lid + water

C = Mass of sample + bowl + lid + water

D = Mass of cage

Table 4.3 shows the specific gravity value for gravel, tyre chips and mixture of gravel and tyre chips with percentage of 50 – 50%.

Table 4.3 Specific gravity

Material	No	Description	Weight (kg)	Specific Gravity, Gs
Gravel	A	Weight of Sample	0.659	2.17
	B	Weight of Bowl + Lid + Water	14.88	
	C	Weight of Sample + Bowl + Water + Lid	15.4	
	D	Weight of Cage	0.162	
50-50% mixture of gravel and tyre chips	A	Weight of Sample	0.514	1.58
	B	Weight of Bowl + Lid + Water	14.88	
	C	Weight of Sample + Bowl + Water + Lid	15.23	
	D	Weight of Cage	0.162	
Tyre Chips	A	Weight of Sample	0.206	0.96
	B	Weight of Bowl + Lid + Water	14.88	
	C	Weight of Sample + Bowl + Water + Lid	15.033	
	D	Weight of Cage	0.162	

4.2.3 Standard Proctor Test

Standard Proctor test is conducted to determine the maximum dry density and the optimum moisture content of material used. This test had been conducted on each material used.

Table 4.4 shows the calculation of dry unit weight for sand. From Figure 4.4, the compaction curve shows the maximum dry unit weight for sand is 17.95 kN/m^3 and the optimum water content is 15%.

Table 4.4 Calculation for dry unit weight and water content for sand

Water content	**Unit**	**5%**		**10%**		**15%**		**20%**	
Mass of mould + base (m_1)	g	4138.02		4138.02		4138.02		4138.02	
Mass of mould + base + compacted specimen (m_2)	g	5823.6		5928.27		6077.1		6102.6	
Mass of compacted specimen (m_2-m_1)	g	1685.58		1790.75		1939.08		1964.58	
Bulk density, p = (m_2-m_1)/v	g/cm³	1.77		1.88		2.04		2.06	
Container no		1	2	1	2	1	2	1	2
Container weight	g	14.38	13.99	14.63	14.21	13.68	14.27	10.77	10.11
Wet soil + container	g	42.37	37.08	27.88	48.01	45.31	51.39	40.79	30.7
Wet soil, W_w	g	27.79	23.09	13.25	33.8	31.63	37.12	30.02	20.59
Dry soil + container	g	40.55	35.63	26.71	45.08	42.07	47.56	37.12	28.26
Dry soil, W_d	g	25.97	21.69	12.08	30.89	28.39	33.29	26.35	18.15
Moisture loss, W_w-W_d	g	1.82	1.4	1.17	2.93	3.24	3.83	3.67	2.44
Moisture content	%	7	6.5	9.7	9.5	11.41	11.5	13.9	13.4
Average moisture content	%	6.75		9.6		11.45		13.65	
Dry density, pd = p/ (1+w)	g/cm³	1.66		1.71		1.83		1.81	
Dry unit weight, yd	kN/m³	16.28		16.98		17.95		17.76	

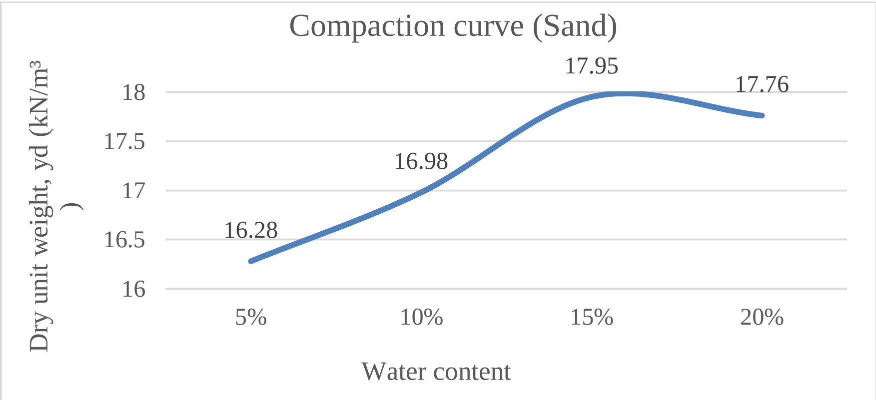

Figure 4.4 Compaction curve for sand

Table 4.5 shows the calculation for dry unit weight for gravel. Based on Figure 4.5, the compaction curve shows that the maximum dry unit weight for gravel is 16.48 kN/m³ and the optimum water content is 15%.

Table 4.5 Calculation for dry unit weight and water content for gravel

Water content	**Unit**	**5%**		**10%**		**15%**		**20%**	
Mass of mould + base (m_1)	g	4081.7		4081.7		4081.7		4081.7	
Mass of mould + base + Compacted specimen (m_2)	g	5601.84		5711		5780		5790	
Mass of compacted specimen (m_2-m_1)	g	1520.14		1629.3		1698.3		1708.3	
Bulk density, p = (m_2-m_1)/v	g/cm³	1.77		1.88		2.04		2.06	
Container no		**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Container weight	g	14.29	15.19	14.9	14.24	14.65	13.88	14.6	14.23
Wet soil + container	g	52.4	69.35	66.11	74.4	71.48	81.67	90.01	71.58
Wet soil, W_w	g	38.11	54.66	52.21	61.16	56.83	67.79	75.41	57.35
Dry soil + container	g	50.76	67.69	64.25	71.89	69	77.36	85.76	68.25
Dry soil, W_d	g	36.47	52.45	49.35	58.65	54.35	63.48	69.19	52.52
Moisture loss, W_w-W_d	g	1.7	2.21	2.86	2.51	2.48	4.31	4.25	4.83
Moisture content	%	4.67	4.21	5.8	4.27	4.56	6.79	6.15	9.2
Average moisture content	%	4.44		5.035		5.675		7.675	
Dry density, pd = p/ (1+w)	g/cm³	1.53		1.6		1.68		1.66	
Dry unit weight, yd	kN/m³	15		15.9		16.48		16.28	

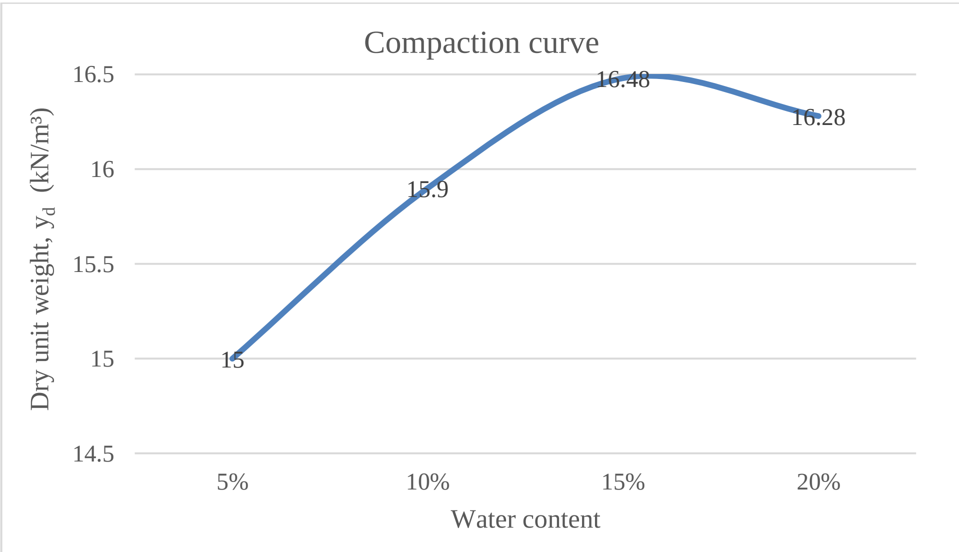

Figure 4.5 Compaction curve for gravel

Table 4.6 shows the calculation for dry unit weight for tyre chips. Based on Figure 4.6, the compaction curve shows that the maximum dry unit weight for tyre chips is 9.91 kN/m³ and the optimum water content is 15%.

Table 4.6 Calculation for dry unit weight and water content for tyre chips

Water content	Unit	5%		10%		15%		20%	
Mass of mould + base (m_1)	g	4130		4130		4130		4130	
Mass of mould + base + Compacted specimen (m_2)	g	4490		5160		5210		5225	
Mass of compacted specimen (m_2-m_1)	g	860		1030		1080		1095	
Bulk density, ρ = (m_2-m_1)/v	g/cm³	0.9		1.08		1.13		1.15	
Container no		**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Container weight	g	10.25	10.03	14.21	9.69	14.66	13.8	14.06	10.89
Wet soil + container	g	39.44	37.9	26.86	22.51	27.36	29.25	27.84	31.19
Wet soil, W_w	g	29.19	27.96	12.65	12.82	18.7	15.45	13.78	20.3
Dry soil + container	g	37.76	35.99	25.69	21.34	31.3	27.63	25.82	28.15
Dry soil, W_d	g	27.51	25.96	11.48	11.65	16.64	17.43	11.76	17.26
Moisture loss, W_w-W_d	g	1.68	2	1.17	1.17	2.06	1.62	2.02	3.04
Moisture content	%	6.11	7.7	10.19	10.19	12.38	11.91	17.18	17.61
Average moisture content	%	6.91		10.12		12.05		17.4	
Dry density, ρd = ρ/(1+w)	g/cm³	0.84		0.98		1.01		0.98	
Dry unit weight, γd	kN/m³	8.24		9.61		9.91		9.61	

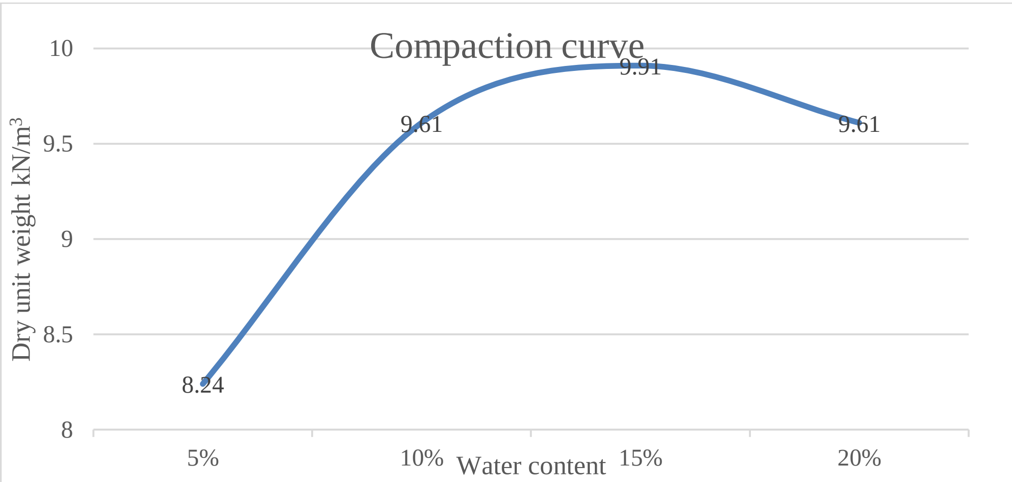

Figure 4.6 Compaction curve for tyre chips

Table 4.7 shows the calculation for standard proctor test for mixture of tyre chips and gravel. Based on Figure 4.7, the compaction curve shows that the maximum dry unit weight for mixture of both material is 15.99 kN/m³ and the optimum water content is 10%.

Table 4.7 Calculation for dry unit weight and water content for mixture of tyre chips and gravel

Water content		**5%**		**10%**		**15%**		**20%**	
Mass of mould + base (m_1)	g	4068.98		4068.98		4068.98		4068.98	
Mass of mould + base + Compacted specimen (m_2)	g	5629.4		5705.9		5717.09		5721.2	
Mass of compacted specimen (m_2-m_1)	g	1560.42		1636.92		1648.11		1652.22	
Bulk density, ρ = (m_2-m_1)/v	g/cm³	1.63		1.71		1.73		1.74	
Container no		**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Container weight	g	13.68	14.4	9.85	10.16	10.25	10.03	14.96	10.05
Wet soil + container	g	42.15	42.3	34.97	31.03	39.44	37.99	45.57	44.22
Wet soil, W_w	g	24.87	28.09	25.12	20.89	29.19	27.96	30.61	34.17
Dry soil + container	g	41.29	41.35	33.99	29.92	37.76	35.99	43.12	42.59
Dry soil, W_d	g	27.61	27.14	24.14	19.76	27.51	25.96	28.16	32.54
Moisture loss, W_w-W_d	g	0.86	0.95	0.98	1.11	1.68	2	2.45	2.89
Moisture content	%	3.11	3.5	4.06	5.62	6.11	7.7	8.7	8.88
Average moisture content	%	3.3		4.84		6.91		8.79	
Dry density, ρd = ρ/ (1+w)	g/cm³	1.57		1.63		1.62		1.59	
Dry unit weight, γd	kN/m³	15.4		15.99		15.89		15.6	

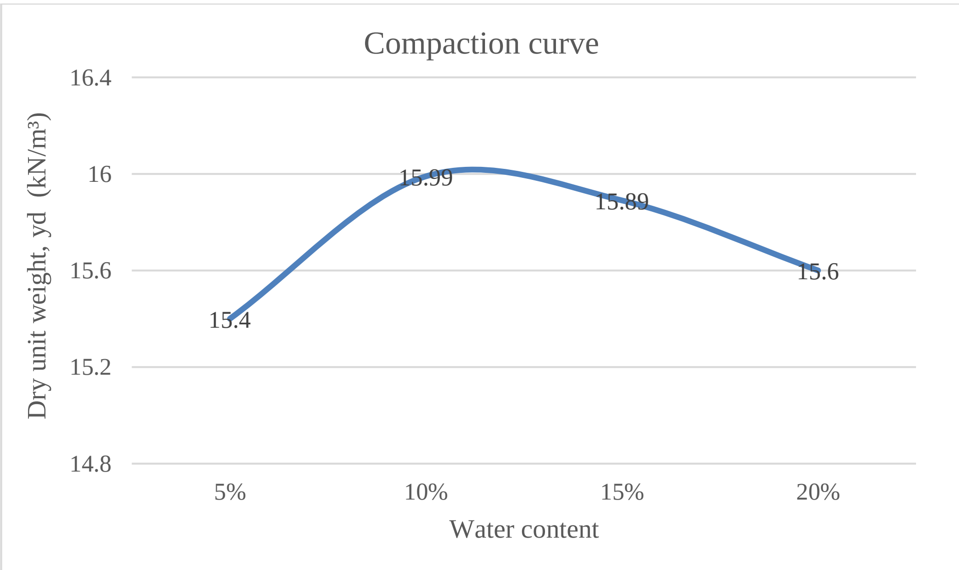

Figure 4.7 Compaction curve for mixture of tyre chips and gravel

4.2.4 Constant Head Permeability Test

Constant head permeability test is 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.

Coefficient of permeability for a constant head test is given by equation 4.3;

$$k = \frac{qL}{AH} \qquad 4.3$$

where k = coefficient of permeability in cm/sec

q = discharge cm^3/sec

L = length of specimen in cm

A = cross-sectional area of specimen in cm^2

H = constant head causing flow in cm

Constant head permeability test we're conducted on each of the material used. Table 4.8 shows the calculation and the value of coefficient of permeability of sand.

Table 4.8 Coefficient of permeability for sand

Length of soil specimen	16	cm		
Diameter of permeameter	7.5	cm		
Volume of soil specimen	706.88	cm^3		
Area of permeameter	44.18	cm^2		
Dry mass of soil + pan	1259.22	g		
Dry mass of soil specimen	1000	g		
Dry density of soil	1.42	g/cm^3		
$\eta T/\ \eta 20$	0.9532			
Trial number	1	2	3	4
Constant head, h (cm)	60	40	20	10
Elapsed time, t (sec)	33.7	36.1	40.3	49.8
Outflow volume, Q (cm^3)	500	500	500	500
Water temperature, T (℃)	22	22	22	22
K_T (cm/sec)	0.089554	0.1254	0.224662	0.363609
K_{20}(cm/sec) = K_T x $\eta T/\ \eta 20$	0.085363	0.119531	0.214148	0.346592
average k_{20}	0.191408408			

Table 4.9, 4.10 and 4.11 show the coefficient of permeability for gravel, sand and mixture of both sample respectively.

Table 4.9 Coefficient of permeability of gravel

Length of soil specimen	16.8	cm		
Diameter of permeameter	7.5	cm		
Volume of soil specimen	742.224	cm^3		
Area of permeameter	44.18	cm^2		
Dry mass of soil + pan	981.21	g		
Dry mass of soil specimen	750	g		
Dry density of soil	1.01	g/cm^3		
$\eta T/\ \eta 20$	0.9532			
Trial number	1	2	3	4
Constant head, h (cm)	37	30	28	24.5
Elapsed time, t (sec)	20.9	21.28	21.25	22
Outflow volume, Q (cm^3)	500	500	500	500
Water temperature, T (℃)	22	22	22	22
K_T (cm/sec)	0.24587	0.297825	0.319548	0.352748
K_{20}(cm/sec) = K_T x $\eta T/\ \eta 20$	0.234363	0.283886	0.304594	0.33624
average k_{20}	0.289770721			

Table 4.10 Coefficient of permeability of tyre chips

Length of soil specimen	19.4	cm		
Diameter of permeameter	7.5	cm		
Volume of soil specimen	857.092	cm^3		
Area of permeameter	44.18	cm^2		
Dry mass of soil + pan	1031.21	g		
Dry mass of soil specimen	800	g		
Dry density of soil	0.933	g/cm^3		
$\eta T / \eta 20$	0.9532			
Trial number	1	2	3	4
Constant head, h (cm)	40	32	26	23
Elapsed time, t (sec)	16.5	17.8	18.7	20.3
Outflow volume, Q (cm^3)	500	500	500	500
Water temperature, T (℃)	22	22	22	22
K_T (cm/sec)	0.332661	0.385457	0.451576	0.470243
K_{20}(cm/sec) = K_T x $\eta T / \eta 20$	0.317093	0.367418	0.430442	0.448235
average k_{20}	0.39079705			

Table 4.11 Coefficient of permeability of mixture of gravel and tyre chips

Length of soil specimen	19.7	cm		
Diameter of permeameter	7.5	cm		
Volume of soil specimen	870.35	cm^3		
Area of permeameter	44.18	cm^2		
Dry mass of soil + pan	831.23	g		
Dry mass of soil specimen	547.93	g		
Dry density of soil	0.63	g/cm^3		
$\eta T / \eta 20$				
Trial number	1	2	3	4
Constant head, h (cm)	60	40	20	10
Elapsed time, t (sec)	25.2	26.2	28.4	30.5
Outflow volume, Q (cm^3)	500	500	500	500
Water temperature, T (℃)	22	22	22	22
K_T (cm/sec)	0.147455	0.21274	0.39252	0.730989
K_{20}(cm/sec) = K_T x $\eta T / \eta 20$	0.140554	0.202784	0.37415	0.696778
average k_{20}	0.35356663			

4.3 Slope Model's Result

Two slope models had been developed for this study. Both of the slope models have 60º of critical angle. Besides that, both of the models are exposed to artificial rainfall with intensity of 570 mm/hr. The difference between the two models is one of the model is developed without having a gabion wall to retain the slope. The slope models are exposed to the artificial rainfall in 10 minutes. Figure 4.8 shows the behaviour of the slope without gabion wall after being exposed to artificial rainfall under some time.

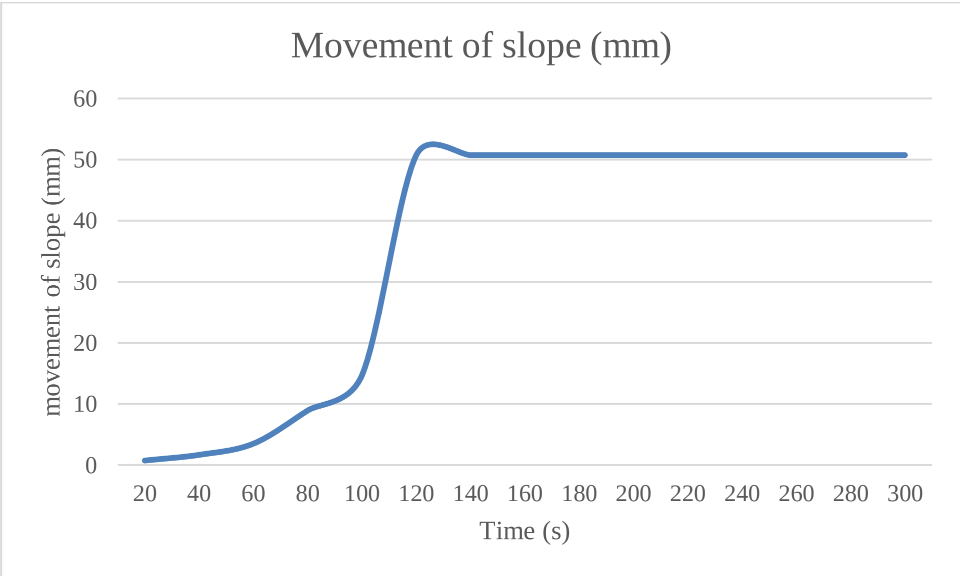

Figure 4.8 Movement of slope without gabion wall

From Figure 4.8, 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 second slope model is developed with gabion wall to retain the slope at 60º of critical angle. There is two layers of gabion wall and is arranged with terrace 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 4.9, 4.10 and 4.11 for each of the material used.

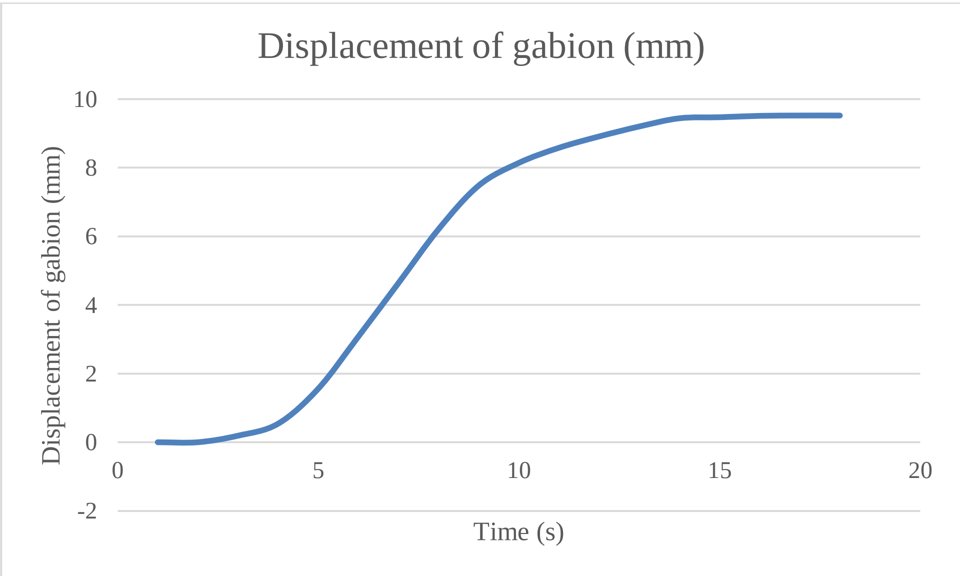

Figure 4.9 Displacement of gabion with gravel material

From Figure 4.9, the top layer of the gabion wall is being settled for as much as 9.52 mm after being exposed to rainfall in 15 seconds. The displacement of the gabion remains constant after 15 seconds.

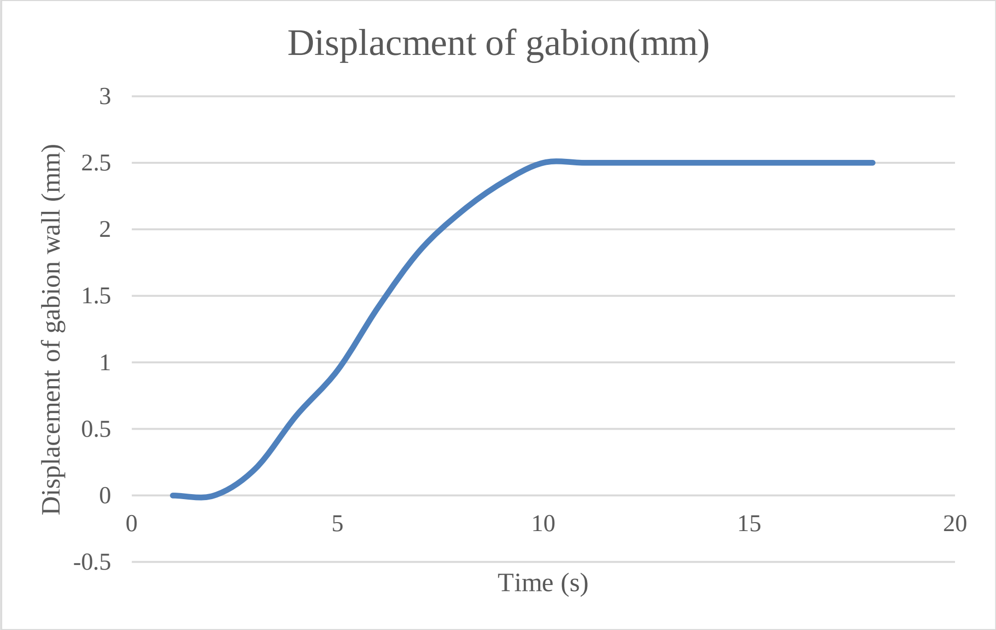

Figure 4.10 Displacement of gabion with tyre chips material

Figure 4.10 shows that the gabion wall with tyre chips material is only settled for as much as 2.5 mm. The displacement of the gabion is remained constant at 2.5mm after 10 seconds.

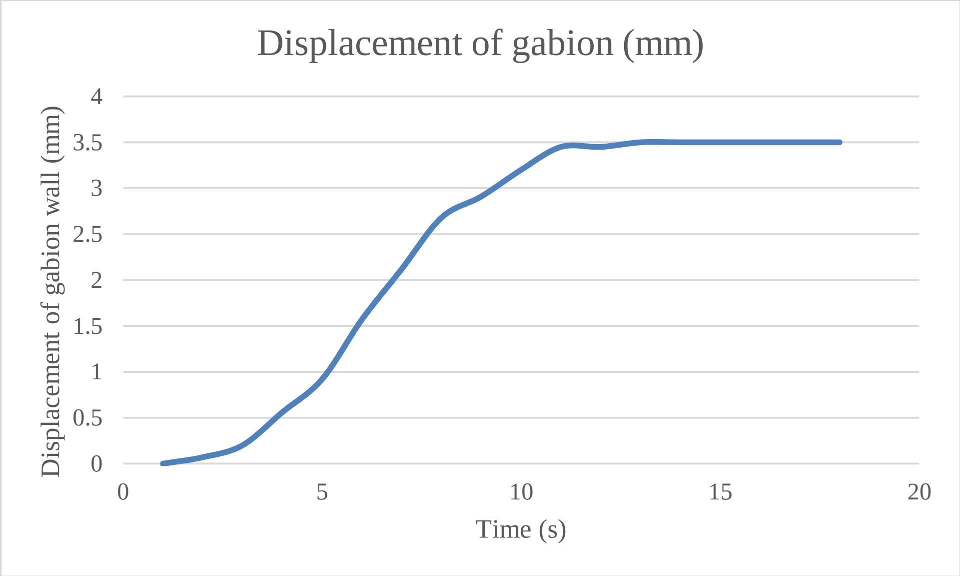

Figure 4.11 Displacement of gabion with mixture of gravel and tyre chips material of (50 – 50)%

From Figure 4.11, the displacement of gabion curve shows that the gabion only settled for as much as 3.5 mm and remained constant after 10 seconds of being exposed to rainfall.

Based on Figure 4.9, 4.10 and 4.11, it can be seen that the maximum displacement of gabion that is being settled into the soil slope varies with different material used. The settlement of the gabion may be affected by the weight of material used in gabion as the gravel gabion is being settled the highest with 9.52 mm while tyre chips gabion is shows the lowest reading of settlement with 2.5 mm.

Figure 4.12 shows the gabion that had been settled after exposed under the influence of rainfall in the slope simulation model.

Figure 4.12 Gabion wall settled after exposed to the rainfall

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Several laboratory tests had 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 had been obtained. The sizes for sand is range from 0.063 – 19 mm, 3.35 – 19mm for gravel, and 3.35 – 6.3 mm for tyre chips. Specific gravity for each material also had 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 is 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 had been obtained, the basic properties of each of the material used had been determined.

Besides that, two slope models had been made for this study. One model is without gabion wall and the other model is with gabion wall but with varies of material inside the gabion. Based on the observation, 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. The slope model with gabion wall was developed and the material inside the gabion had been made to vary from gravel, tyre chips, and mixture of both materials with 50 – 50% percentage. Based on the observation, gabion wall consists of all materials manage to retain the slope from failure and only settled for as much as 10 mm into the soil slope. From the results obtained, it can be concluded that tyre chips is effective as alternative material inside the gabion wall to ensure slope stability under small scale.

Furthermore, with the effectiveness of tyre chips as alternative material in gabion wall, the stockpiling of waste tyres can be reduced as the stockpiling of the waste tyres can be shredded and used as material in the gabion.

On the other hand, with the increasing usage of waste tyres as material in gabion, the usage of gravel as the sole material in gabion can be limited.

5.2 Recommendation

For future studies, it is recommended to conduct the slope model but with more percentage of mixture of the material in the gabion. The percentage mixture of material that can be use are 80 – 20 %, 60 – 40 %, 50 – 50 %, 40 – 60 %, and 20 – 80 %. From the variety of percentage mixture of material used, the optimum percentage mixture of gravel and tyre chips that can retain the slope from failure can be achieve.

Besides that, it is also recommended to develop the slope model with varies critical angle of the slope. The critical angle of the slope that can be developed are 60º, 70º and 80º. 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.

Furthermore, it is also recommended to expose the slope model to variety value of rainfall intensity for future studies. The rainfall intensities that is being used in this study is specifically for Kuantan area. For future studies, it is recommended to apply rainfall intensity in Kelantan or Terengganu area as both of the states received a high rainfall intensity during monsoon season. This is because the intensity of rainfall has a high effect to slope failure as it is one of the many reasons reported to be the cause of a slope to fail.

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