UNIVERSITI PUTRA MALAYSIA

THE USED OF CRUSHED COCKLE'S SHELL AS FILLER IN ASPHALT MIXTURE

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THE USED OF CRUSHED COCKLE'S SHELL AS FILLER

IN ASPHALT MIXTURE

By

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ABSTRACT

The demand for road construction in Malaysia keep increasing every year which will lead to demand of more filler. In the future, the percentage of filler in asphalt mixture will be increased and the cost of road construction also will be increased. Besides, the process of getting filler is difficult and the amount that will get is in small quantity. Therefore, it can be concluded that demand for filler content in road construction is higher. Since the price for limestone filler is costly, the used of crushed cockle shell has been introduced. This is because cockle shell is one of the waste material that consist of Calcium Carbonate which has the same characteristic as filler. It is one of the effective way to reduce the cost for road construction.

There are three stages in this study which are identify the physical properties of crushed cockle's shell, optimum asphalt content (OAC) determination and the performance tests. For identifying the physical properties of the crushed cockle's shell, the test that will be performed are LA abrasion test and soundness test. The result obtained will be compared with JKR standard. The next stage is to determine the OAC for both conventional and crushed cockle's shell sample. The testing that will be conducted are Density and Air Void, Resilient Modulus, and Marshall Stability. The final stage is the performance analysis which are fatigue and rutting test. The performance test is done by using the OAC obtain in the stage before which shows that crushed cockle's shell can be replaced as filler in asphalt mixture. From the results obtained, the OAC for conventional sample is 5.1% while for crushed cockle's shell is 5.2%.

ABSTRAK

Permintaan untuk pembinaan jalan raya di Malaysia semakin meningkat setiap tahun yang akan membawa kepada permintaan lebih filler. Pada masa akan datang, peratusan filler dalam campuran asfalt akan bertambah dan kos pembinaan jalan raya juga akan meningkat. Proses untuk mendapatkan filler adalah sukar dan dalam kuantiti yang kecil. Oleh itu, dapat disimpulkan bahawa permintaan untuk kandungan filler dalam pembinaan jalan raya adalah tinggi. Disebabkan harga untuk filler batu kapur adalah mahal, penggunaan kulit kerang yang dihancurkan telah diperkenalkan. Ini kerana kulit kerang adalah salah satu daripada bahan buangan yang mempunyai Kalsium Karbonat juga merupakan ciri-ciri filler. Ia adalah salah satu cara yang berkesan untuk mengurangkan kos dalam pembinaan jalan raya.

Terdapat tiga peringkat dalam kajian ini, ia adalah untuk mengenal pasti ciri-ciri fizikal kulit kerang yang hancur, penentuan kandungan asfalt optimum (OAC) dan ujian prestasi. Untuk mengetahui ciri-ciri fizikal kulit kerang hancur, ujian seperti LA abrasion dan ujian kekukuhan akan dilakukan. Keputusan akan dibandingkan dengan piawaian JKR. Seterusnya adalah untuk menentukan OAC bagi kedua-dua sampel iaitu sampel konvensional dan sampel kulit kerang hancur. Ujian yang akan dijalankan adalah Ketumpatan dan Ruang Udara, Modulus Berdaya Tahan dan Kestabilan Marshall. Peringkat akhir adalah analisis prestasi ujian fatigue dan ujian rutting. Ujian prestasi dilakukan dengan menggunakan OAC dalam peringkat yang sebelumnya sejurus menunjukkan bahawa kulit kerang yang dihancurkan boleh digantikan sebagai pengisi dalam campuran asfalt. Dari hasil yang diperolehi, OAC untuk sampel konvensional adalah 5.1% manakala untuk kulit kerang hancur ialah 5.2%.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

There are about 328,550 km² of land area in Malaysia which are comprises of peninsular Malaysia and East Malaysia (UNDP, 2014). The population is about 27 million which keep on increasing each year. In 2016, the population in Malaysia is 31.7 million. Malaysia is one of the central income country which started multi-sector economy and one of the significant economic providers come from natural resources in areas such as minerals, agriculture and forestry. Therefore, solid waste produced from the high population and it will leads to environmental problem. One way to solve the environmental problem due to the waste material is to reuse or recycling the waste.

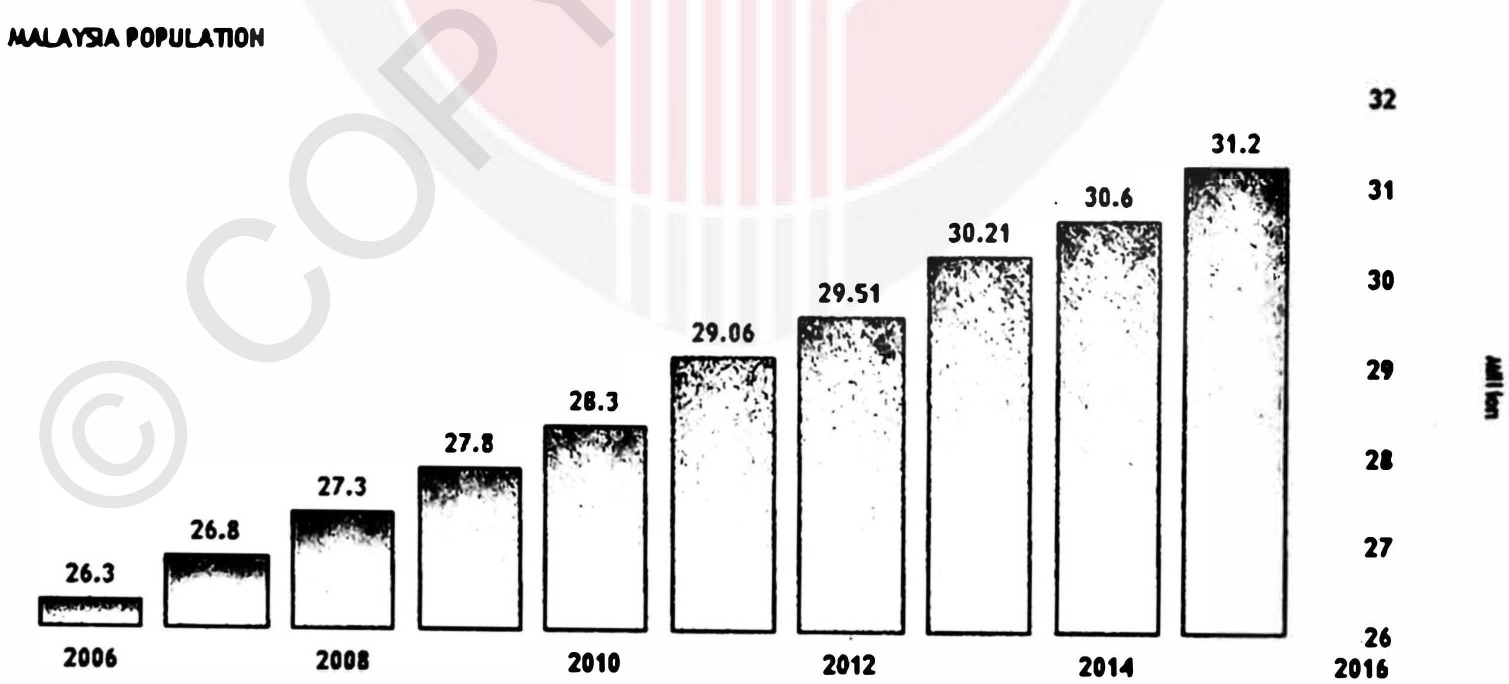

Figure1.1: Malaysian population

Source : Tradingeconomics.com

One of the waste material which contribute to environmental problem is pavement engineering. Various of studies have been made to improve the quality of pavement where one of the mostly conducted research is the utilization of waste materials in asphaltic concrete. Research into new and innovative uses of waste materials become more advance where more research of agricultural waste as aggregates in engineering sector is carried out by the researchers. Many past researches used the waste material such as tyres, glasses, plastics, recycled concrete and fly ash as material replacement. Meanwhile, agricultural waste such as oil palm shell, coconut shell, rice husk, corn cob and others have shown successfully used as aggregates replacement in concrete. The use of agricultural waste not only help to reduce the waste material but also help to save the environment by making the industry become more sustainable and environmentally friendly.

Aggregate includes natural aggregates, processes aggregates and artificial aggregates. Natural aggregates obtained by extraction of larger rock either by blasting or digging from the quarry (Pavement Interactive, 2008). Gravel and sand are example of natural aggregates. Processed aggregates are the crushed and screened of natural gravel or stone meanwhile artificial aggregates are produced from the physical and chemical changes (Asphalt Institute, 1989).

Aggregate is the largest composition in the asphalt concrete mix design apart from bitumen and filler. Aggregate contributes about 90 to 95% by weight or 75 to 85% by volume of asphalt concrete mix (Asphalt Institute, 1989). Highways in Malaysia consist of paved road for about 116 169 km while unpaved road is 28 234 km (The World

Factbook, 2014). Other than that construction of local two lane highway can consumes over 15,000 tonnes of aggregates per kilometre (ECO Annual Report, 2003).

Apart from that, aggregate not only required in construction of roads and highways but also in maintenance and rehabilitation of roads where in Malaysia the cost for road maintenance is higher than the cost for construction of new roads. Hence, it can be seen that large quantity of aggregate is needed in road construction and it is not include consumption of aggregate from other industries yet. Thus, more aggregates need to be extracted from the natural sources. Unfortunately, extraction of the natural sources will keep on increasing which lead to decreasing in natural sources and affect the environment. As a result, other resources of aggregate need to be searched and more cost will be needed.

Cockle shell or scientifically known as *Anadara granosa* is a local bivalve mollusc having a rounded shell with radiating ribs. Cockle's shell belongs to the family of Arcidae and known as 'kerang' in Malaysia (Awang Junaidi, Awang Hazmi and Abu Bakar Zakaria, Md Zuki and Mohamed Mustapha, Noordin and Abu, Jalila and Yusof, 2007). It is one of an inexpensive protein source which is common to be prepared as local dishes (Awang Junaidi, Awang Hazmi and Abu Bakar Zakaria, Md Zuki and Mohamed Mustapha, Noordin and Abu, Jalila and Yusof, 2007).

Cockle Shell contains of CaCO3 which enable it to be used for quite a number of purpose such as biomaterial for bone repair (Awang Junaidi, Awang Hazmi and Abu Bakar Zakaria, Md Zuki and Mohamed Mustapha, Noordin and Abu, Jalila and Yusof, 2007) and also for industries and daily practice such as in waste water and sewage treatment, glass production, construction material, agricultural, and more.

1.2 PROBLEM STATEMENT

Every year the demand for road construction is increasing. Therefore, the amount of filler also will be increasing. The process of getting filler is difficult and the amount obtained is in a small quantity. It can be concluded that demand for filler content in road construction is higher. Since the price for limestone filler is costly, the used of crushed cockle shell has been introduced. Besides, cockle's shell also one of the waste material that can be used because it has Calcium Carbonate which also can be replaced as filler.

As reported in 2006, Malaysia had produced 45,674.58 metric tonnes of cockle for seafood industry (Nazatul Izura & Kim Hooi, 2008). However, cockle aquaculture areas extend about 10,383.09 hectares contributing a production of 78,024.7 tonnes in year 2010 (Department of Fisheries Malaysia, 2010). From this statistics, can be conclude that the waste of cockle shell is increasing every year. Therefore, the active cockle trade has leads toward the generation of abundant waste of shell. (Boey *et. al.,* 2011).

The demand for more roads, increasing cost of production of asphaltic mixture and scarcity due to depletion of the naturally occurring materials been used had necessitated the search for alternative and sustainable materials, that will satisfy the aforementioned needs and aid in the production, placement and performance of pavements. Also, growth of population, increasing urbanization, and rising standards of living due to technological innovations have contributed to increase in the quantity of a variety of solid wastes generated by industrial, mining, domestic and agricultural activities.

The cost for road construction has been increasing year by year and the present of big amount of cockle shell waste needs an effective ways to solve the problem. The replacement of fine aggregate with crushed cockle shell in asphalt mixture is a good approach to reduce the cost of materials and also solve a waste problems posed by cockle shell. Therefore, additional of cockle shell as partial fine aggregate replacement would reduce the high dependency on natural aggregate supply and it also assist towards preservation of this material for future generation.

In conjunction with the high demand from consumers to use cockle as an ingredient in food industry (i.e. canning food), promote the existence of cockle's processing plants. With more factories doing the suckling process, meaning more shells will be thrown to the surrounding areas. As the shells take a long time to decay, it will become a pollutant to the environment.

Therefore, the idea of using cockle shell waste as partial replacement of fine aggregate is one of the efficient way to solve the problem. Moreover, the concept of green technology in road construction should be concomitant with the current development in this industry.

1.3 OBJECTIVES

The objectives of the study are:

- To identify the physical properties of the crushed cockle's shell.
- To determine the optimum asphalt content for conventional sample and crushed cockle's shell sample.

- To compare the performance test between the conventional sample and crushed cockle's shell sample.

1.4 SIGNIFICANCE OF STUDY

In the future, the use of filler in road construction will increase. Therefore, the cost for road construction will be higher. In this research, cockle's shell will be used in asphalt mixture. Cockle's shell is one of the biggest waste problem since it take longer times to decay. Furthermore, the cost of the road construction will be reduced and it also can gives benefits to the environment.

1.5 SCOPE OF STUDY

This study was carried out in Highway and Transportation Laboratory at Faculty of Engineering, UPM. This scope of study was focusing on the used of crushed cockle's shell as filler in hot mix asphalt. The percentage of filler for hot mix asphalt is 4% from weight of aggregates. Material testing for aggregate, asphalt and cockle's shell will be conducted in the laboratory. In addition, testing in determination of Optimum Asphalt Content and performance test also will be performed. The results will be analysed and discussed.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this section, there are several subtopics will be discussed on the idea of crushed cockle shell as the replacement of partial filler in asphalt mixture. The sub-topics will begin with the explanation about cockle shells. Due to the increasing concern in order to get rid of the cockle shell waste, there are also the studies on the production of cockle shell in Malaysia will be explored wider in this section. The explanation about cockle shells as replacement in concrete mixture also will be included. Thus, the studies on asphalt mixture containing crushed cockle shell were act as partial fine aggregate replacement material will be include in this section.

2.2 DEFINITION OF COCKLE SHELL

Cockle shell which one of the types of seashell is abundantly available in Malaysia as a by-product from seafood industry. In Malaysia, this waste usually has been used in small-scaled craft production. It is a group of mostly small, edible, saltwater clams, marine bivalve molluscs in the family Cardiidae is known as cockle (Lamarck et. al., 1809).

Besides that, cockle is one of the type of bivalve shellfish that grows well in muddy coastal area. Abundant species of cockles live in sandy, sheltered beaches throughout the world. The distinctive rounded shells of cockles are bilaterally symmetrical, and are heart-shaped when viewed from the end.

2.3 MINERAL CONTENT IN COCKLE'S SHELL

Chemical property analysis using x-ray fluorescene (XRF) shows cockle shell is made up of 97% Calcium (Ca) element and CaO is produced after decomposition was conducted (Mohamed et al.,2012). There are other mineral composition reported as element of cockle shell which are of Carbon (C), Magnesium (Mg) and Silica (Si). Based on previous study, it shows that cockle shell were made up of CaCO3, which is one of the sources of CaO. Thus, the finding suggests the possibility of using cockle shell as alternative biomaterials for production of CaO.

From previous study done by Zuki et al, almost 98.68% of CaC content in cockle shell. Awang-Hazmi et al who also achieved mineral composition cockle shell determine that 98.70% of CaC. Meanwhile, S.Yusup et al also determine that mineral content in cockle shell contained 98.99% of CaC content in cockle shell. In various studies of other seashell types like oysters, scallops and mussels revealed that they are quite well developed and applied in varied industry around the world for fertilizers, construction materials, cement clinkers and tiles (Barros, 2004).

2.3.1 Uses of Calcium Carbonate (Caco3)

Seashell contained of 95-99% by weight of $CaCO_3$ which has enable it to be applied for quite a number of purpose (Barros et al., 2009 ; Nakatani et al., 2009). The suitability of cockle shell as calcium-based adsorbent is confirmed by its high calcium content, as reported by Awang-Hazmi et al. Calcium oxide is recognized as an efficient carbon dioxide adsorbent and separation of CO_2 from gas stream using CaO based adsorbent is widely applied in gas purification process especially at high temperature reaction (Mohamed et al., 2012).

The experimental variables such as calcination temperature and particle sizes were put under study in order to optimize the calcination process. As Malaysia is rich in waste cockle shells, and also the production of cockle shell was great by year, the potential to exploit them for the production of CaO is great. Hence this program aims to utilise the $CaCO_3$ in cockle shell as new potential source of CaO. This project helps meet the medium term objective for cockle shells by raising awareness of possible ways to generate economic return from waste and in the development of a regional approach to facilitate further development. For this research, the $CaCO_3$ is used as fine aggregate in asphalt mixture.

2.4 PHYSICAL PROPERTIES OF COCKLE SHELL

Cockle shell is the name of a group of family double shell cardiidae that is one commodity that has long fishing cultivated as a side venture coastal communities.

Technique facile sense of force, does not require large capital and can harvested after the age of 6-7 months. Shellfish harvest per hectare per year can reach 200-300 tons of shells intact or about 60-100 tons of shellfish meat (Porsepwandi, 1998).

Cockle shell shape like heart, symmetrical and have reinforcement on the outside as shown in Figure 2.1. Shell has three openings inhalen, ekshalen and pedal to drain the water and to remove the leg. Shells usually dig a hole with his feet and eat plankton obtained from water flow in and out. Cockle shells are also able to jump past the bend straighten his legs. In contrast to most double shell, clams are hermaphrodites. Composition of cockle shells of West Coast of Peninsular Malaysia (Zuki, 2007), is tabulated in Table 2.1.

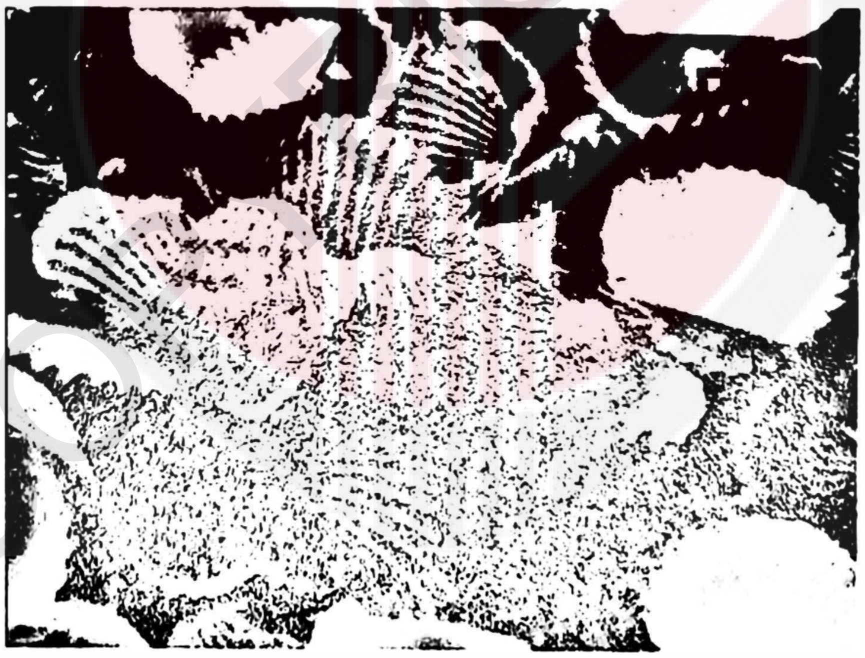

Figure 2.1: Cockle Shell

Table 2.1 : Minerals composition of cockle shell

Component	Percentage (%)
Cac	98.7
Mg	0.05
Na	0.9
P	0.02
Others	0.2

Source: Zuki, 2007

2.5 AVAILABILITY OF COCKLE SHELL IN MALAYSIA

The history of cockle culture in Malaysia started in 1948 in Perak. It's found in muddy bottoms of coastal regions of South East Asian particularly Malaysia, Thailand and Indonesia. As reported in 2006, Malaysia had produced 45,674.58 metric tonnes of cockle for seafood industry (Izura and Hooi, 2008). 4000-5000 hectares of the west coast of Peninsular Malaysia were used for cockle culture (FAO, 2006). While in 2010, Malaysia had produced 78,024.70 metric tonnes of cockle for seafood industry (Izura and Hooi, 2008). It shows that the production of cockle has increased every years.

The production of cockles started to decline from 2010 till 2012 due to limited suitable culture area for expansion in Peninsular Malaysia and inadequate spat-fall areas in Sabah and Sarawak. Higher operational costs and reduction of mangrove areas that helps to supply the cockle seeds also contribute towards the decline in cockles' production. During Ninth Malaysia Plan, Malaysia is expected to produce 13000 metric ton of cockles (Utusan Malaysia, 2007). Therefore, several steps had been recommended such as reserving and gazetting spat-fall areas, reducing operational costs, and increasing research on development of more spat-fall areas.

During 2010, Selangor aims to produce 10 mt/halyr of cockle (Bernama. 14 February 2009). Involving 6000 hectare of cultivation area, Malaysia is having 1055 number of farmers working in cockle cultivation agriculture till 2007 (Izura et.al., 2008). However, it does not only indicate the vast availability of cockles but also the amount of waste shells generated.

Cockle shell is a major financial and operational burden on the shellfish industry. In Malaysia, the shells are treated as waste and mostly left at dumpsite to naturally deteriorate. This is because, in Malaysia, cockle shells were not widely used. There will be unpleasant smell and disturbing view to the surrounding when there are shells that been dumped and left untreated (Mohamed et. al., 2012). It is expected the availability of cockle shell as waste would be in bigger amount as well which will lead to negative impact to the nearby area by referring the growing cockle production which retail the value of cockles alone increased by 33.53% by RM 91.60 million in 2010 from 68.60 million the previous year (Department of Fisheries Malaysia (2010) Annual Fisheries Statistic 2010 Jabatan Perikanan Malaysia).

The waste is hard to dispose due to its strong property. Only very recently, some initial studies were done to investigate the potential of this material. Success in incorporating this material as partial fine aggregate replacement in asphalt mixture would contribute towards reduction in the quantities of cockle shell ending up as waste.

2.6 ENVIRONMENTAL ISSUES RELATED TO COCKLE SHELL

In order to have an exclusive environmental friendly composite material, cockle shell could be integrated as partial fine aggregate replacement material in asphalt mixture so that it could be creating a win-win situation between the two industries, fisheries and road construction.

In both long term engineering properties studies and durability aspect, this fact-finding study attempting to discover the potential of this free locally available waste in asphalt mixture production intended for road construction work requires further in depth research.

The type of treatment process and the level of cleaning can have an important effect on the shell quality. Cockle shell samples can have a low odour although this can vary according to the cleaning process and the type of shell processed. Residual organics in a raw untreated wet sample are likely to give rise to odour related problems.

A further consideration is that there is a potential for cross contamination in some systems handling differing waste streams where common equipment is used. This may particularly be the case where a concentrated byproduct stream (e.g rotary kiln crab) is processed alongside a less concentrated material (e.g free of flesh scallop).

2.7 COCKLE SHELL AS REPLACEMENT IN CONCRETE

Shell by-products (such as mussel shell, oyster shell, scallop shell etc.) have long been applied in industries (Barros *et al*., 2009). For example, in the construction of roads, replacement of industrial lime, ash cements, fertilizer, lime agent, moisturizers and tile. However, based on research, cockle shells was widely used in building construction compared to road construction. Moreover, the uses of shell waste as a replacement material in concrete also have been increasing now. The table below has shown the list of research using various shells as a replacement material in concrete mix.

Table 2.2 : List of research as replacement material

Researchers	**Country**	**Type of shells**	**Replacement material in concrete**
Sugiyama, (2004)	Japan	Scallop	Coarse aggregate
Falade, (1995)	Nigeria	Periwinkle	Coarse aggregate
Eun-Ik Yang *et al.*,(2005)	Korea	Oyster	Fine aggregate
Yusof *et al*,. (2011)	Malaysia	Clam	Fine aggregate
Muthusamy & Sabri, (2012)	Malaysia	Cockle	Coarse aggregate

Awang-Hazmi *et al.,* (2007) have used cockle shell ash as a mixture in making bone substitutes and as a sand replacement material in the making of artificial reefs has been done by Faridah Sahari and Nurul Aniza, (2011). Cement product for masonry and plastering also use ground waste seashells (short-neck clam, green mussel, oyster and cockle) were investigated by Lertwattanaruk *et al.,* (2012). Relying on the literature review, the potential of using shells as an aggregate would decrease the strength and workability of concrete compared to normal concrete. More proportion of shell used would decrease the strength of concrete.

The content of calcium carbonate, CaCO3 (accounts 95-99% by weight) in the cockle shells was high and almost equal to limestone. Consequently, the physical and chemical properties of cockle shell ash is also similar to limestone and suitable to be used as a filler material in concrete. In this study, different proportion of cockle shell ash containing 5% (CSA5), 10% (CSA10), 15% (CSA15), 25% (CSA25) and 50% (CSA50) as a cement replacement material.

2.8 COCKLE SHELL AS AN ALTERNATIVE CONSTRUCTION MATERIAL FOR ARTIFICIAL REEF

There are previous study on cockle shell that has been used as an alternative construction material for artificial reef. It is one of the waste material which are abundantly available in Malaysia as a by-product from seafood industry. This waste has not yet been exploited in other applications except that it has been used in small-scaled craft production. The mineral composition of the cockle shell which consist of Calcium (Ca), Carbon (C), Magnesium (Mg) and Silica (Si) which is similar to that sand, gravel and cement suggest its potential as an alternative material in fabricating artificial reef.

Research have been made by using cockle's shell as part of the aggregate in concrete composition for artificial reef fabrication. The results shows that the used of cockle shell in concrete can improve some of the properties of the artificial reef; compared with those without shell. There are no significant effect to seawater in terms of salinity and temperature, although it increased alkalinity of the water with the utilization of cockle shell in the artificial reef. Integration of this material on the reef surface provides texture to expedite settlement of marine organism. Furthermore, through observation, fish is more attracted to cockle shell reef rather than the one without it.

2.9 HOT-MIX ASPHALT

Hot-mix asphalt (HMA) is defined as a complex mixture composed of bituminous binders and mineral aggregate. The bitumen, black or dark brown in colour, acts as an adhesive, gluing the aggregate into a dense mass and waterproofing the aggregate particles. The mineral aggregate, when bound together, acts as a stone framework to give strength and toughness to the composite system. HMA performance is affected by the individual properties of both aggregate and bitumen and the interaction between them (Reubush, 1999).

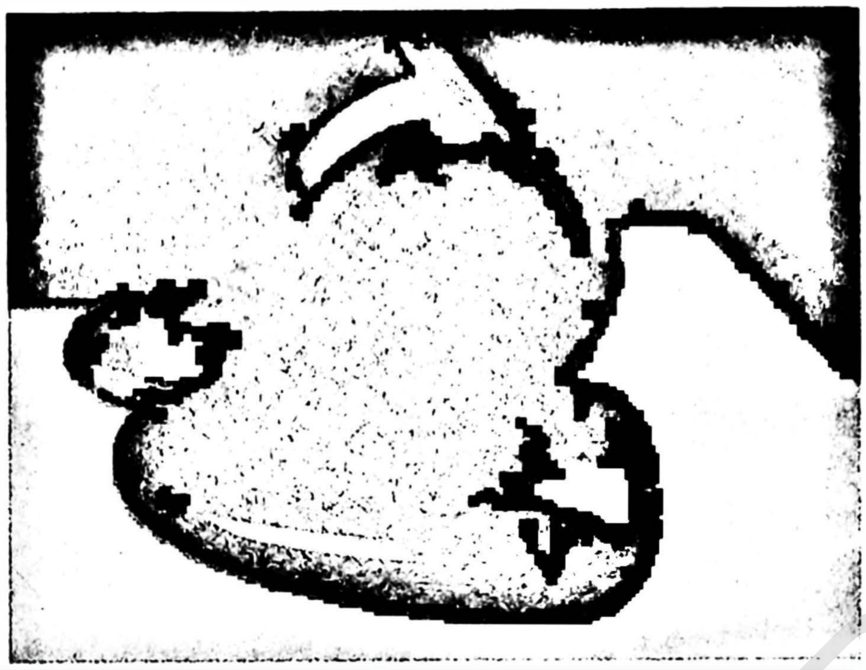

Figure 2.2 : Asphalt

HMA contains a significant amount of mineral aggregate, approximately 95% by weight and 85% by volume (Liu and You, 2011). Besides, The American Society for Testing and Materials (ASTM) defines aggregate as a granular material of mineral composition such as sand, gravel, shell, slag, or crushed stone, with a cementing medium to form mortar or concrete, or alone as in base course or railroad ballast.

Aggregates for HMA are usually classified by size as coarse aggregates, fine aggregates, or mineral fillers. ASTM also defines coarse aggregates as particles retained on a No. 4 (4.75 mm) sieve, fine aggregate as that passing through a No. 4 sieve (4.75 mm) and mineral filler as material with at least 70 per cent passing through a No. 200 (75 μm) sieve (ASTM, 2003).

Aggregate gradation is the most important property of HMA, as well as stiffness, stability, durability, workability, fatigue resistance and resistance to moisture damage. Aggregate grading is the distribution of particle size expressed as a percentage of the total weight. Grading is determined by passing the aggregate through a series of sieves stacked with progressively smaller holes from top to bottom, and weighing the material retained on each sieve. The gradation of an aggregate is normally expressed as the percentage passing through various sieve sizes (Robert et al., 1996).

The large increase in the number of vehicles and the volume of heavy traffic on the roads has consequently increased the tire pressure and axle loads imposed on the pavement structure. Hence, there is a need to enhance asphalt pavement mixtures that may prone to rutting and cracking to withstand the increase in loading, mitigate the adverse effects on pavement performance and reduce the occurrence of premature rutting. Therefore, the selection of aggregate gradation for use in HMA pavement is important to pavement performance (White et al., 2006). The proper gradation of aggregates is strongly affected by the mix properties such as air voids, stability and resistance to permanent deformation.

This study was conducted to evaluate the effectiveness of aggregate gradation on HMA according to Malaysian Public Works Department specification; namely JKR specification (ACW14, 1988) and JKR specification (ACW14, 2005). This study also aims to vary aggregate gradation in the HMA mixtures to determine the effects on HMA criteria such as stability, density and strength. The laboratory tests carried out to determine the properties of the aggregates included sieve analysis, the Los Angeles Abrasion Test (LAAT),

Aggregate Impact Value (AIV) and Aggregate Crushing Value (ACV). A Resilient Modulus Test and Static Creep Test were also carried out to determine the performance of HMA by using Materials Testing Apparatus (MATTA). Samples were prepared by means of the Marshall Design method (Malaysian Public Work Department Specifications).

2.10 AGGREGATE

2.10.1 Definition

Aggregate are inert granular materials such as sand, gravel, or crushed stone that, along with water and Portland cement, are as essential ingredient in concrete (Portland Cement Association, 2009). In order to achieve good concrete mix, aggregates need to be clean thoroughly. Among the three substances, aggregate is commonly considered inert filler, which accounts for 70 to *85* percent of the weight of concrete and 60 to 80 percent of the volume (Basith, 2014). It is a necessary component that defines the elastic properties, dimensional stability and concrete's thermal even though aggregate is considered as inert filler.

Aggregate is classified as two different types which are fine and coarse. Fine aggregate is usually less than *5* mm while coarse aggregate is usually gr eater than *5* mm as stated by Meddah (2010), Dumitru (1998), R.0 (1954) , Abdullahi (2012) and Wai (2012). It is also stated by Falade (2010), Awang-Hazmi (2007) and Manguriu *et.* al., (2013).

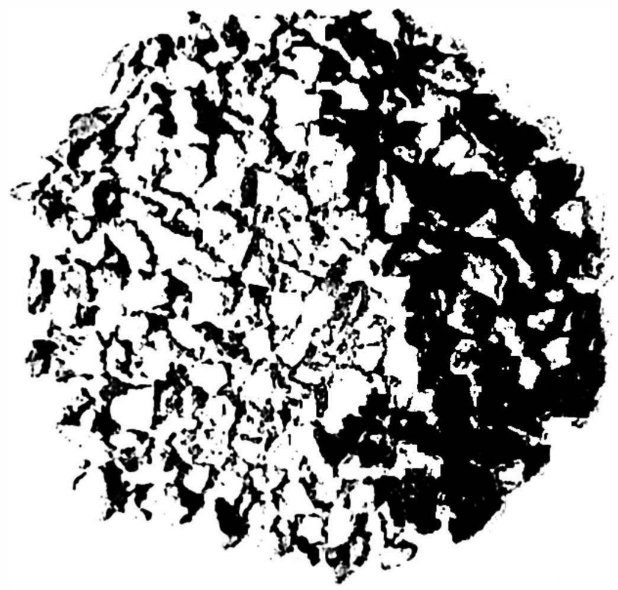

Figure 2.3 : Coarse Aggregate

The quality of aggregate is very important factor involves in the selection of aggregate for example the compressive aggregate should be emphasized. Mostly, aggregate are several times stronger compare to the other components in concrete when determining the strength of normal concrete. Compressive strength of the aggregates is also one of the factors that influence the lightweight aggregate concrete. Figure 4 shows the fine aggregate used in asphalt mixture production.

Figure 2.4 : Fine Aggregate

2.10.2 Physical Properties of Fine Aggregate

In order to get a desirable mixture, physical properties of aggregate is very important to be known before mixing concrete. Shape and texture, size gradation, moisture content, specific gravity, reactivity, soundness and bulk unit weight are the example of the properties. The strength, workability, and durability of concrete can be determined by the properties along with water or cementitious material ratio. The properties of fresh concrete easily affected by the shape and texture of aggregate compare to hardened concrete. Instead of rough angular or elongated aggregate, concrete is more workable when smooth and rounded aggregate is used.

Therefore, riverbeds or seashores are the suitable places to get most natural sands and gravel which are smooth and rounded as there are the excellent aggregates can be found. A workable mixture can be produced by using crushed stone where it produces much more angular and elongated aggregates. The aggregates have a higher surface-to-volume ratio and it requires more cement paste to get a better bond characteristics as well as to produce a workable mixture.

Besides that, both fresh and hardened concrete's properties strongly influence by coarse aggregate fraction. Hence, regarding the predicted performance of concrete it is important issue on the selection of both content and particle size distribution (PSD) for concrete mixture. From the reading stated, in order to investigate the effect of the PSD of aggregate on the properties of concrete, there are four granular fractions were combined in different proportions. Water reducer agent (WRA), two types of chemical admixtures, and superplasticizer were used to reduce the water-cement ratio which ranges from 0.58 to 0.40 (Meddah *et.* al., 2010).

Compressive strength function the PSD of coarse aggregate was determined at 7, 14 and 28 days. Thus, it is shows that assures a continuous granular size distribution, have shown the highest compressive strength of the mixtures without chemical admixture made with a ternary combination of granular fraction and having a highest size of *25* mm. Nevertheless, reducing the water-cement ratio by the inclusion of WRA or HRWRA requires a reduction of the maximum size of coarse aggregate and some adjustment in the granular size distribution system. The binary granular system has led to the highest compressive strength when dealing with low water-Cement ratio.

The moisture content of an aggregate is very necessary factor when developing the proper water or cementitious material ratio. Based on the porosity of the particles and the moisture condition of the storage area, it shows that all aggregates contain some moisture. The moisture content can range from less than one percent in gravel to up to 40 percent in very porous sandstone and expanded shale.

There are four different moisture states that include oven-dry (OD), air-dry (AD), saturated-surface dry (SSD) and wet where aggregate can be found. Among these four states, only OD and SSD correspond to a specific moisture state and can be used as reference states for calculating moisture content (Siddique R., et al 2002). Absorption capacity, effective absorption, and surface moisture are the three quantities that must be calculated in order to calculate the quantity of water that aggregate will either add or subtract to the paste. In order to establish weight-volume relationships, the density of the aggregates is needed in mixture proportioning. By determining the densities using the displacement of water, specific gravity is easily calculated.

The specific gravity value depends on whether these pores are included in the measurement as all aggregates contain some porosity. Absolute specific gravity and bulk specific gravity are the two terms that are used to differentiate this measurement. The solid material excluding the pore known as absolute specific gravity (ASG) and sometimes apparent specific gravity refers to bulk specific gravity (BSG) includes the volume of the pores. It is significant to know the space occupied by the aggregate particles, including the pores within the particles for the purpose of mixture proportioning. Although the specification of BSG is usually done to meet minimum density requirement, the BSG of an aggregate is not directly related to its performance in concrete.

The different properties of aggregate have a huge impact on the strength, durability, workability, and economy of concrete even though aggregates are most commonly known to be inert filler in concrete. Designers and contractors have more flexibility in designing and construction requirement as there are various properties of aggregate.

2.10.3 Use of Fine Aggregate

There are various types of aggregates and the potential use in concrete and road construction materials. The benefits and limitations of the use in concrete and road construction and their availability were described in terms of sources and production process, physical and mechanical characteristics. Only the suitable strength, durability and shape characteristics are considered in the source materials. Crushing, screening and possibly washing are generally involves in production process.

Workability, bleeding rate, finish ability and susceptibility to plastic cracking of concrete may affected by the shape, grading and excessive amount of fines. When unprocessed dust is put through an autogenous crushing action of specific crusher, an improvement in grain shape of manufactured sand can be achieved. More workable and generally superior concretes to those with fine and coarse natural sands can be produced by blending of *50%* fine sand with manufactured sand (Dumitru, 1997).

The amount of —*75* tm of up to 15% can be accounted realistic and not harmful to most plastic hardened properties of concrete pavement mix for both basaltic and crushed river gravel manufactured sands. In coarse aggregate to sand ratio or admixture dosages are essential to achieve the full benefits of the use of manufactured sand in concrete as the adjustments of concrete mix proportions (Dumitru *et. al.,* 1998). Removal of clay and silt from basalt crusher dust has been tried using numerous methods (Sullivan *et. al.,* 1997).

A main proportion of natural sand with no essential loss of performance in cement-based products can be replaced by manufactured. From the reading stated that most manufactured sands in Australia are not used as the only source of fine aggregate in most concrete mix designs. Manufactured sand may be. customized for use in concrete, tile, asphalt, or masonry production. Table 2.2 shows the aggregate used in construction.

2.10.4 Production of Fine Aggregate in Malaysia

From the reading of the strength of concrete with ceramic waste as coarse aggregate and quarry dust as fine aggregate. There is industrial in Malaysia being one of the sources of ceramic waste and quarry dust (Abdullah *et. al.,* 2002). Currently, the production in ceramics industries goes as waste, which is not experience the recycle process yet. Besides that, in Malaysia there are other previous research have been conducted using waste material such as agricultural by-product will be reviewed in the coconut shell plantation.

Oil palm shell, wood, coconut shell in producing panel board and material used for construction which are the example of agricultural by-product have received rising attention in current years as one of the best solution to the escalating agricultural waste problem. Materials which can be used as replacement for normal materials which possess such properties as would enable their use for new designs and innovations have been continuously looking by scientists, engineers and technologies.

On the other hand, aggregates produced in Malaysia are obtained from two primary sources, namely quarries and river beds. They consist mainly of granite and limestone rock types, and are abundant throughout the states of Perak, Selangor, Johor, Sabah and Sarawak. Production of aggregates in 2012 is estimated to have increased to 122,000,000 tonnes from 118,509,699 tonnes produced in 2011 (Department of Mineral and Geoscience, Malaysia.)

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

Methodology describes every steps which includes in this project. The step was organized and will indirectly helps in completing the tasks faster. Therefore, in this chapter, the steps and procedures of this study will be explain in details.

The information collection need to be done in order to know the background of the study. Therefore, some readings from other materials such as magazine, books, journal, and etc. should be done before start the project to get some data and information. After that, the test that need to be used in this project need to be figured out. Besides, the material for testing will be determined too. Then, the prepared sample is tested by using the procedure of Marshall Test in order to get the data. From the data obtained, analysis can be done and conclusion will be made. All of the project will be carried out in Highway and Transportation Laboratory. Figure 3.1 shows the steps that will be conducted during completing this project.

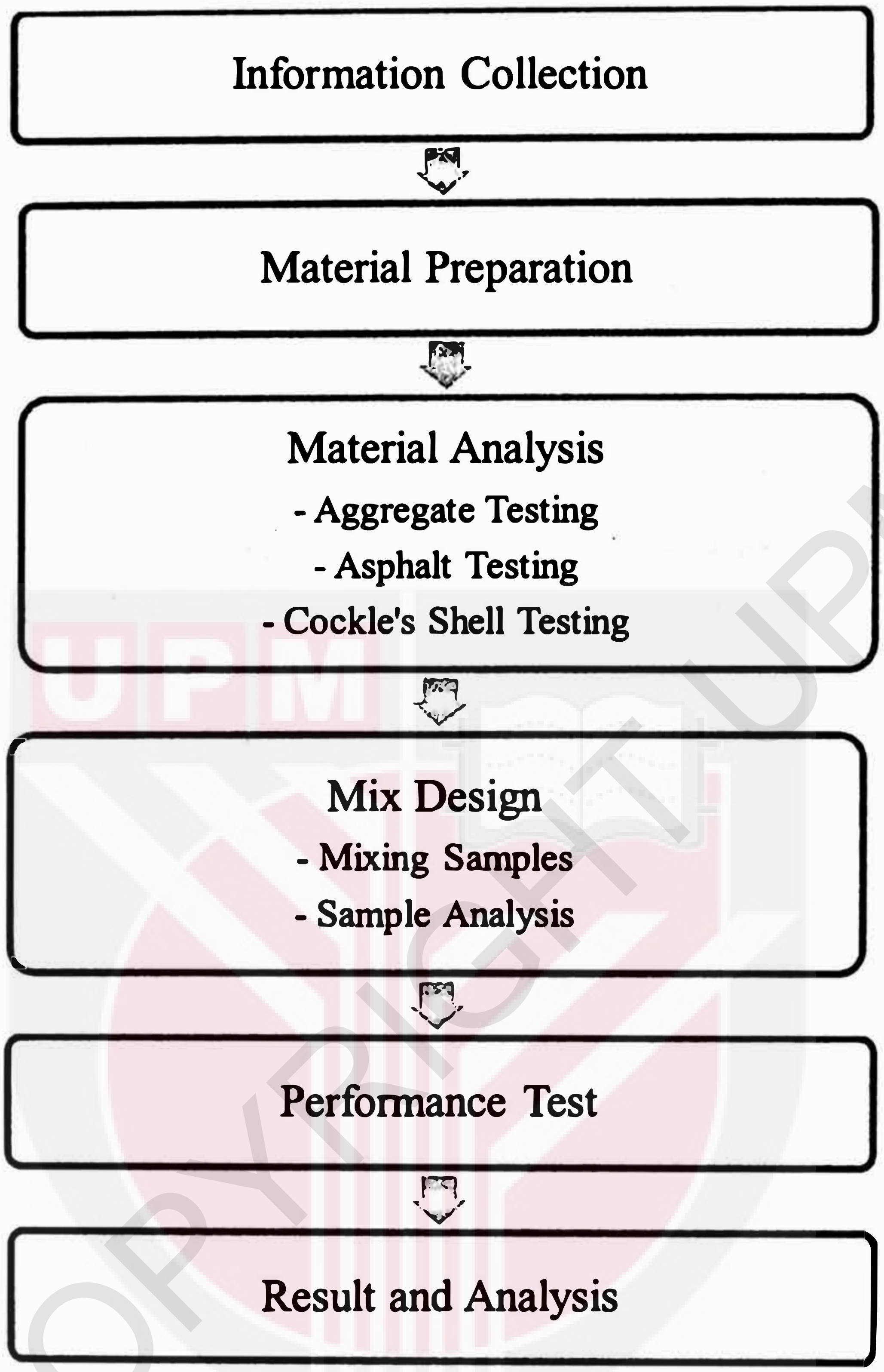

Figure 3.1 : Procedure for this project

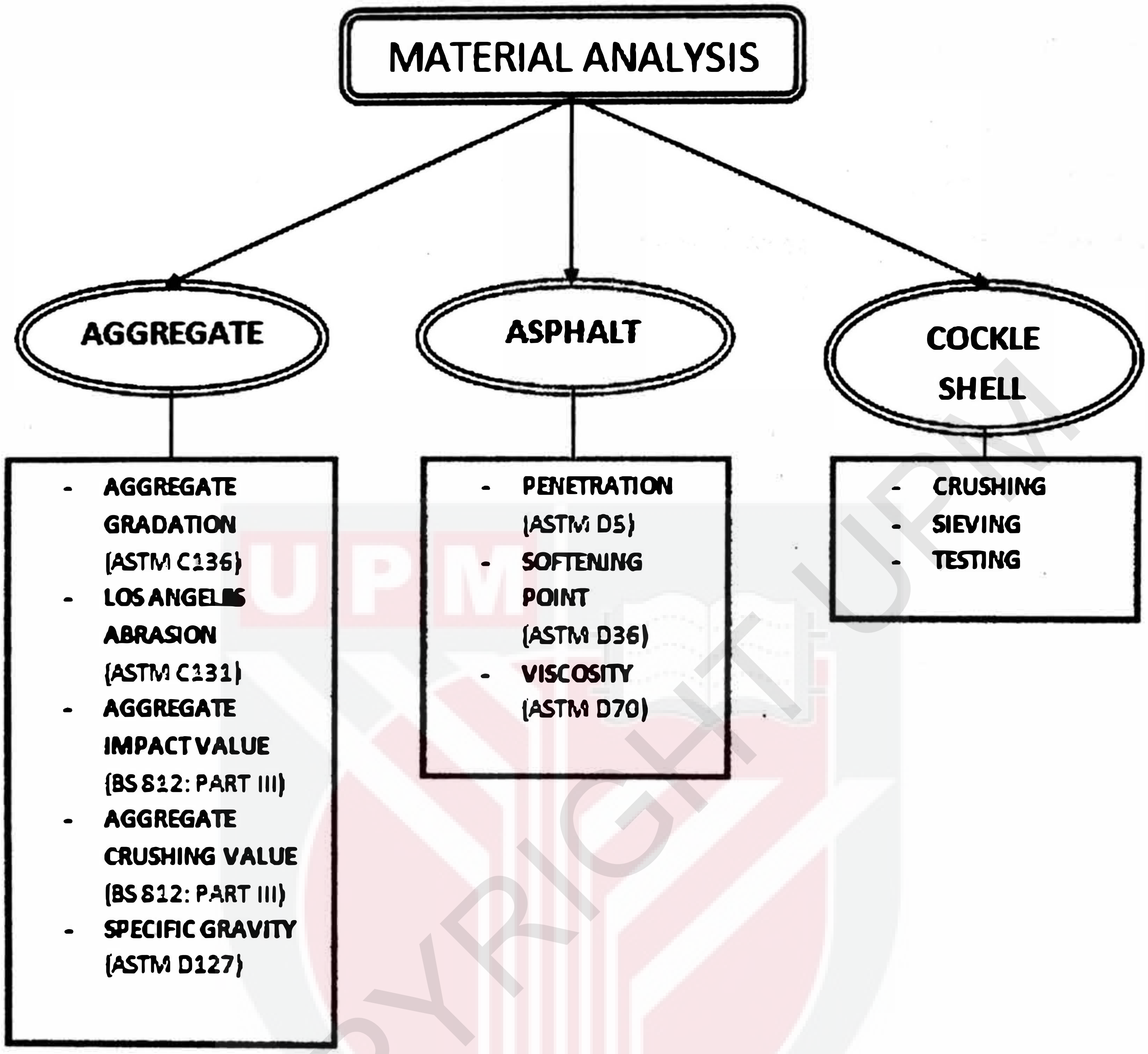

Figure 3.2: Flowchart for material analysis

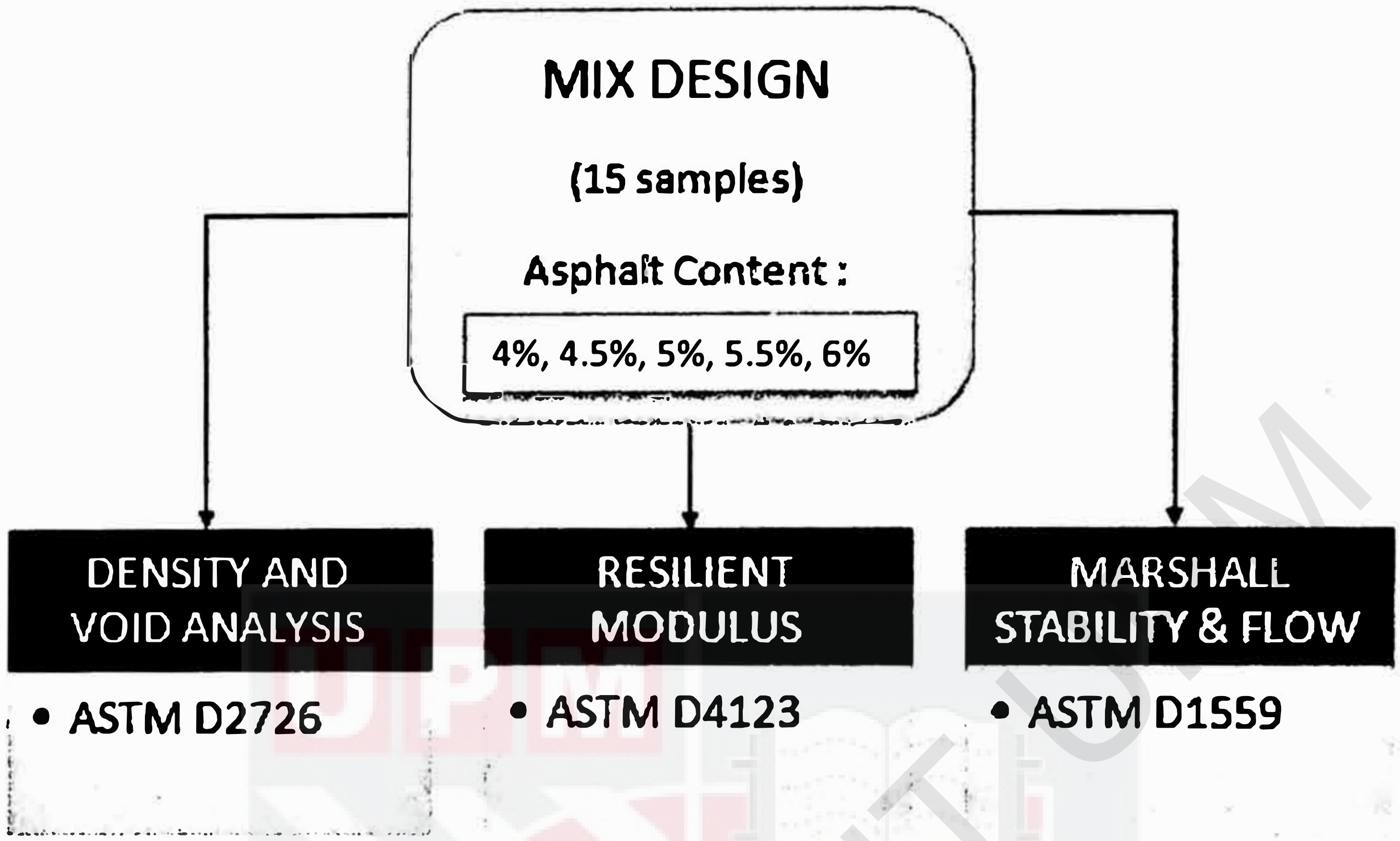

Figure 3.3: Mix design analysis

Figure 3.4 : Performance test

3.2 MATERIALS

The material used for asphalt mixture is, aggregates, asphalt and crushed cockle's shell as filler.

3.2.1 Aggregate

Aggregate used for this study will be granite. Therefore, there are several test will be conducted and will be explained in details.

3.2.2 Asphalt

Type of bitumen used in this study is grade 60/70. The percentage of asphalt will be used in the study are 5%, 5.5%, 6.0%, 6.5% and 7.0% of total weight of aggregates.

3.2.3 Cockle Shell

The cockle shell will be obtained from can food factory. The shell will be washed, crushed and tested in order to be used in this project.

3.3 MATERIAL TESTING

3.3.1 Aggregate Test

3.3.1.1 Aggregate Gradation (ASTM C136)

The gradation of aggregate is the blend of particle size of the mix that affects the density, strength and economy of the pavement structure. There is various size of sieve to design the proportion in a mineral aggregate mix. Aggregate grading is carried out to determine the proportion of aggregate required from each stockpile to fit into the given specification.

Apparatus :

- Sieves (20 mm, 14mm, 10mm, 5mm, 3.35mm, 1.18mm, 0.425mm, 0.15, 0.075mm)
- Sieve Shaker
- Balance machine

Procedure :

1. Approximately 5 kg aggregate from each stockpile are sieved in the specified sieve size.
2. After allocating the aggregate in the sieve, then the mechanical sieve shaker is used to sieve it.
3. The percent passing the sieve aggregate through the selective size are determined by taking the weight retained on each individual sieves over the original weight of the aggregate.
4. The passing percent then is plotted on a 0.45 power gradation chart.
5. In highway projects, the material that gain the no.4 sieve is called the coarse aggregate meanwhile the material that passes the no.4 sieve but retained in the no.200 sieve is known as the fine aggregate.

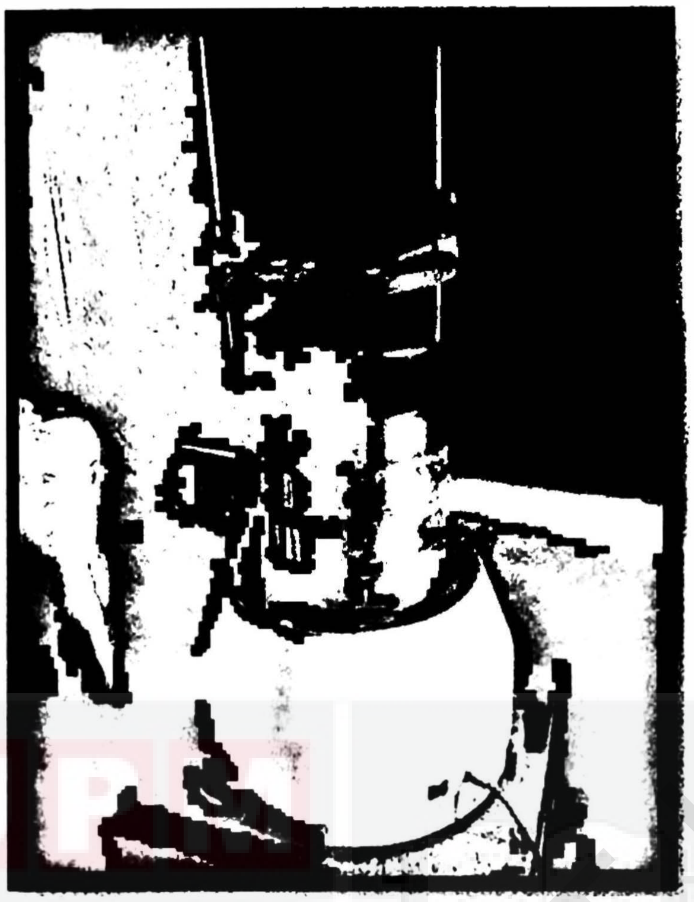

Figure 3.5: Sieve shaker

3.3.1.2 Los Angeles Abrasion Test (ASTM C131)

The Los Angeles test is a measure of degradation of aggregates by abrasion and impact. The number steel charges depend upon the amount and grading of the test sample. As the drum rotates s self plates picks up the sample and the steel spheres, carrying them until they are dropped to the opposite site of the drum creating an impact-crushing effect. The content s the roll within the drum with an abrading and grinding action until the self plate impacts and the cycle is repeated. After the prescribe number of revolutions, the contents are removed from the drum and the aggregate portion is sieved to measure the degradation as percent loss.

Apparatus :

- Los Angeles abrasion machine
- Sieve (19mm, 12.5mm, 1.7mm and pan)
- Sieve Shaker
- Balance machine

Procedure :

1. The sample is washed and dried and later the weight is obtained.
2. The sample is place in LA Abrasion machine.
3. Eleven steel balls are added in the machine.
4. The drum is rotated for about 500 revolutions at 30-33rpm.
5. After being rotated, the sample is removed from the drum and is sieved on no. 12 sieve. Later the sample that is retained on the sieve on dried at the temperature of 105 to 110°C.The weight of the sample is takes after the sample is cooling down.

3.3.1.3 Aggregate Impact Value (BS 812: PART III)

Impact value of an aggregate is the percentage loss of weight of particles passing 2.36 mm sieve by the application of load by means of 15 blows of standard hammer and drop, under specified test condition. The aggregate impact value gives a relative measure of the resistance of an aggregate to sudden shock or impact, which in some aggregates differs from their resistance to a slowly applied compressive load.

Apparatus :

- Impact testing machine
- Measure
  A cylinder of internal diameter 7.5 cm and 5 cm deep for measuring aggregate.
- Tamping rod of 1 cm diameter and 23 cm long rounded at one end and pointed at the other end.
- Sieve
  12.5 mm, 10 mm and 2.36 mm openings.
- Balance
  5000-g capacity
- Laboratory oven capable of maintaining a constant temperature up to 110°C.

Procedure :

1. The aggregate is sieve to obtain the portion passing 12.5 mm and retained on 10 mm sieve.
2. Then, the aggregate obtained is washed and dried at a constant temperature of 105° to 110°C; and the sample is cooled.
3. The aggregate obtained in the cylindrical measure is filled in layers, tapped each layer 25 times with the tamping rod. Using the straight edge, the surface of tamping rod is leveled.
4. Then the aggregate is weight in the measure. This weight of the aggregate is used for the duplicate test on the same material.

5. After that, the aggregate is transferred from the cylindrical measure to the cup in three layers and each layer compacted by tamping in 25 strokes with the tamping rod.
6. The hammer is release to fall freely on the aggregate. The test sample is subjected to a total of 15 blows.
7. Then, the aggregate sample is removed from the cup and is sieved through 2.36 mm sieve.
8. Finally, the fraction passing the sieve is weighed.

3.3.1.4 Specific Gravity Test (ASTM D127)

The specific gravity is important properties that are required for the design of concrete and bituminous. The specific gravity of aggregate is the ratio of its mass to that of an equal volume of distilled water at the specified temperature. This test is carried out to determine the specific gravity of aggregate from different source and type. It also helps to get the absorption value.

Apparatus :

- A balance to permit the basket containing the sample to be suspended from the beam and weighed in water.
- A well-ventilated oven.
- A wire basket or perforated container.
- A stout, watertight container in which the basket may be suspended.
- Cloth.
- A shallow tray
- An airtight container

Procedure :

1. The sample of 1 kg aggregate is thoroughly washed, drained and the placed in the wire basket and immersed in distilled water.
2. Then, the entrapped air is removed from the sample by lifting the basket containing it 25 mm above the base of the tank and allowing it to drop 25 times. The basket and aggregate remain completely immersed during this operation for a period of 24 hours afterwards.
3. The basket and sample are then jolted again and the weighed in water.
4. The basket and aggregate are removed from the water and emptied from the basket on to the dry cloths.
5. The aggregate placed on the dry cloth shall be gently surface –dried with the cloths. The aggregate then weighed.
6. The aggregate is then placed in the oven in the shallow tray at a temperature of 105°C ± 5°C and maintained at this temperature for 24 hours.
7. Then it will be removed from the oven, cooled in the airtight container, and weighed.

3.3.2 Asphalt Test

3.3.2.1 Penetration Test (ASTM D5)

The penetration test is an empirical test used to measure the consistency of asphalt cement. Generally, the penetration of a bituminous substance may be defined as distance in hundredths to which a standard needle penetrates the material under known conditions of time, loading and temperature.

Apparatus :

- Penetration Needle
- Water bath
- Time device
- Penetration Container
- Penetrometer
- Thermometers

Procedure :

1. The asphalt is heated until it is fluid enough to pour. Then asphalt is poured into appropriate sample container which the container should be large enough such that sample depth is at least 10 mm greater than maximum needle penetration depth and minimum lateral dimension of 70 mm.
2. The sample container (100g) is place directly on the submerged stand into the penetrometer. Then the sample container is keep completely covered with water at temperature of 25°±0.5°C.
3. Needle holder is checked and guided to ensure that needle is cleaned and guided apparatus was functioning properly. The penetration needle is clean with toluene or other solvent and dries it with a clean cloth. Then insert the needle carefully in the penetrometer.
4. The needle slowly lowered into the water bath until the tip just makes contact with the surface of the asphalt sample. Then either note the penetrometer reading or set it to zero.

5. Quickly the needle holder is released and allowed the needle to move under its own weight for a total of 5 seconds, then locked the position of the needle. Get the reading in units of 0.1 mm. (If the sample container moves during the test, that result should be discarded.)
6. Three penetration measurements at points on the surface is make not less than 10 mm from the side of the container and not less than 10 mm apart.

3.3.2.2 Softening Point Test (ASTM D36)

The softening test is defined as the mean of the temperature at which the bitumen disks often and sag downward a distance of 25 mm under the weight of a steel ball. In other word, it can be simplified that it is (softening point) the temperature at which bitumen becomes soft enough to flow. The softening point of asphalt is measured by the "ring-and-ball" test (ASTM Standard D 2398). The softening point of coal tar pitch is measured by the "cube-in-water" test (ASTM Standard D 61).

Apparatus :

- Steel ball, 9.53mm in diameter, weighing between 3.55g
- Ring
- Ball-centering guide
- Ring Holder
- Bath
- Thermometer

Procedure :

1. The hot asphalt is poured into the ring and cooled it to room temperature for about 30 minutes. Then, the sample is leveled.
2. The ring is placed on the ring shoulder. the temperature in the water bath is maintained at 5 ± 1 °C for 40 minutes and the sample is kept in the water bath at a level of not less than 102 mm and not more than 108 mm from the bottom of the bath.
3. Place the ball in each ball centrering guide by using forceps. Then the heat is applied at a rate of 5 °C per minute and make sure it is increased uniformly.
4. Temperature of each ring and ball is recorded by using thermometer when the specimen surrounding the ball touches the bottom plate .

3.3.2.3 Viscosity Test (ASTM D4402)

Viscosity test was carried out to determine the viscosity of the asphalt cement at different temperatures. Viscosity can be adjusted by blowing air through hot bitumen - causing oxidation and an increase in molecular weight - and leading to more viscous "semi-blown" or "blown" grades.

Apparatus :

- Brookfield rotational Viscometer

Procedure :

1. Preheat spindle, sample chamber and viscometer environmental chamber to 275°F (135°C)
2. Heat unaged asphalt binder until fluid enough to pour. Stir the sample, being careful not to entrap air bubbles.
3. Pour appropriate amount of asphalt binder into sample chamber. The sample size varies according to the selected spindle and equipment manufacturer.
4. Insert sample chamber into RV temperature controller unit and carefully lower spindle into sample.
5. Bring sample to the desired test temperature within approximately 30 minutes and allow it to equilibrate at test temperature for 10 minutes.
6. Rotate spindle at 20 RPM, making sure the percent torque as indicated by the RV readout remains between 2 and 98 percent.
7. Once the sample has reached temperature and equilibrated, take 3 viscosity reading from RV display, allowing 1 minute between each reading. Viscosity is reported as the average of 3 readings.
8. Repeat the same procedures at temperature of 165°C

3.4 MIX DESIGN ANALYSIS

Asphalt mix design is a complex issue with a lot of variables involved. However two methods of mix design have become popular worldwide. They are the Marshall Mix Design and the Hveem Mix Design Method. In Malaysia the Marshall Method of mix design has become the norm in the road industry. To prepare standard specimens of asphaltic concrete for the determination of stability and flow in the Marshall apparatus and to determine density, percentage air voids and percent of aggregate voids filled with binder.

Apparatus

- mould
- filter paper
- Marshall compaction pedestal

Procedure :

1. The aggregate is graded for 20 set according to the ASTM standard and are oven-dried at 170-180 °C and a sufficient amount is weighed (about 1200g) for sample preparation that may give a height of 63.5mm when compacted in the mould.
2. After grading the aggregate, it is then inserted into 20 separated tray together with filler and dried in oven for 24 hours.
3. The required quantity of asphalt is weighed out and the equipment to be used for mixing are heated to a temperature of 160-165 °C 2 hours before conducting the mixing step.
4. A crater is formed in the aggregates, the binder poured in and mixing carried out until all the aggregate are coated. The mixing temperature shall be within the limit set for the binder temperature. The thoroughly cleaned mould is heated in an oven to a temperature between 140 and 170 °C. The mould is 101.6mm diameter by 76.2mm high and provided with a base plate and extension collar.

5. For first 5 sets of mixed aggregate, the sample is separated into pieces and is allowed to cool on a zinc plate once the mixing of aggregates, filler and asphalt is completed for TMD test and the other samples are mixed and store into a mould for density, resilient modulus and stability test.
6. A piece of filter paper is fitted in the bottom of the mould and the whole mix poured in three layers. Oil grease is applied on the surface of the inner wall of the mould and the filter paper. The mix is then vigorously trowelled 15 times round the perimeter and 10 times in the centre leaving a slightly rounded surface. After cover the surface of the mould with another piece of filter paper, the mould is again heated to 158 °C in oven.
7. The mould is placed on the Marshall Compaction pedestal and given 50 blows on top and bottom of the mould.
8. The specimen is then carefully removed from the mould, transferred to a smooth flat surface and allowed to cool to room temperature.
9. Finally, the specimen is measured and weighed in air and water (for volume determination). If the asphalt mix has an open (porous) texture the weighing in water will lead to error in the volume and so the specimen must be coated with a measured mass of paraffin wax. The specimen is then marked and stored for stability and flow measurements.

3.4.1 Density and Void Analysis (ASTM D2726)

The specific gravity and absorption of aggregates are important properties that are required for the design of concrete and bituminous mixes. The specific gravity of a solid is the ratio of its mass to that an equal volume of distilled water at a specified temperature. Because aggregates may contain water-permeable voids, two measures of specific gravity of aggregates are used: apparent specific gravity and bulk specific gravity.

3.4.1.1 Bulk Density of Specimen

Apparatus :

- Balance
- Water bath
- drying cloth

Procedures :

1. Weigh the dry samples then immersed them in a water bath at 25°C for 3 to 5 minutes then weigh them. Designate the mass.
2. Mass of saturated surface dry specimen in air – surface dry the specimen by blotting quickly with a damp towel and then weigh in air. Designate this mass as ; B
3. Mass of oven – dry specimen – oven dry the specimen to constant mass at 110 ± 5 °C. Allow the specimen to cool and weigh in air and designate this mass as ; A
4. The bulk specific gravity for the specimens is calculated using the following equation:

$$Bulk\ Specific\ Gravity = \frac{A}{B-C} \times 100$$

Where;

A = Weight of dry specimen in air

B = Weight of saturated surface dry specimen in air

C = Weight of saturated specimen in water

3.4.1.2 Maximum Theoretical Density TMD

Apparatus :

- Balance
- water bath
- vacuum
- baskets

Procedures :

1. Prepare the sample according to the specification and make the materials separated in specific sizes.
2. Weigth the basket which will be used in Vacuum container then put the sample in the basket and weight it again.
3. Put the basket with the sample inside the vacuum container and completely cover the sample by adding water at approximately 25°C to the container.
4. Remove the entrapped air in the sample by applying a vacuum of 30mm Hg or less.
5. Slowly release the vacuum and weight the sample in water.
6. To find the weight of sample in water, weight the containers.
7. The theoretical maximum density is calculate using formula below :

TMD = (W(sample+basket)-W(basket)) — (W(basket, sample and container in water) – W(basket and container in water)) / Weight (dry sample)

Figure 3.6: Rice method apparatus

3.4.1.3 Voids In Total Mix, VTM or (Va)

The total volume of the small pockets of air between the coated aggregate particles throughout a compacted paving mixture, expressed as a percent of the bulk volume of the compacted paving mixture.

$$V_a = \left(1 - \frac{G_{mb}}{G_{mm}}\right) \times 100$$

3.4.1.4 Voids in the Mineral Aggregates (VMA)

The volume of inter granular void space between the aggregate particles of a compacted paving mixture that include the air voids and the effective asphalt content, expressed as a percent of total volume of the specimen.

$$VMA = \left(1 - \frac{G_{mb}(1 - P_b)}{G_{sb}}\right) \times$$

3.4.1.5 Voids Filled with Asphalt (VFA)

It is the portion of the voids in the mineral aggregate that contain asphalt binder. This represents the volume of the effective asphalt content. It can also be describe as the percent of the volume of the VMA that is filled with asphalt cement. VFA is inversely related to air voids; as air voids decreases, the VFA increases.

$$VFA = \frac{VMA - V_a}{VMA}$$

3.4.2 Resilient Modulus Test (ASTM D4123)

1. Specimens were kept in the MATTA machine at a temperature of 25°C for at least two hours and the pressure was adjusted to 750 kPa.
2. The specimen was putting into the diametral yoke. Four thumb screws were rotated until the sample in balance level. The loading strip was put on the top of sample. The hole on loading strip is adjusted in same vertical line with loading ram. LVDT was adjusted to zero value to avoid any zero error.
3. When specimen put in the direct compressive load was applied through a 12 mm wide loading strip along the vertical diameter of the specimens. The linear variable differential transducers (LVDTs) were used to monitor the resultant indirect tensile stress and strain along the horizontal diameter.

4. Prior to the actual test, an initial conditioning of five load pulses with a three second interval between pulses, was applied to assess the strength and determine the load that was applied in the subsequent test period to generate sufficient horizontal deformation without damaging the specimens. These pulses also serve to bed the loading strips on to the specimens.
5. The rise and the rest times in between the initial application and the peak value of the load is arbitrarily specified at 100 milliseconds. Observe that the rise time gives a load-time relationship with a clearly defined peak at 20°C for all the specimens tested. The test conditions as described above are essentially maintained throughout the test, as the stiffness depends on these conditions.
6. For each specimen, the test was repeated after rotating the specimen through approximately 90°C. Provided the difference is about 10% or less, the mean of the two test result is taken as the elastic stiffness of the specimen.

3.4.3 Marshall Stability & Flow Test (ASTM D1559)

The most widely used method of asphaltic mix design is the Marshall method developed by the U.S. Corps of Engineers. Stability and flow, together with density, voids and voids filled with binder are determined at varying binder contents to determine an optimum for stability, durability, flexibility and fatigue resistance.

Apparatus

- Marshall apparatus
- Water bath
- Thermometer

- Cloth
- Watch

Procedure :

1. Three specimens of different asphalt percentage are prepared according the Standard and immersed in a water bath for 30 to 40 minutes or in an oven for 2 hours at 60°C ± 1.0°C.
2. The testing heads and guide rods are thoroughly cleaned, guide rods lubricated and head maintained at a temperature between 21.1°C and 37.8°C.
3. A specimen is removed from the water bath or oven and placed in the lower jaw and the upper jaw placed in position as shown in the figure below. The complete assembly is then placed in the compression-testing and the flow meter adjusted to zero.
4. The load is applied to the specimen at a constant strain rate of 50.8mm/minute until the maximum load is reached. The maximum force and flow at that force are read and recorded. The maximum time that is allowed between removal of the specimens from the water bath and maximum load is 5 minutes.

3.5 PERFORMANCE TEST

Performance test is the test that is done by preparing the samples using the OAC obtained from the mix design and the samples are then being tested for fatigue and rutting.

3.5.1 Fatigue Test

Procedure:

i. Prepare 3 samples by using the OAC obtained from mix design
ii. Condition the samples for two hours at 20c inside the MATTA machine.
iii. Perform fatigue test by using the MATTA machine with the following parameters:
    - Poisson ratio = 0.4
    - Cycle=3600
    - Cycle duration =100ms
    - Cycle repetition time =500ms
    - Seating force=100N
    - Cyclic loading force =200N
iv. Analysis of data

3.5.2 Rutting Test

Procedure:

i. Prepare 3 samples by using the OAC obtained from mix design
ii. Condition the samples for two hours at 40c inside the MATTA machine.
iii. Perform rutting test by using the MATTA machine with the following parameters:
    - Loading function=Haversine
    - Preload stress=10Kpa

- Preload time=60s
- Cyclic loading stress=200Kpa
- Cycle=7200
- Cycle duration =100ms
- Cycle repetition time =500ms
- Confine stress=100kPa
- Cyclic loading force =200N

iv. Analysis of data

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

All of the results obtained from the laboratory work are entitled in this chapter. The test results include material properties, mix design analysis and performance tests. The material properties test includes aggregate, asphalt and cockle's shell. The results are analysed and shown in tables, graphs and figures form. All of this laboratory works are being conducted at Highway and Transportation Laboratory, UPM.

4.2 AGGREGATE PROPERTIES TEST

The test are done to determine the properties of aggregate. The test includes aggregate gradation, Los Angeles abrasion, aggregate impact value, soundness, and specific gravity test for coarse and fine aggregates.

4.2.1 Aggregate Gradation (ASTM C136)

The determination of HMA mixture performance as pavement material influences by particle size distribution, or gradation, of the constituent aggregate. The result of aggregate gradation is shown in Table 4.1 is carried out to determine the proportion of aggregate required to fit in the grading limit.

Table 4.1: Aggregate gradation results:

Sieve Size	Percent Passing (%)	Percent Retained (%)	Grading Limit	
			Lower	**Upper**
20.00	100	0	100	100
14.00	95	5	90	100
10.00	81	14	76	86
5.00	56	25	50	62
3.35	47	9	40	54
1.18	26	21	18	34
0.425	18	8	12	24
0.150	10	8	6	14
0.075	6	4	4	8
Pan	0	6		

4.2.2 Los Angeles Abrasion Test (ASTM C131)

LA Abrasion test is to ascertain the degradation of aggregates by abrasion and impact. The weight loss for LA Abrasion is 1350g. Therefore, the percentage loss is 27% as shown in Table 4.2, which are under the JKR requirement of 30% and it is suitable to be used for road work.

Table 4.2 : LA Abrasion results

Aggregate Size (mm)	Weight of Sample Before (g)	Weight of Sample After (g)	Loss (g)
14-12.5	2500	3650	1350
12.5-9.5	2500		

Weight loss = Weight of sample before – Weight of sample after

= 5000 – 3650

= 1350 g

Percentage loss = (Weight loss) / (Total weight of sample)

= 1350 / 5000

= 27 %

4.2.3 Aggregate Impact Value (BS 812: Part III)

The test is to determine the aggregate impact value in the laboratory. Table 4.3 below shows AIV result which is 11.02%. The results obtained are below the requirement of 15% according to JKR requirement and it is suitable to be used

Table 4.3: Aggregate impact value results

Sample	Aggregate Size (mm)	Weight of Sample Before Crush (g)	Weight of Sample After Crush (g)	Weight Passing 2.36mm Sieve (g)
A	14-10	630	560	70
B	14-10	640	570	70
Average	14-10	635	565	70

$$\text{Aggregate Impact Value, AIV} = \frac{\text{Average weight of aggregate passing 2.36mm}}{\text{Average weight before impact}} \times 100$$

$$= \frac{70}{635} \times 100$$

$$= 11.02\ \%$$

4.2.4 Soundness Test (ASTM C88)

Soundness test is conducted to determine the resistance of aggregates to disintegration by saturated solution of sodium sulphate, cycle freezing and thawing and weathering action. The percentage loss for both group sieve size are shown in Table 4.4. The average of percentage loss is 11.03% and it is below of the requirement of 12%.

Table 4.4: Soundness test result

Sieve size (mm)	Weight of aggregate before testing(g)	Weight of aggregate after testing (g)	Percentage of loss (%)
14-10	1000	993.1	6.69
5	500	478.3	4.34

Example of calculation for sieve size 14-10mm :

Percentage of loss = [(weight of sample before testing - weight of sample after testing) / (weight of sample before testing)] x 100

= [(1000 - 933.1)] / 1000] x 100

= 6.69%

Total soundness loss of the sample = summation of loss of all fractions

= 6.69% + 4.34 %

= 11.03%

4.2.5 Specific Gravity Test (ASTM D127)

The tests are carried out to determine the specific gravity of aggregate from different source and type. It is also can determine the absorption value.

4.2.5.1 Specific Gravity Coarse Aggregate

The size used for specific gravity coarse aggregate are more than 5mm. The results obtained are shown in Table 4.5 where the specific gravity is 2.581 with water absorption of 0.91%. Both specific gravity and absorption are in the range of JKR requirement which are 2.4% to 3% and less than 2% respectively.

Table 4.5: Specific gravity for coarse aggregate

Coarse Aggregate	Label	Sample
Mass of Oven dry sample in air (g)	A	1000
Mass of SSD sample in air (g)	B	1009.1
Mass of SSD sample in water (g)	C	621.6
Bulk Specific Gravity, Gsb	A/(B-C)	2.581
Bulk SSD Specific Gravity, Gbulk SSD	B/(B-C)	2.604
Apparent Specific Gravity, Gsa	A/(A-C)	2.643
Water Absorption (%)	[(B-A)/A * 100]	0.91%

4.2.5.2 Specific Gravity Fine Aggregate

The size used for specific gravity fine aggregate are in the range of 75μm to 3.35mm. The results obtained are shown in Table 4.6 where the specific gravity is 2.595 with water absorption of 0.81%. Both specific gravity and absorption are in the range of JKR requirement which are 2.4% to 3% and less than 2% respectively.

Table 4.6: Specific gravity for fine aggregate

Fine Aggregate	**Label**	**Sample**
Mass of Oven dry sample in air (g)	A	496
Mass of pcynometer + Water (g)	B	640.1
Mass of pcynometer + SSD + Water (g)	C	949
Mass of SSD sample (g)	S	500
Bulk Specific Gravity, Gsb	A/(B+S-C)	2.595
Bulk SSD Specific Gravity, Gbulk SSD	S/(B+S-C)	2.616
Apparent Specific Gravity, Gsa	A/(B+A-C)	2.651
Water Absorption (%)	[(S-A)/A * 100]	0.81%

4.3 ASPHALT PROPERTIES TEST

The test are done to determine the properties of asphalt. The test includes penetration, softening point, flash and fire point and viscosity tests. The results are shown in Table 4.7 where all of the results are in between JKR requirement.

Table 4.7 : Asphalt properties test results

Types of Test	**Standard**	**Result**	**JKR Requirement**
Penetration	ASTM D5	61.75mm	60mm to 70mm
Softening Point	ASTM D36	49.25°C	48°C to 56°C
Flash and Fire point	ASTM D92	290°C	276°C
Viscosity at 135°C	ASTM D4402	0.515 Pa.s	-
Viscosity at 165°C	ASTM D4402	0.171 Pa.s	-

4.4 COKCLE'S SHELL PROPERTIES TEST

The test are done to determine the properties of cockle's shell. The test includes Los Angeles abrasion, and soundness test.

4.4.1 Los Angeles Abrasion Test

LA Abrasion test is to ascertain the degradation of cockle's shell by abrasion and impact. The result of percentage loss is 25% as shown in Table 4.8, which are under the JKR requirement of 30% and it is suitable to be used.

Table 4.8: LA Abrasion result for cockle's shell

Weight of Sample Before (g)	Weight of Sample After (g)	Loss (g)
2500	1875	625

Weight loss = Weight of sample before – Weight of sample after

= 2500 – 1875

= 625 g

Percentage loss = (Weight loss) / (Total weight of sample)

= 625 / 2500

= 25 %

4.4.2 Soundness Test

Soundness test is conducted to determine the resistance of cockle's shell to disintegration by saturated solution of sodium sulphate, cycle freezing and thawing and weathering action. The percentage loss for both group sieve size are shown in Table 4.9. The percentage loss is 0.91% and it is below of the requirement of 12%.

Table 4.9 : Soundness test result for cockle's shell

Weight of Sample Before Testing(g)	Weight of Sample After Testing (g)	Percentage of Loss (%)
500	495.45	0.91

Percentage of loss = [(weight of sample before testing - weight of sample after testing)/ (weight of sample before testing)] x 100

= [(500 – 495.45) / 1000] x 100

= 0.91%

4.5 MIX DESIGN ANALYSIS

For Mix Design, 20 samples are prepared in determination of Optimum Asphalt Content (OAC) for both conventional and crushed cockle's shell sample. These samples are testing for density and air void analysis, resilient modulus test and Marshall stability and flow test. The graphs for all test are plotted against percentage of asphalt content are plotted and OAC are obtained. the final OAC will be determined by finding the average of OAC for every testing.

4.5.1 Conventional Sample

20 samples are prepared for conventional sample, where 15 samples are for mixing and another 5 samples are for rice method.

4.5.1.1 Density and Void Analysis (ASTM D2726)

This testing are conducted to determine the bulk density and void analysis of the asphalt mixture. The density and void analysis is important in the mix design analysis because it can directly affect the strength and durability of the pavement. Air voids are define as small air spaces that occur between the coated aggregate particles in final compacted asphalt mixture. A certain percentage of air voids is necessary in all dense-graded mixes to prevent the pavement from flushing, shoving and rutting. The amount of asphalt content will affect the air voids. In addition, the more fines added to asphalt mixture, it will lower the air voids. The durability of asphalt mixture is function of the air void content. This is because the lower the air void, may lead flushing. However, too high air void content will provides passageways through the mix for the entrance of damaging air and water. Hence, density and air void content are directly related. The higher the density, the lower the percentage of air voids in asphalt mixture.

Figure 4.1 shows a graph of bulk density against asphalt content which shows that density increases as the percentage asphalt increases. The results of optimum asphalt content at 5.60% which gives the maximum density of 2.356 g/mm.

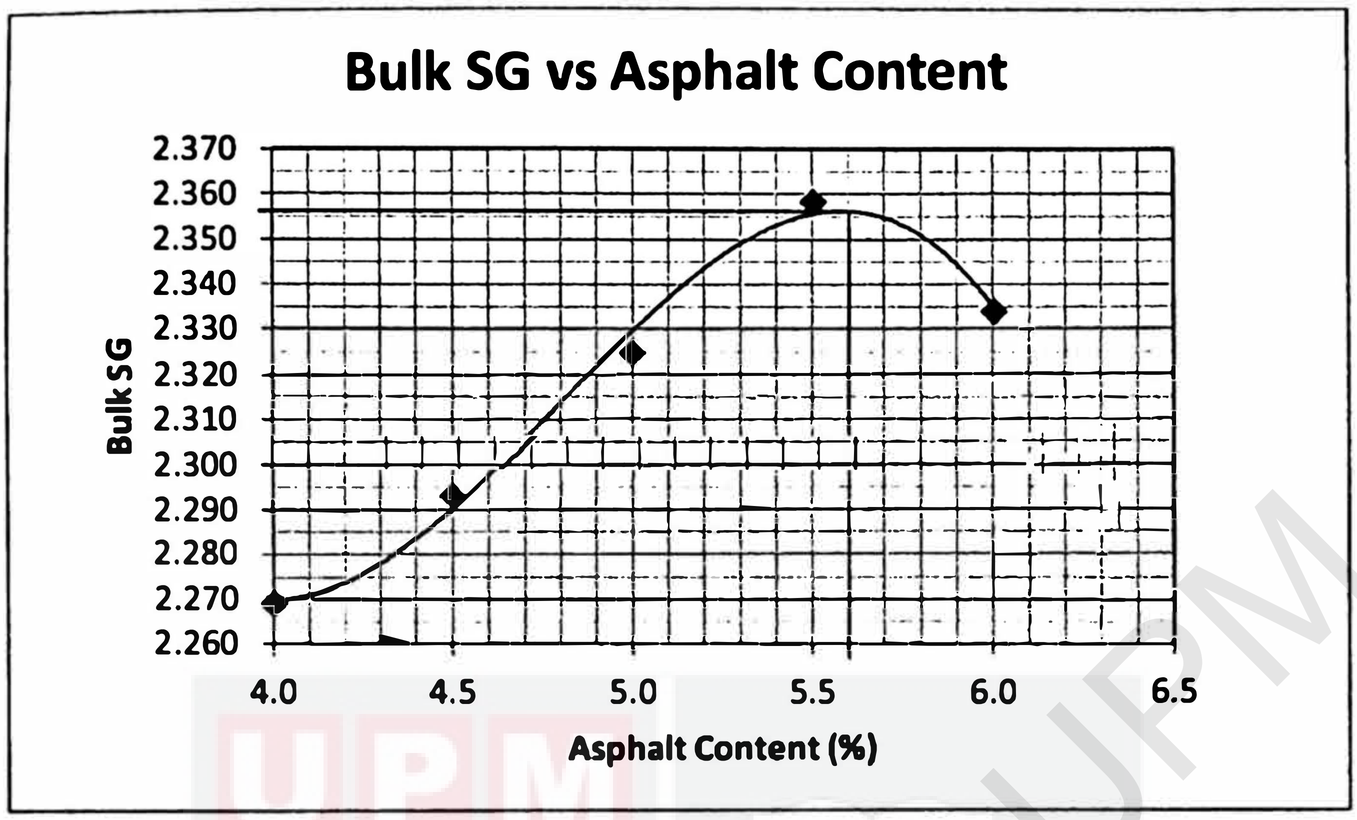

Figure 4.1: Graph of density vs asphalt content for conventional sample

4.5.1.2 Voids in Mineral Aggregates (VMA)

VMA is the volume of void space between the aggregate particles of a compacted paving mixture that includes the air voids and the effective asphalt content. If VMA is too low, there is no space in the mixture to add sufficient asphalt to adequately coat the individual aggregate particles. Also, mixes with a low VMA are more sensitive to small changes in asphalt content. Furthermore, excessive VMA will cause unacceptably low mixture stability. Figure 4.2 below shows the analysis of the results VMA against asphalt content. It can be seen that optimum asphalt content is at 4.0%.

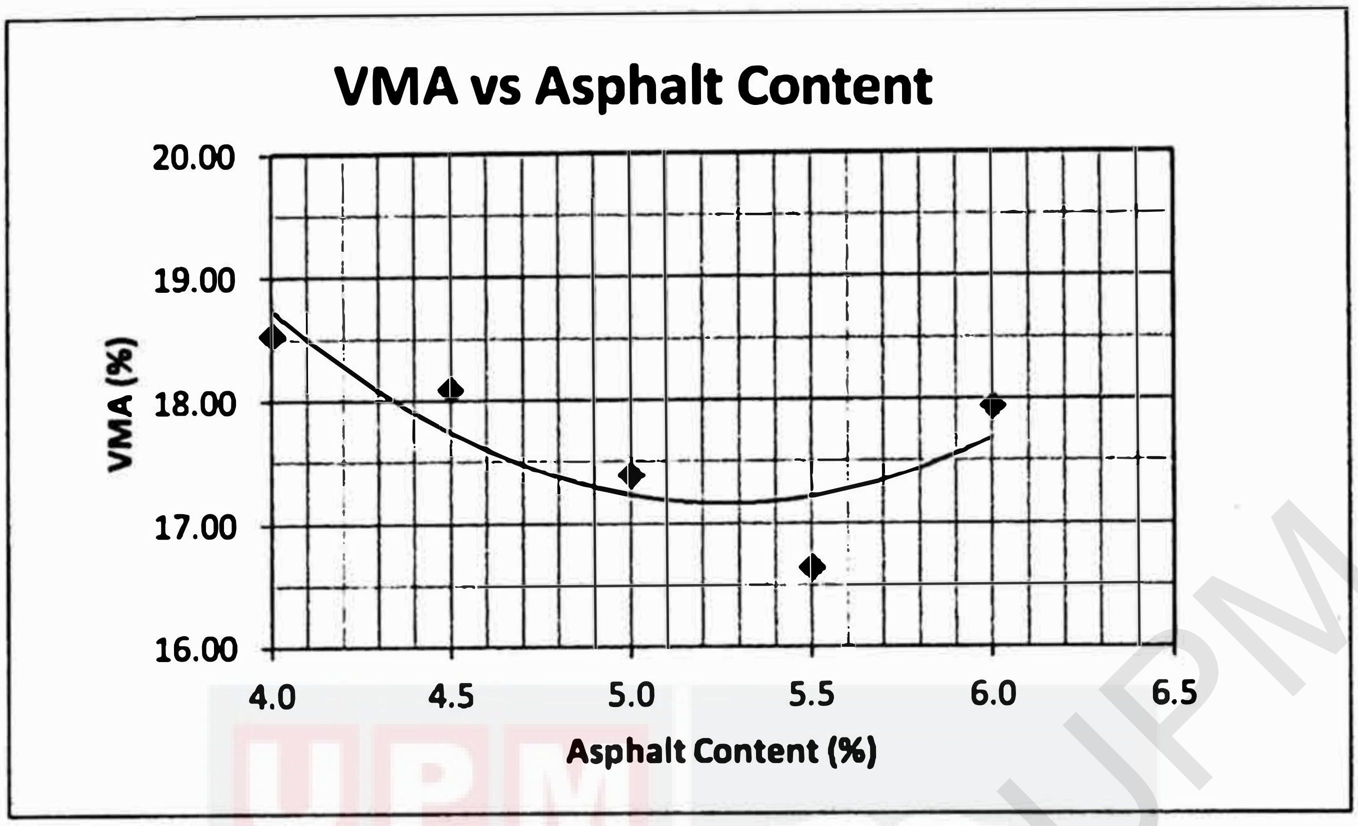

Figure 4.2: Graph of VMA vs asphalt content for conventional sample

4.5.1.3 Voids Filled with Asphalt (VFA)

VFA are the void spaces that exist between the aggregate particles in the compacted paving HMA that are filled with asphalt. In theoretically, VFA is inversely related to air voids. As air voids decrease, VFA will increase. The main effect of the VFA is to limit maximum levels of VMA and subsequently maximum levels of asphalt content. Hence, percent of VFA increase with increasing asphalt content as shown in Figure 4.3. From result obtained, the highest VFA is 77 % corresponding to 6.0 % asphalt content.

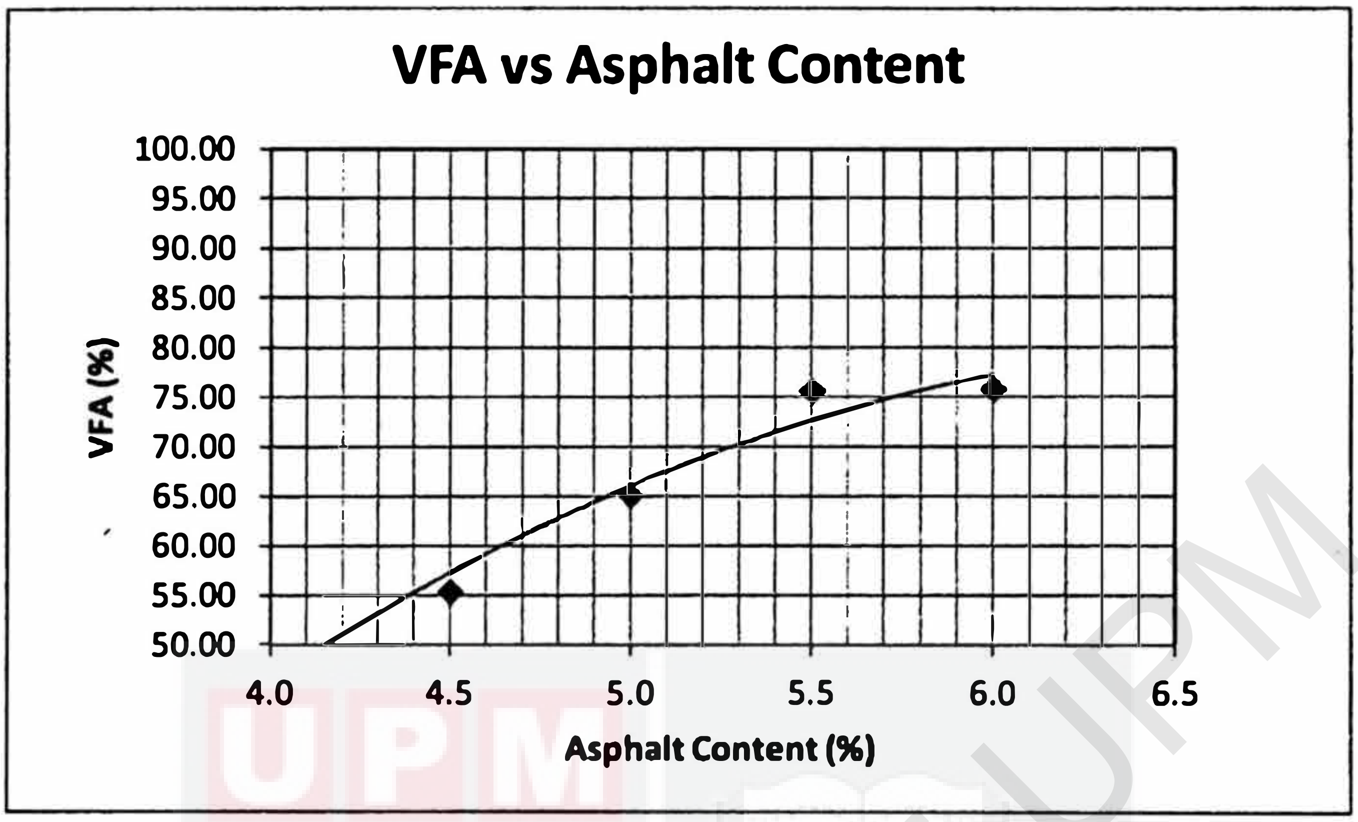

Figure 4.3: Graph of VFA vs asphalt content for conventional sample

4.5.1.4 Voids in Total Mix (VTM)

Figure 4.4 shows the analysis of the results VTM against asphalt content. The optimum asphalt content should corresponds to the specifications median air void content which is 4%. At 4% of air void, the optimum asphalt content obtained from the graph is 5.40%. The decreasing percentage of air voids shows the increasing of asphalt content.

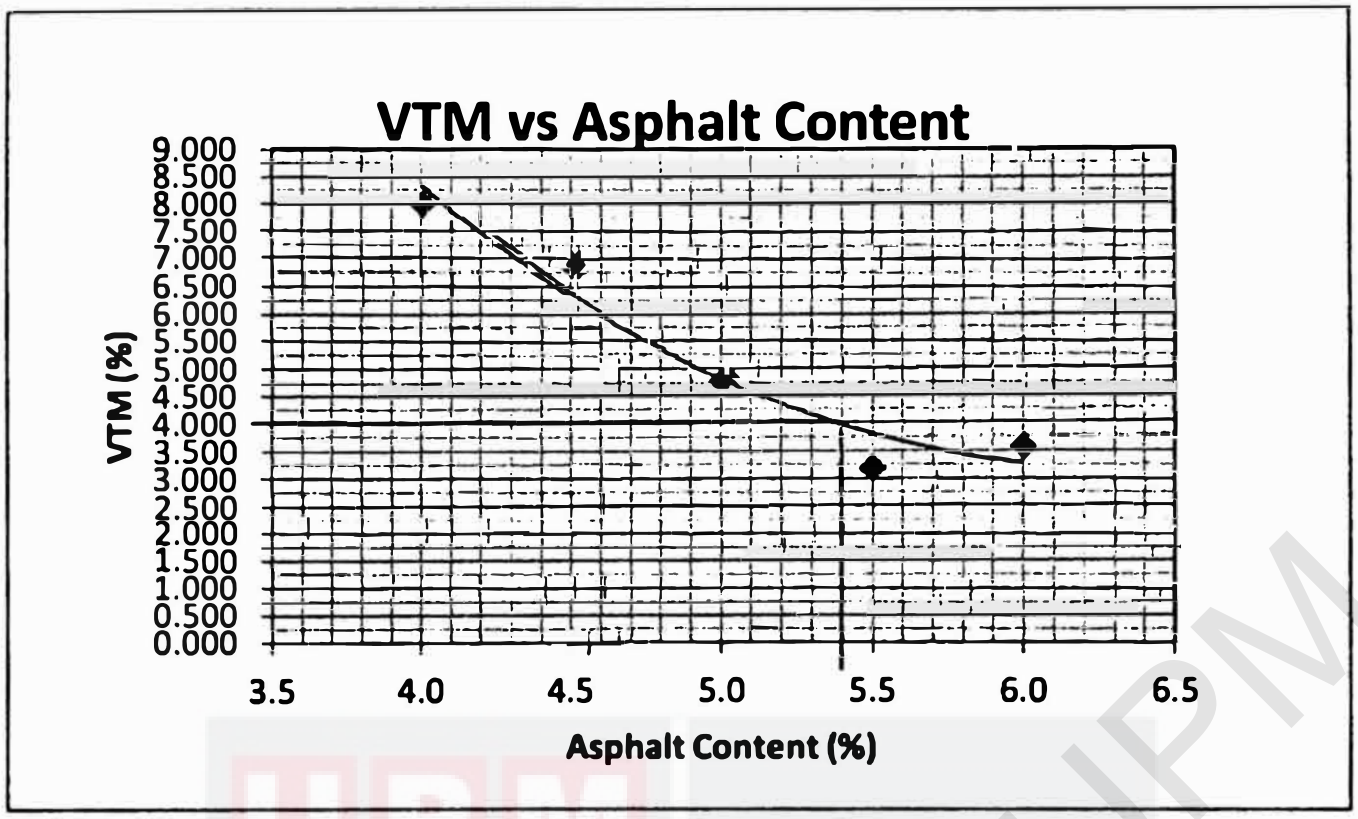

Figure 4.4 : Graph of VTM vs asphalt content for conventional sample

4.5.1.5 Resilient Modulus Test (ASTM D4123)

Resilient modulus is an important property used in the mechanistic analysis of pavement response under moving loads as well as an input parameter for design of flexible pavements. The effectiveness and efficiency of pavement structural thickness design is contingent on the accuracy in measuring the resilient modulus (MR). It is an important parameter for flexible pavements thickness design as the resilient modulus of structural layers are used to estimate the layer coefficients hence layer thicknesses. Therefore, the effectiveness of thickness design is directly related to the accuracy in measuring the resilient modulus. The test was done by measuring the elastic stiffness in repeated loading using Material Testing Apparatus (MATTA).

Figure 4.5 shows the analysis of the resilient modulus against asphalt content. The test is carried out to measure the stiffness modulus of asphalt mixtures. The optimum asphalt content obtained from the graph is 4.60% which gives the resilient modulus of 3200 Mpa. It shows that 4.60% of asphalt content can gives better resistance in tension. The relationship between the asphalt and the resilient modulus are presented in graph which as the percent of asphalt increases, the value of the resilient modulus of the sample is also increases up to the optimum point.

Furthermore, there are a few factors that could be influence the value of the resilient modulus. Firstly is the compaction. The specimen should be prepared at the target field density to obtain the most realistic estimation of in-place performance. Specimen compacted at low density normally has lower resilient modulus compare to those compacted at higher density. The parameters that cause the differences in magnitude include the maximum aggregate size, particle shape, grading and the applied normal stress. Secondly is moisture content. It should be tested in a moisture condition as close as possible as field condition. As the moisture content increase, the resilient modulus will decrease.

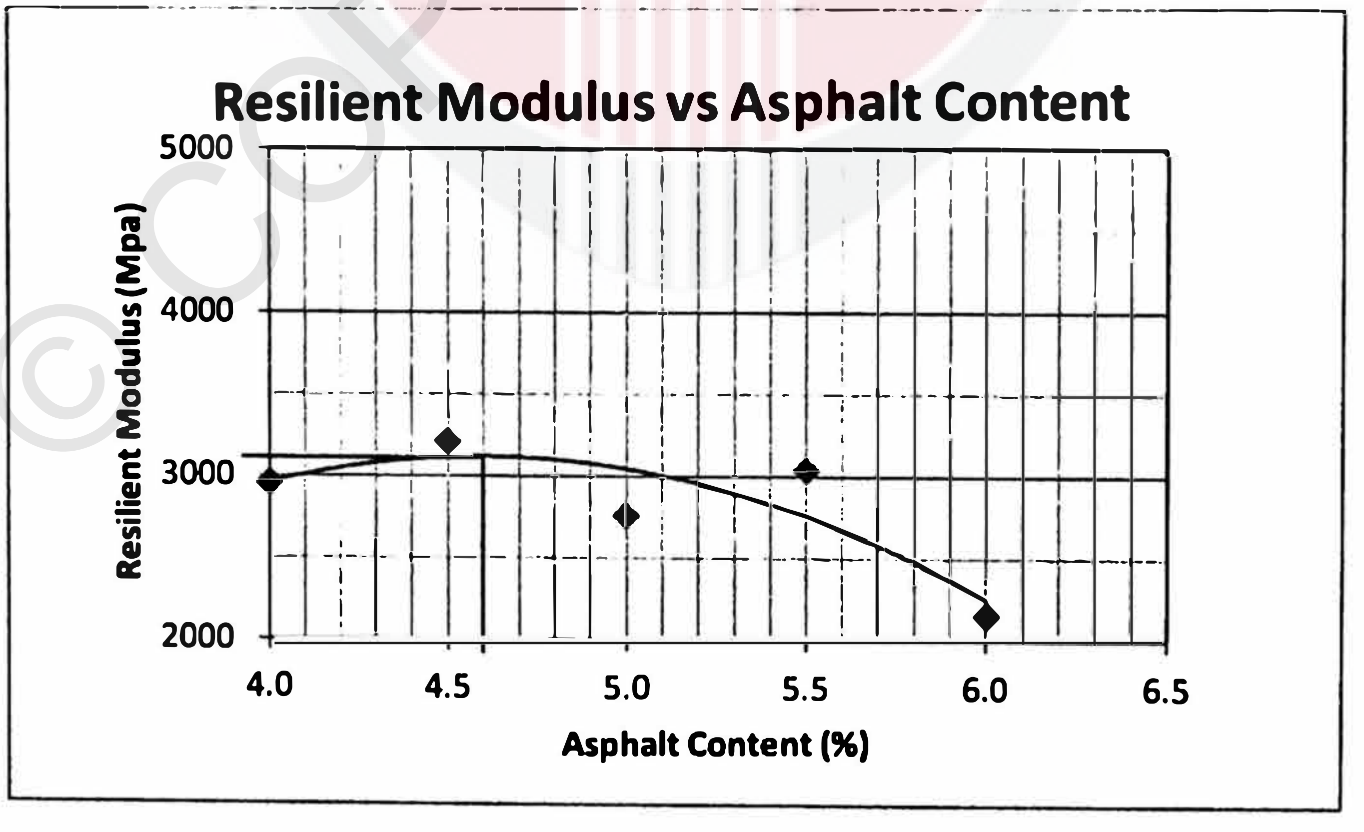

Figure 4.5: Graph of resilient modulus vs asphalt content for conventional sample

4.5.1.6 Marshall Stability and Flow Test (ASTM D1559)

Figure 4.6 shows the analysis of the stability against asphalt content. The test is to measure the resistance to plastic flow of cylindrical specimens of an asphaltic paving mixture loaded on lateral surface. The optimum asphalt content for stability is 5.15% which gives stability of 11.4 kN. The stability of asphalt sample indicates resistance against plastic and durability which is important to pavement design. Higher stability of the asphalt sample, higher overall performance and quality of asphalt sample used for pavement design. From the result, the asphalt sample with 5.15% asphalt content has highest overall performance and quality since it has highest stability.

Based on JKR in mix design requirements (Arahan Teknik Jalan, 5/85), the maximum stability is at least 6.4 kN. From result obtained, maximum stability of the sample is in the JKR requirement. The Marshall stability result obtained is corrected with the height correlation ratio as it is possible that the thickness of specimen is slightly varying from the standard specification. This done by multiplying each measured stability with calculated correlation factor.

The high flow values show that the mixture experiences a plastic behavior and might undergo permanent deformation such as rutting or shoving. Besides that, the low flow values show that the mixture does not have enough binder percentage and cause the pavement has low durability performance and cracking might occur. The Marshall Stability and flow test is important for the performance of mix design and also provide a quality control of asphalt concrete mixture. Its disadvantage is does not provide fundamental engineering properties.

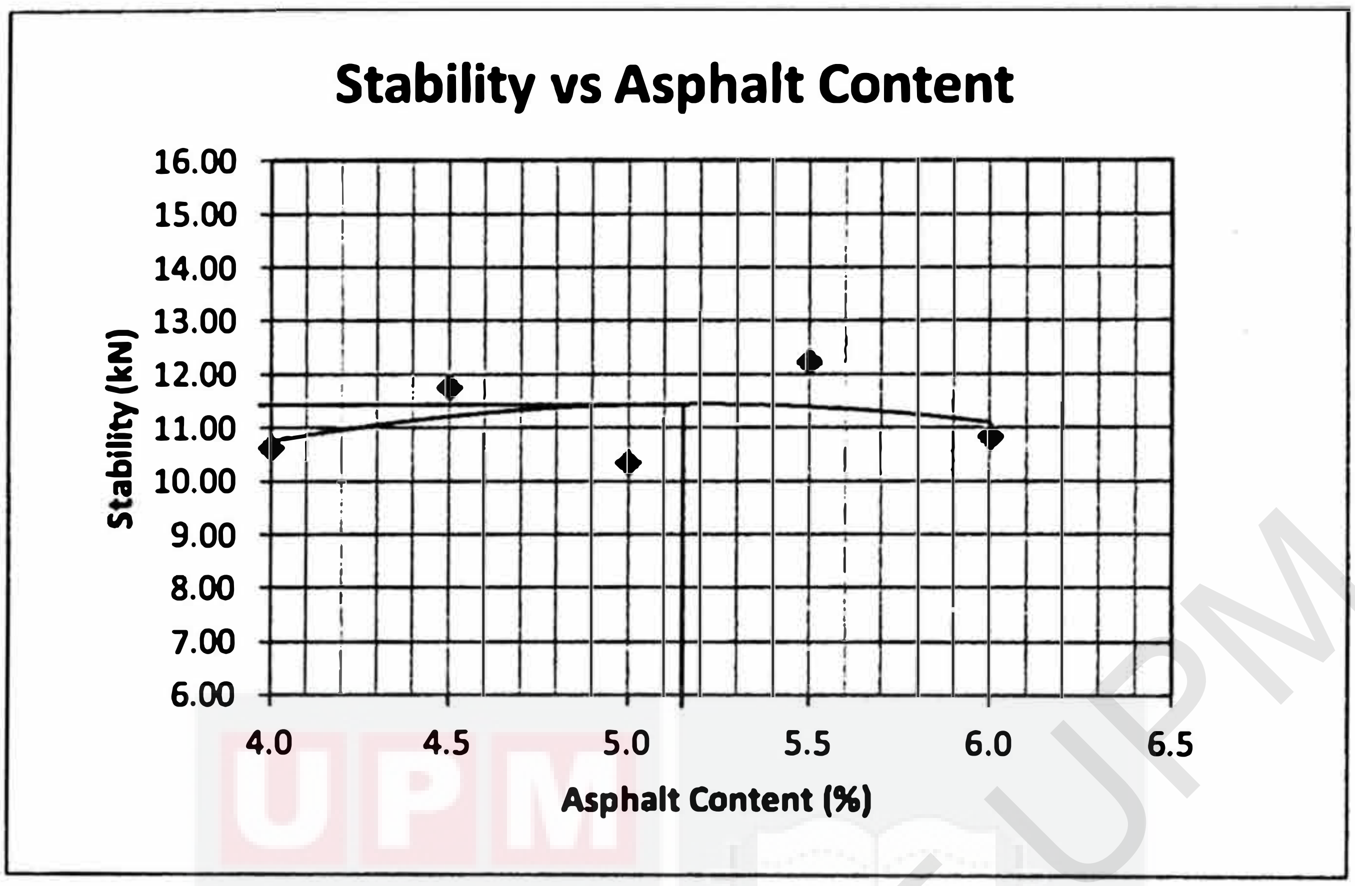

Figure 4.6 : Graph of stability vs asphalt content for conventional sample

4.5.1.7 Marshall Results for Conventional Sample

Table 4.10 below shows that the summary of the results for Marshall conventional sample. The yellow highlighted box is not included in the calculations.

Table 4.10 : Results for Marshall conventional sample

Sample	AC by weight of mix	Specimen Diameter	Specimen Height	Weight			Bulk	Density		Total Volume (%)			Voids, %			Stability			Flow	Resilient Modulus
				In Air	In Water	SSD	Volume	Bulk SG	TMD				VMA	VFA	VTM	Measured	Correction	Adjusted		
	(%)	(mm)	(mm)	(g)	(g)	(g)	cm³		(Loose Mix)	Asphalt	Aggregate	Voids				(lb)	factor		(mm)	(MPa)
A	4.0	101.00	70.00	1237.3	700.8	1248.6	547.80	2.259		8.772	81.089	10.139	18.911	46.38	8.445	12.3	0.86	10.578	3.65	2408
B	4.0	101.00	69.00	1228.0	700.0	1239.6	539.60	2.276		8.838	81.699	9.463	18.301	48.29	7.756	11.57	0.88	10.182	2.85	4024
C	4.0	101.00	69.00	1232.1	703.2	1245.2	542.00	2.273		8.828	81.609	9.563	18.391	48.00	7.858	12.73	0.88	11.202	2.74	3514
Average		101.00	69.33					2.269	2.487	8.812	81.466	9.722	18.534	47.56	8.019			10.654	3.08	2961
A	4.5	101.00	69.00	1239.0	708.7	1247.8	539.10	2.298		10.041	82.081	7.878	17.919	56.04	6.726	12.05	0.88	10.604	3.47	2969
B	4.5	101.00	71.00	1248.9	711.6	1258.7	547.10	2.283		9.973	81.527	8.499	18.473	53.99	7.355	11.8	0.84	9.912	4.97	3215
C	4.5	101.00	68.70	1241.2	710.3	1250.2	539.90	2.299		10.044	82.105	7.851	17.895	56.13	6.899	14.71	0.88	12.945	4.18	3450
Average		101.00	69.57					2.293	2.464	10.019	81.905	8.076	18.095	55.38	6.927			11.774	4.21	3211
A	5.0	101.00	69.00	1251.6	726.0	1255.9	529.90	2.362		11.466	83.914	4.620	16.086	71.28	3.278	15.32	0.88	13.482	5.37	3539
B	5.0	101.00	70.00	1237.6	698.85	1235.6	536.75	2.306		11.193	81.916	6.891	18.084	61.89	5.580	10.18	0.86	8.755	4.8	2528
C	5.0	101.00	69.70	1252.1	711.1	1253.7	542.60	2.308		11.202	81.983	6.816	18.017	62.17	5.504	10.31	0.86	8.867	5.44	2230
Average		101.00	69.57					2.325	2.442	11.287	82.604	6.109	17.396	65.12	4.787			10.368	5.20	2766
A	5.5	101.00	66.30	1249.0	726.15	1254.75	528.60	2.363		12.617	83.504	3.879	16.496	76.48	3.043	13.24	0.94	12.446	3.64	2850
B	5.5	101.00	67.00	1252.1	724.4	1256.4	532.00	2.354		12.568	83.176	4.256	16.824	74.70	3.423	11.35	0.92	10.442	4.81	3119
C	5.5	101.00	67.00	1248.9	723.4	1252.65	529.30	2.359		12.599	83.383	4.018	16.617	75.82	3.183	15.05	0.92	13.846	5.1	3143
Average		101.00	66.77					2.359	2.437	12.595	83.354	4.051	16.646	75.67	3.216			12.245	4.52	3037
A	6.0	101.00	66.00	1234.5	704.2	1238.9	534.70	2.309		13.449	81.158	5.394	18.842	71.37	4.639	11.73	0.95	11.144	5.58	2064
B	6.0	101.00	66.00	1259.3	727.7	1262.5	534.80	2.355		13.717	82.776	3.507	17.224	79.64	2.738	11.78	0.95	11.191	5.28	2062
C	6.0	101.00	68.00	1253.0	721.2	1256.9	535.70	2.339		13.625	82.223	4.151	17.777	76.65	3.387	11.35	0.90	10.215	6.17	2350
Average		101.00	66.67					2.334	2.421	13.597	82.052	4.351	17.948	75.89	3.588			10.850	5.68	2159

4.5.2 Crushed Cockle's Shell Sample

20 samples are prepared for crushed cockle's shell sample, where 15 samples are for mixing and another 5 samples are for rice method. The filler used is crushed cockle's shell.

4.5.2.1 Density and Void Analysis (ASTM D2726)

Figure 4.7 below shows a graph of bulk density against asphalt content. The results of optimum asphalt content at 5.68% which gives the density of 2.323 g/mm.

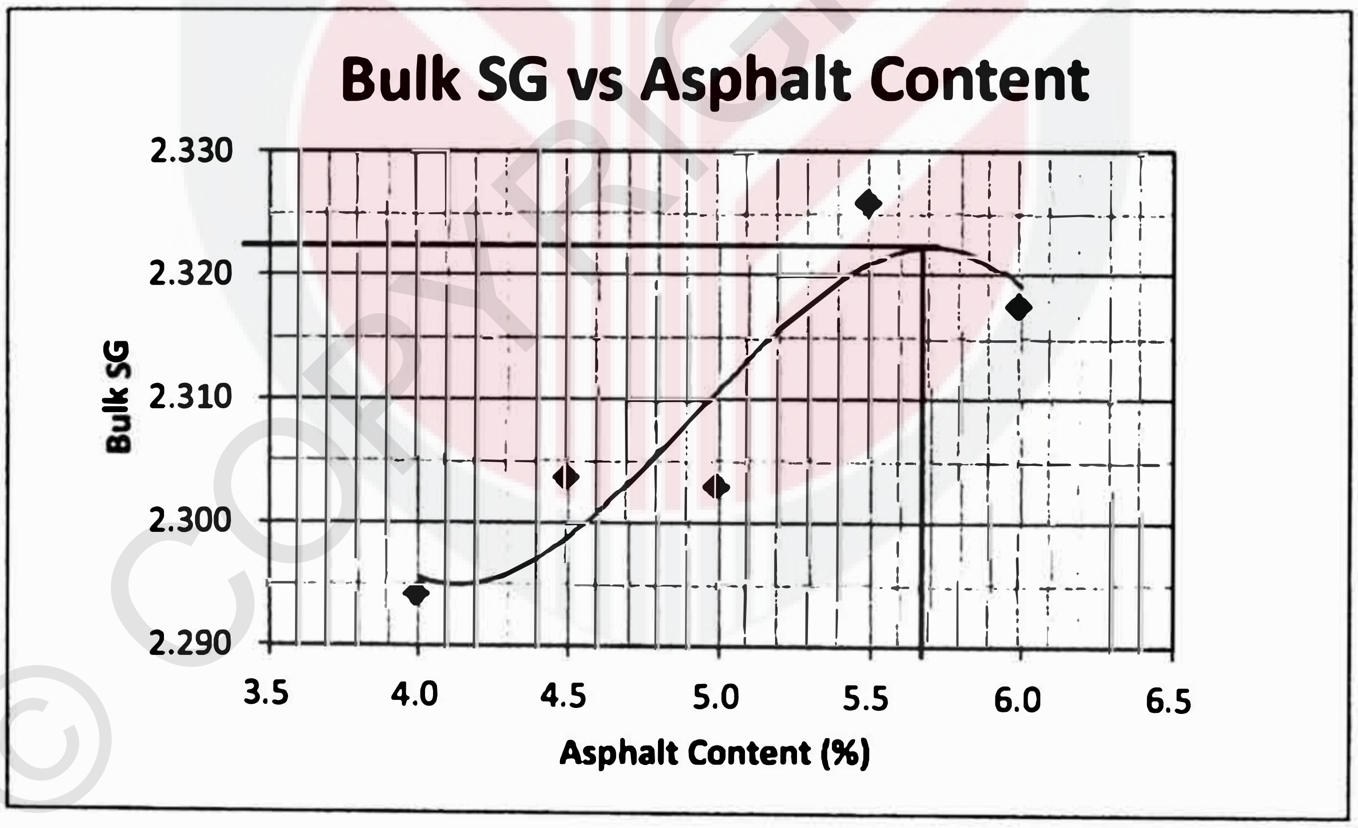

Figure 4.7: Graph of density vs asphalt content for crushed cockle's shell sample

4.5.2.2 Voids in Mineral Aggregate (VMA)

Figure 4.8 below shows the analysis of the results VMA against asphalt content. It can be seen that optimum asphalt content is at 6.0% with 18.5% of VMA percentage.

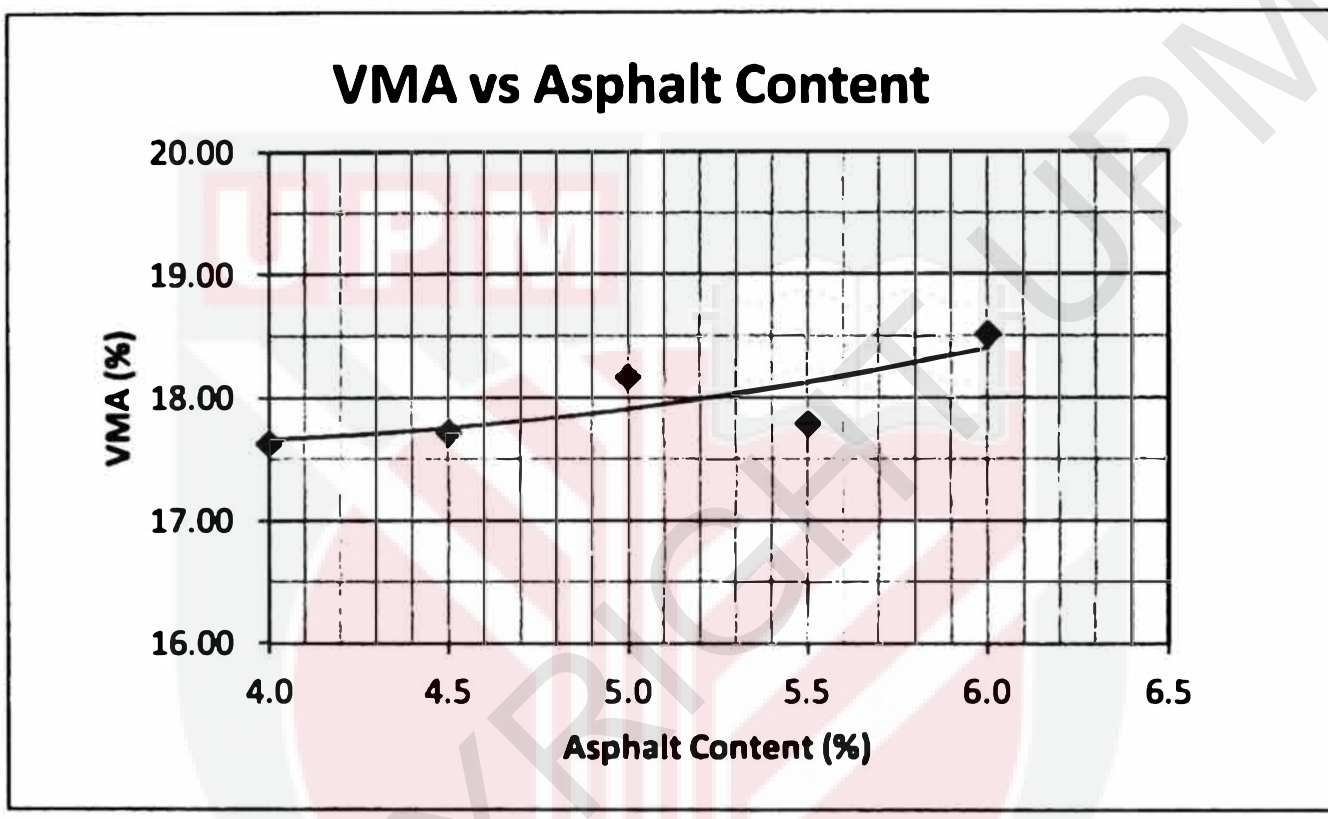

Figure 4.8 : Graph of VMA vs asphalt content for crushed cockle's shell sample

4.5.2.3 Voids Filled with Asphalt (VFA)

For VFA, the percentage of VFA increase with increasing asphalt content as shown in Figure 4.9. From result obtained, the highest VFA is at 73 % corresponding to 6.0 % asphalt content.

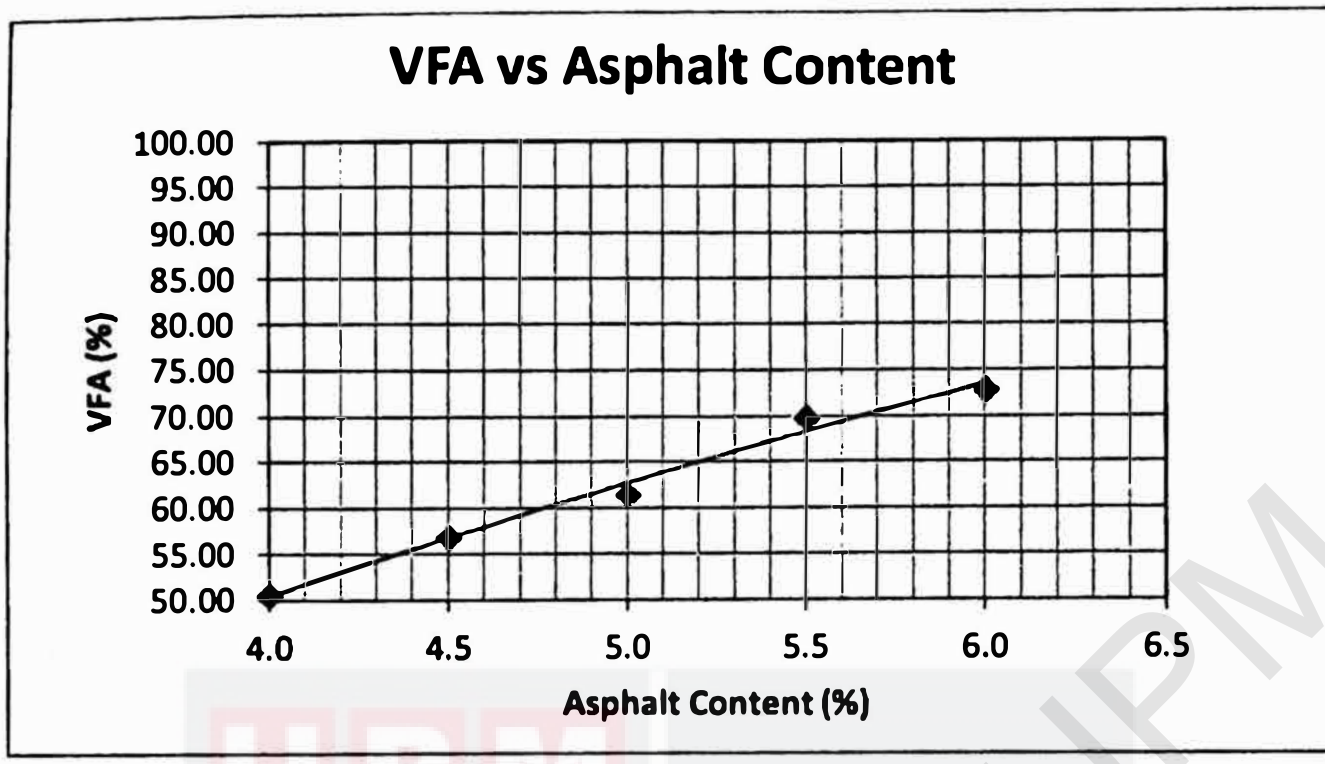

Figure 4.9 : Graph of VFA vs asphalt content for crushed cockle's shell sample

4.5.2.4 Voids in Total Mix (VTM)

Figure 4.10 shows the analysis of the results VTM against asphalt content. At 4% of air void, the optimum asphalt content obtained from the graph is 4.16%. The decreasing percentage of air voids shows the increasing of asphalt content.

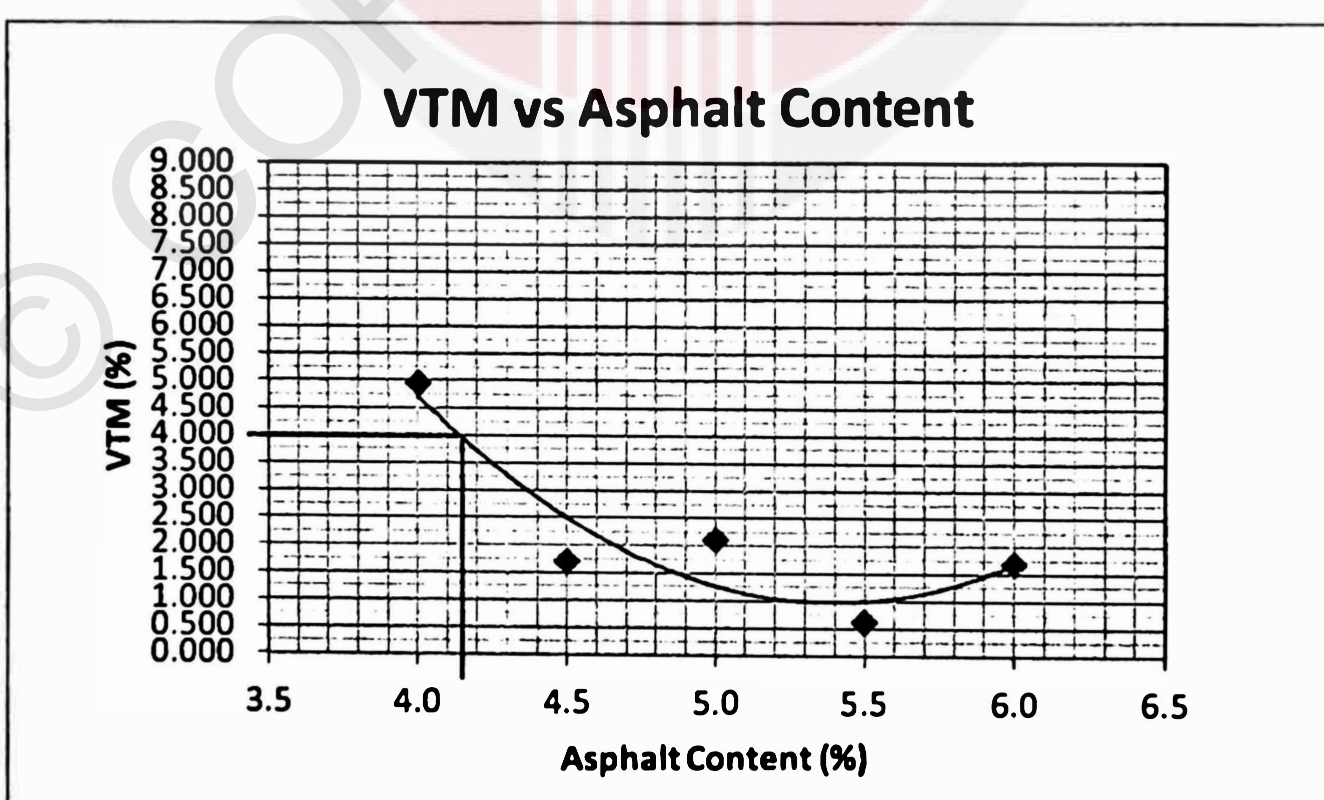

Figure 4.10 : Graph of VTM vs asphalt content for crushed cockle's shell sample

4.5.2.5 Resilient Modulus Test (ASTM D4123)

Figure 4.11 shows the analysis of the resilient modulus against asphalt content. The test is carried out to measure the stiffness modulus of asphalt mixtures. The optimum asphalt content obtained from the graph is 5.50% which gives the resilient modulus of 3500 Mpa. It shows that 5.50% of asphalt content can gives better resistance in tension. The relationship between the asphalt and the resilient modulus are presented in graph which as the percent of asphalt increases, the value of the resilient modulus of the specimen is also increases up to the optimum point.

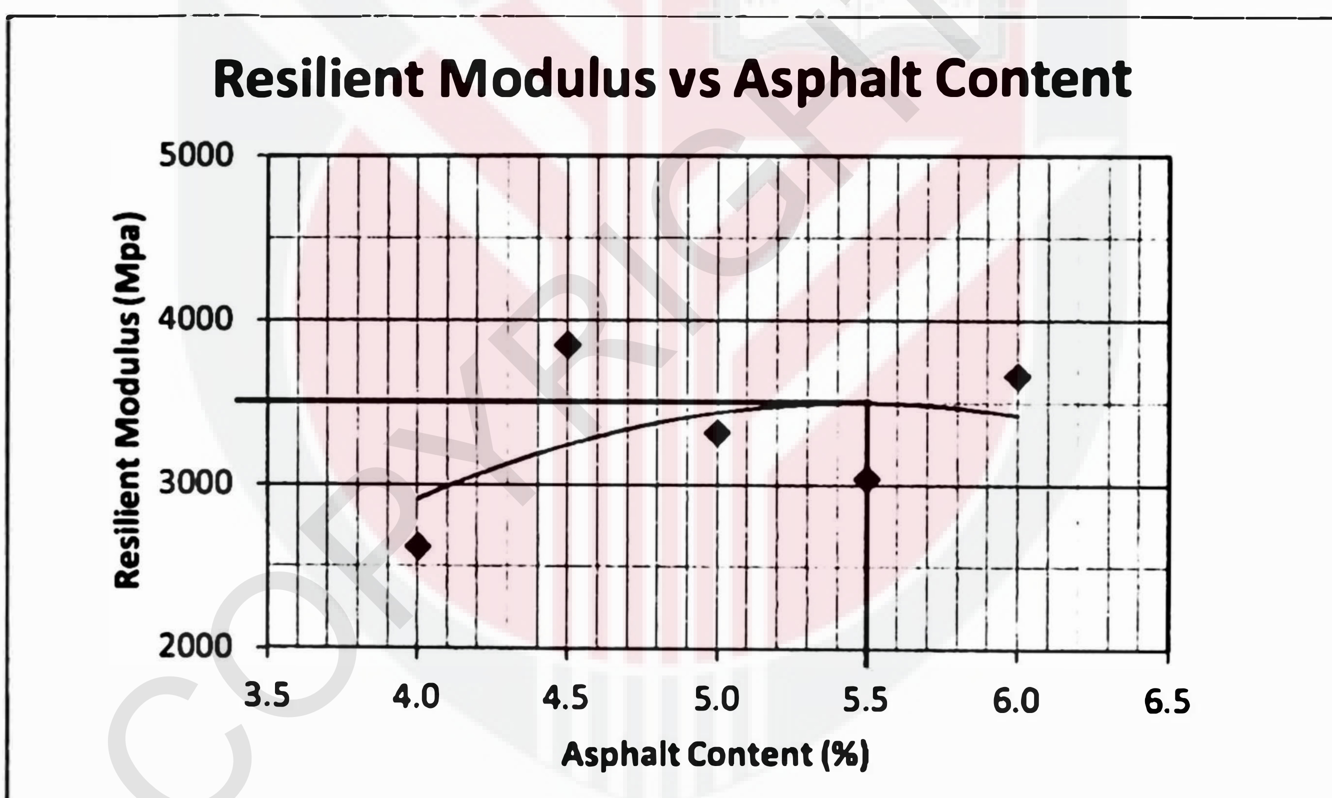

Figure 4.11: Resilient Modulus vs asphalt content for crushed cockle's shell sample

4.5.2.6 Marshall Stability and Flow Test (ASTM D1559)

Figure 4.12 shows the analysis of the stability against asphalt content. The test is to measure the resistance to plastic flow of cylindrical specimens of an asphaltic paving mixture loaded on lateral surface. The optimum asphalt content for stability is 5.4% which gives stability of 11.2 kN. The stability of asphalt sample indicates resistance against plastic and durability which is important to pavement design. Higher stability of the asphalt sample, higher overall performance and quality of asphalt sample used for pavement design. From the result, the asphalt sample with 5.15% asphalt content has highest overall performance and quality since it has highest stability.

Based on JKR in mix design requirements (Arahan Teknik Jalan, 5/85), the maximum stability is at least 6.4 kN. From result obtained, maximum stability of the sample is in the JKR requirement. The Marshall stability result obtained is corrected with the height correlation ratio as it is possible that the thickness of specimen is slightly varying from the standard specification. This done by multiplying each measured stability with calculated correlation factor.

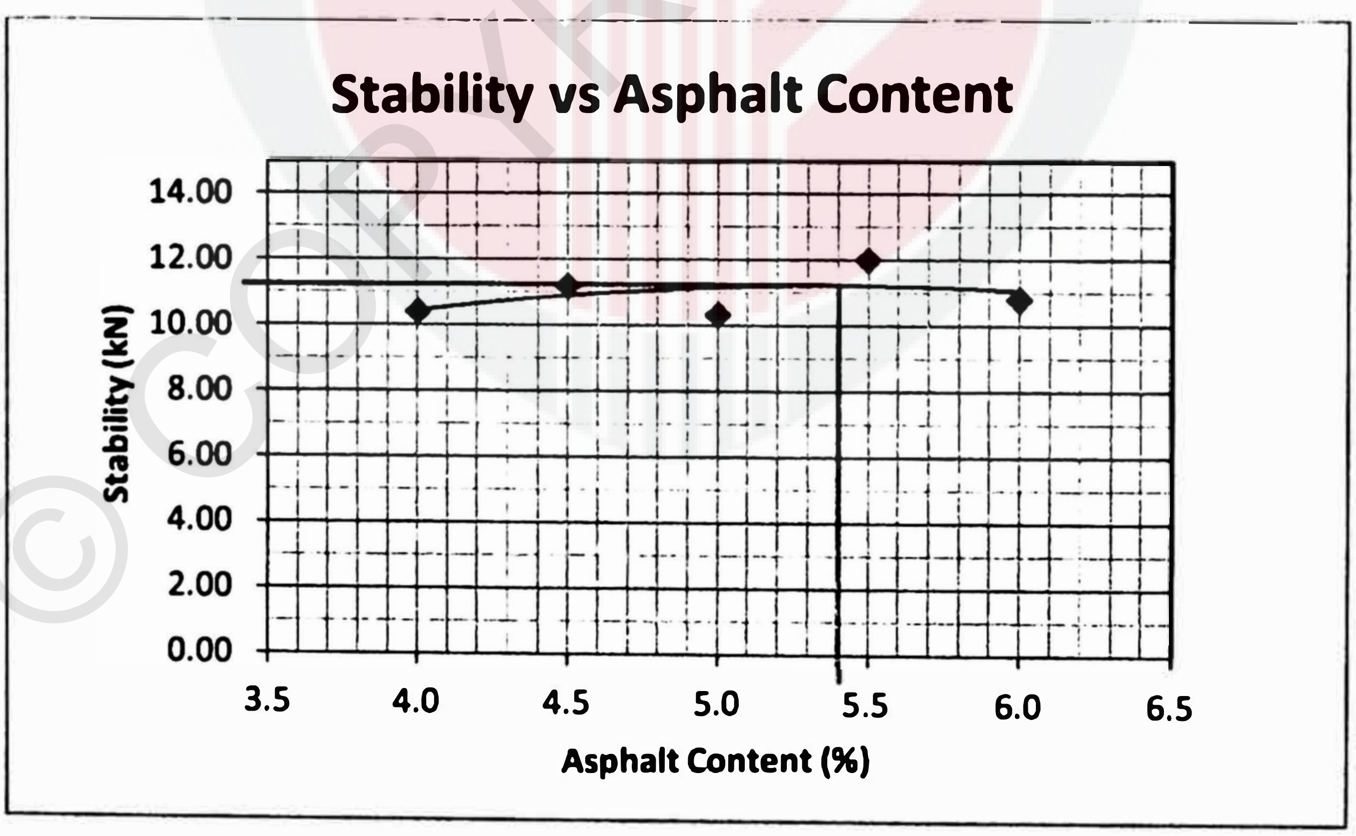

Figure 4.12: Graph of stability vs asphalt content for crushed cockle's shell

4.5.2.7 Marshall Results for Crushed Cockle's Shell Sample

Table 4.11: Marshall results for crushed cockle's shell sample

Sample	AC by weight of mix	Specimen Diameter	Specimen Height	Weight			Bulk	Density		Total Volume (%)			Voids, %			Stability			Flow	Resilient Modulus
				In Air	In Water	SSD	Volume	Bulk SG	TMD				VMA	VFA	VTM	Measured	Correction	Adjusted		
	(%)	(mm)	(mm)	(g)	(g)	(g)	cm³		(Loose Mix)	Asphalt	Aggregate	Voids				(kN)	factor		(mm)	(MPa)
A	4.0	101.00	69.00	1231.4	706.0	1236.7	530.70	2.320		9.011	83.303	7.686	16.697	53.97	3.880	11.67	0.88	10.270	3.03	2624
B	4.0	101.00	69.00	1242.2	704.0	1247.6	543.60	2.285		8.874	82.039	9.086	17.961	49.41	5.338	12.73	0.88	11.202	6.43	4193
C	4.0	101.00	69.00	1246.4	702.0	1249.3	547.30	2.277		8.844	81.760	9.396	18.240	48.49	5.660	11.12	0.88	9.786	3.89	3759
Average		101.00	69.00					2.294	2.414	8.910	82.367	8.723	17.633	50.62	4.960			10.419	4.45	2624
A	4.5	101.00	68.00	1240.3	706.9	1246.6	539.70	2.298		10.040	82.076	7.884	17.924	56.02	1.957	11.78	0.90	10.602	3.87	3807
B	4.5	101.00	69.00	1245.5	707.7	1252.1	544.40	2.288		9.995	81.709	8.296	18.291	54.65	2.396	11.53	0.88	10.146	4.33	3135
C	4.5	101.00	68.00	1242.8	712.1	1246.5	534.40	2.326		10.160	83.057	6.783	16.943	59.97	0.785	14.33	0.90	12.897	4.92	4620
Average		101.00	68.33					2.304	2.344	10.065	82.281	7.654	17.719	56.88	1.713			11.215	4.37	3854
A	5.0	101.50	72.00	1256.1	719.9	1262.2	542.30	2.316		11.244	82.290	6.466	17.710	63.49	1.562	10.08	0.83	8.366	5.42	3884
B	5.0	101.50	72.00	1250.2	715.4	1259.9	544.50	2.296		11.146	81.573	7.282	18.427	60.49	2.420	11.79	0.83	9.786	4.77	3589
C	5.0	101.50	70.50	1246.8	710.3	1253.1	542.80	2.297		11.150	81.605	7.244	18.395	60.62	2.381	15.15	0.85	12.878	5.40	2493
Average		101.50	71.50					2.303	2.353	11.180	81.823	6.997	18.177	61.53	2.121			10.343	5.20	3322
A	5.5	101.00	69.00	1262.6	725.8	1267.4	541.60	2.331		12.448	82.387	5.165	17.613	70.68	0.417	14.84	0.88	13.059	5.22	3758
B	5.5	101.00	70.00	1254.5	718.3	1258.6	540.30	2.322		12.398	82.055	5.547	17.945	69.09	0.818	13.33	0.86	11.464	5.65	1616
C	5.5	101.00	71.50	1267.6	726.3	1271.5	545.20	2.325		12.415	82.167	5.418	17.833	69.62	0.683	13.90	0.83	11.537	6.36	2328
Average		101.00	70.17					2.326	2.341	12.421	82.203	5.376	17.797	69.80	0.639			12.020	5.74	3043
A	6.0	101.00	67.00	1261.0	727.4	1272.9	545.50	2.312		13.466	81.262	5.272	18.738	71.86	1.966	11.65	0.92	10.718	4.93	3654
B	6.0	101.00	66.00	1250.9	723.5	1260.2	536.70	2.331		13.577	81.933	4.490	18.067	75.15	1.157	11.13	0.95	10.574	3.71	3913
C	6.0	101.00	66.00	1249.3	716.3	1256.9	540.60	2.311		13.462	81.238	5.301	18.762	71.75	1.995	11.75	0.95	11.163	4.84	3442
Average		101.00	66.33					2.318	2.358	13.502	81.477	5.021	18.523	72.92	1.706			10.818	4.49	3670

4.7 OPTIMUM ASPHALT CONTENT

4.7.1 Comparison Results between Conventional and Crushed Cockle's Shell Sample

Table 4.12 shows the results in obtaining the optimum asphalt content for conventional and crushed cockle's shell sample. The average OAC for conventional sample is , while for crushed cockle's shell sample is . The percentage of OAC sample for both conventional and crushed cockle's shell sample will be used to prepared samples for performance tests.

Table 4.12: Comparison results between conventional and crushed cockle's shell sample

Property	Conventional Sample	Crushed Cockle's Shell Sample
	OAC (%)	OAC (%)
Resilient Modulus	5.60	5.68
Marshall Stability	5.40	4.16
Bulk Density	4.60	5.50
VTM	5.15	5.40
Average	**5.14**	**5.20**

4.7.2 Comparison of Specification and JKR Standard

Table 4.13 shows comparison between the results and the requirements. All of the results for both conventional and crushed cockle's shell sample are in between the requirement.

Table 4.13: Comparison of specification and JKR standard

Properties	Requirement	Conventional Sample	Crushed Cockle's Shell Sample	Status
		Results	Results	
Density	2.2 – 2.4	2.356	2.232	Accepted
VTM	3% - 5%	4%	4%	Accepted
Resilient Modulus	> 2500 MPa	3200 MPa	3500 MPa	Accepted
Marshall Stability	> 8 kN	11.4 kN	11.2 kN	Accepted

4.6 PERFORMANCE TEST

The performance tests are done by using the OAC obtained which are 5.1% and 5.2% for conventional and crushed cockle's shell sample respectively. The performance tests includes fatigue and rutting.

4.6.1 Fatigue

From the graph analysis, there are stage one and stage two. From Figure 4.13 below, it was divided with two stage, stage I and stage II. Graph analysis shown below is the example for crushed cockle's shell sample which is obtained from laboratory testing.

Figure 4.13: Graph of strain vs number of cycles for fatigue test

Both sample has higher value at stage one. Unit strain value was calculated by using a formula which is :

$$\text{Unit Strain} = \frac{\Delta\ \%\ \text{strain}}{\textit{Number of Cycle}}$$

Figure 4.14 shows analyses of unit strain against types of sample. Number 1 is conventional sample while number 2 is for crushed cockle's shell. The results fatigue obtained for crushed cockle's shell (0.2819) is a little higher compared to conventional sample (0.2753). This shows that crushed cockle's shell can be replaced as it can provides better resistance towards fatigue.

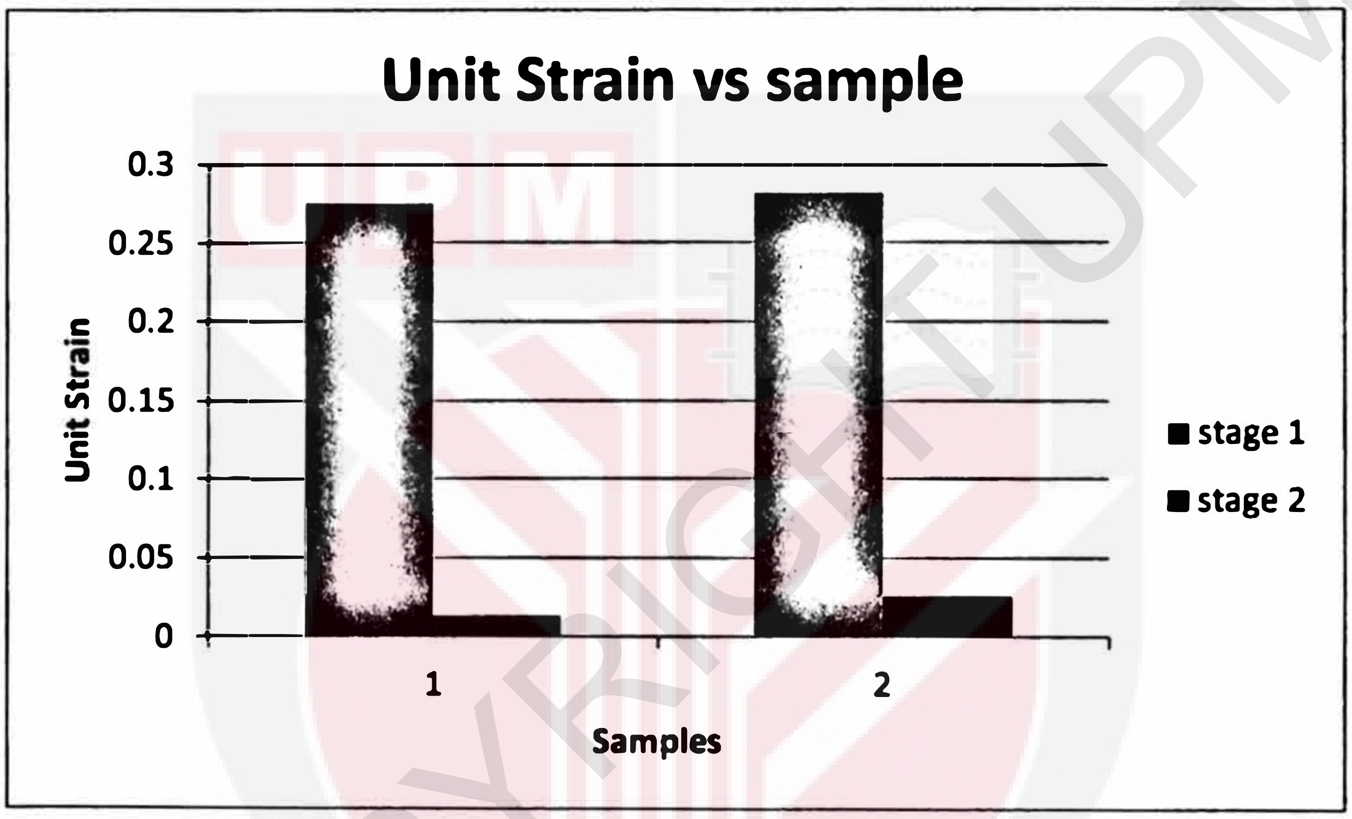

Figure 4.14 : Unit strain bar chart for fatigue test

4.6.2 Rutting

Rutting is one of the most serious forms of pavement distress, and severe rutting is a significant cause of pavement failure. In order to avoid rutting, the pavement structure needs to provide sufficient support for the roadway surface, while the design and construction of the asphalt mix must create a pavement that can resist deformation. From Figure 4.15 below, it was divided with two stage, stage I and stage II. Graph analysis shown below is the example for crushed cockle's shell sample which is obtained from laboratory testing.

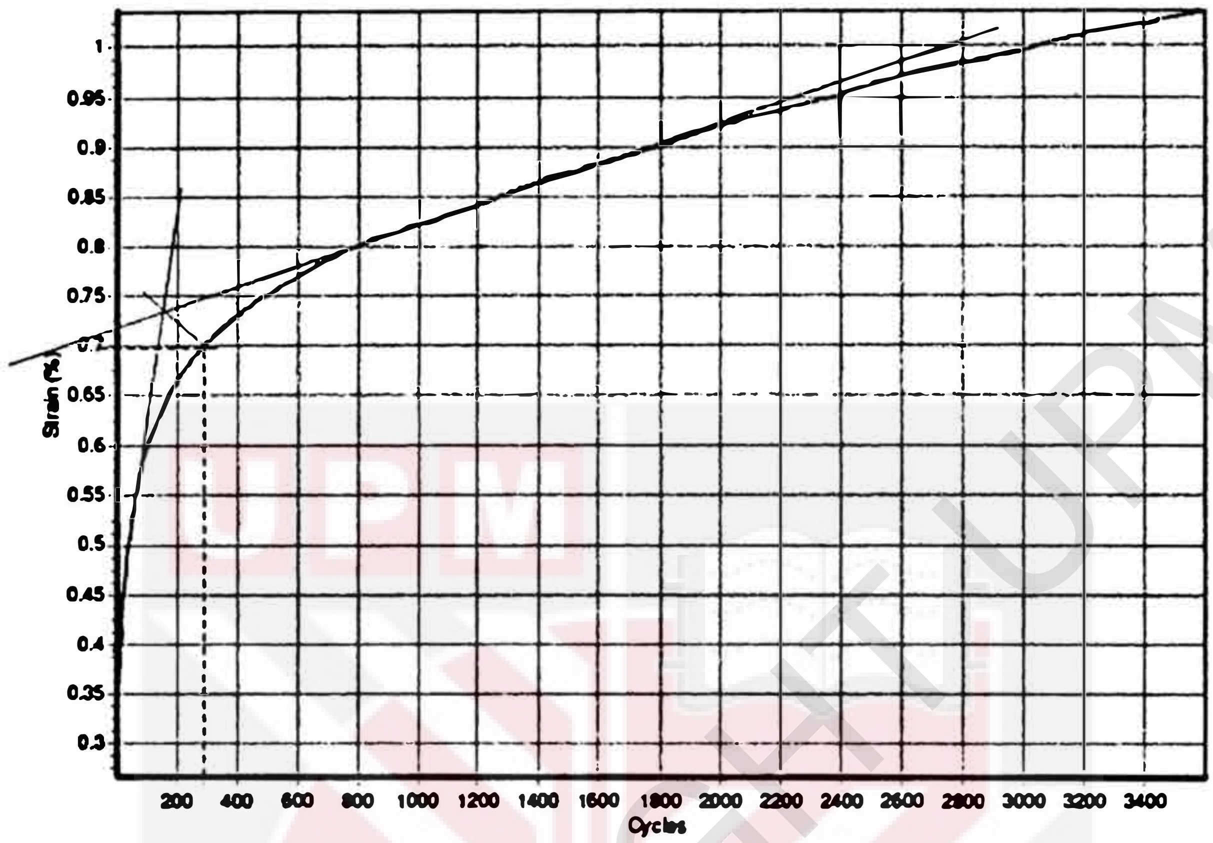

Figure 4.15: Graph of strain vs number of cycles for rutting test

Both sample has higher value at stage one. Unit strain value was calculated by using a formula which is :

$$\text{Unit Strain} = \frac{\Delta\,\%\,\text{strain}}{\textit{Number of Cycle}}$$

Figure 4.16 shows analyses of unit strain against types of sample. Number 1 is conventional sample while number 2 is for crushed cockle's shell. The results for rutting obtained for conventional sample (0.00210) is higher compared to crushed cockle's shell sample (0.00173). This shows that, the crushed cockle's shell can be replaced because it has good interlocking between the aggregate. It is also can increase the internal friction between them and makes the pavement become stronger.

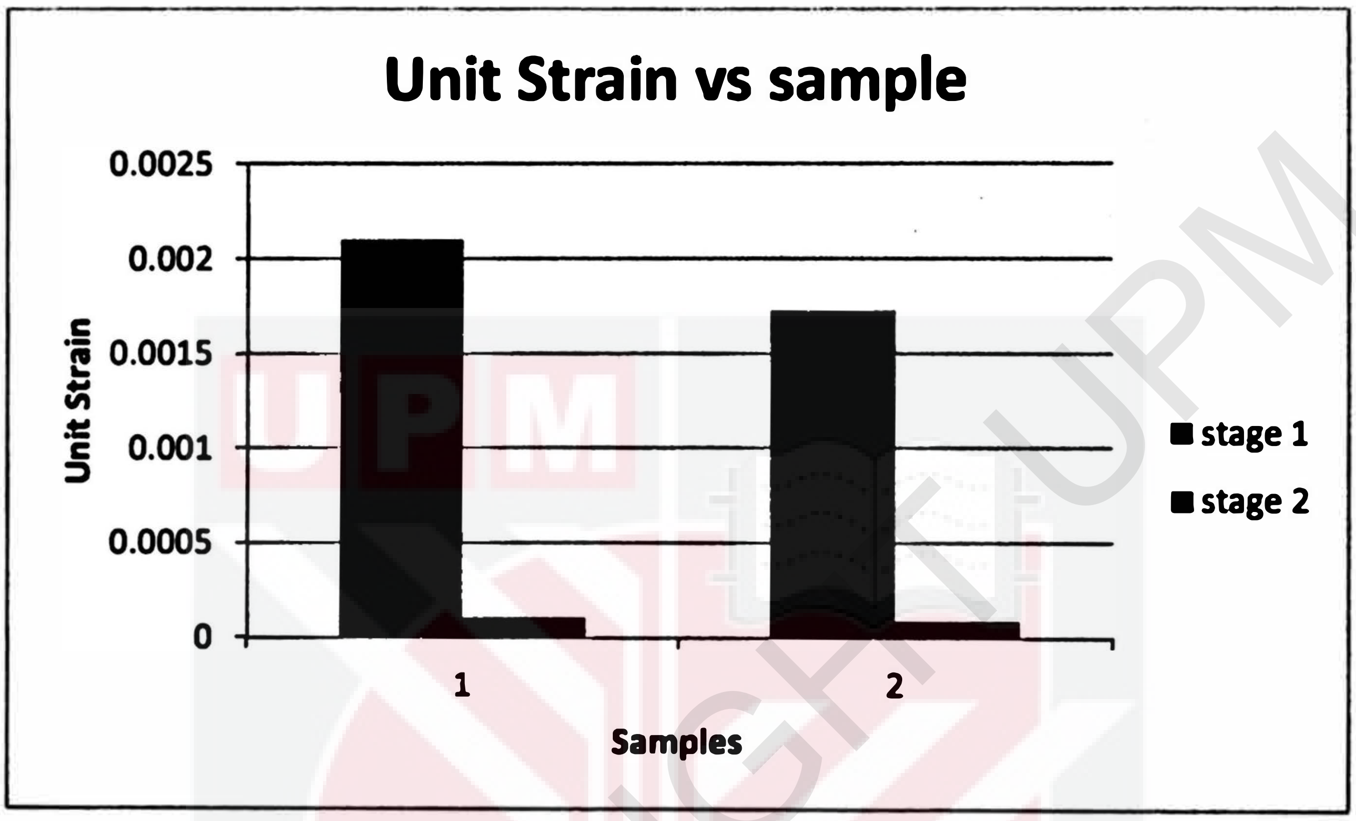

Figure 4.16 : Unit strain bar chart for rutting test

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The main objectives of this research is to identify the physical properties of crushed cockle's shell. LA abrasion and soundness test was conducted in order to identify the physical properties. The results obtained for LA abrasion percentage loss and soundness test percentage loss are 25 % and 0.91% respectively. Both results are in the JKR requirement.

The second objective is to determine the optimum asphalt content (OAC) for conventional sample and crushed cockle's shell. At this stage, 20 samples have been prepared for both conventional and crushed cockle's shell sample in order to find the OAC. The OAC obtained for conventional sample is 5.1% while for crushed cockle's shell sample is 5.2%. The analysis includes Density and Air Void Analysis, Resilient Modulus Test and Marshall Stability and Flow Test.

From the OAC obtained, another six samples are prepared for both conventional and crushed cockle's shell sample to conduct the performance analysis. Based on the results obtained for fatigue and rutting, it shows that the unit strain values for conventional sample and crushed cockle's shell sample are not much differences. Therefore, the uses of crushed cockle's shell as filler in can help improving the performance of the asphalt mixture.

This can be concluded that the filler in asphalt mixture can be replaced by crushed cockle's shell. It can improve the performance of the road pavement and also can reduce the material cost. In addition, the waste problems posed by cockle shell also can be solved. Overall, all of the objectives are achieved.

5.2 RECOMMENDATION

In the future, further research should be done in order to improve this study. There are some of the recommendation can be proposed for a better research. Firstly, the percentage of the filler should be increased since the demand for filler in road construction is increased.

Besides, the material testing to determine the mineral composition of the cockle's shell should be conducted in further research. The performance test for crushed cockle's shell sample can be added such as Dynamic Modulus, TSR and others. Performance test for both fatigue and rutting should be tested until the sample reach the failure mode for conventional and crushed cockle's shell sample.

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APPENDICES

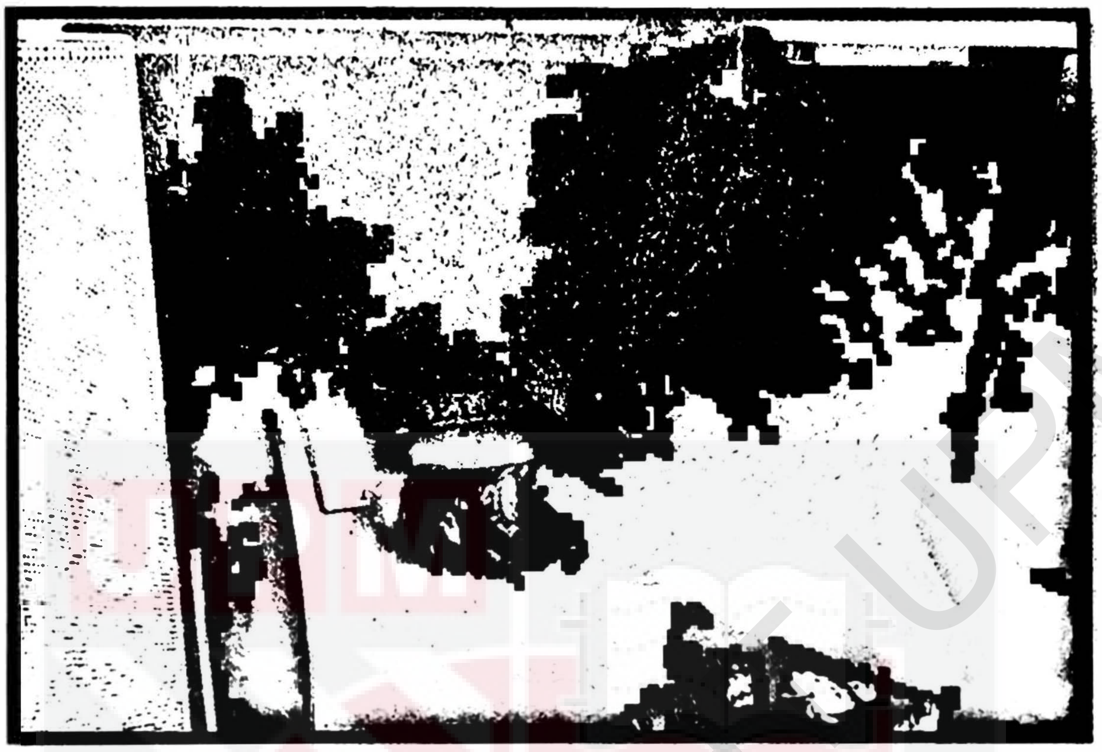


Figure 6.1: Cockle's shell are crushed by using LA Abrasion

Figure 6.2: Sample was mixed by using bowl and spatula

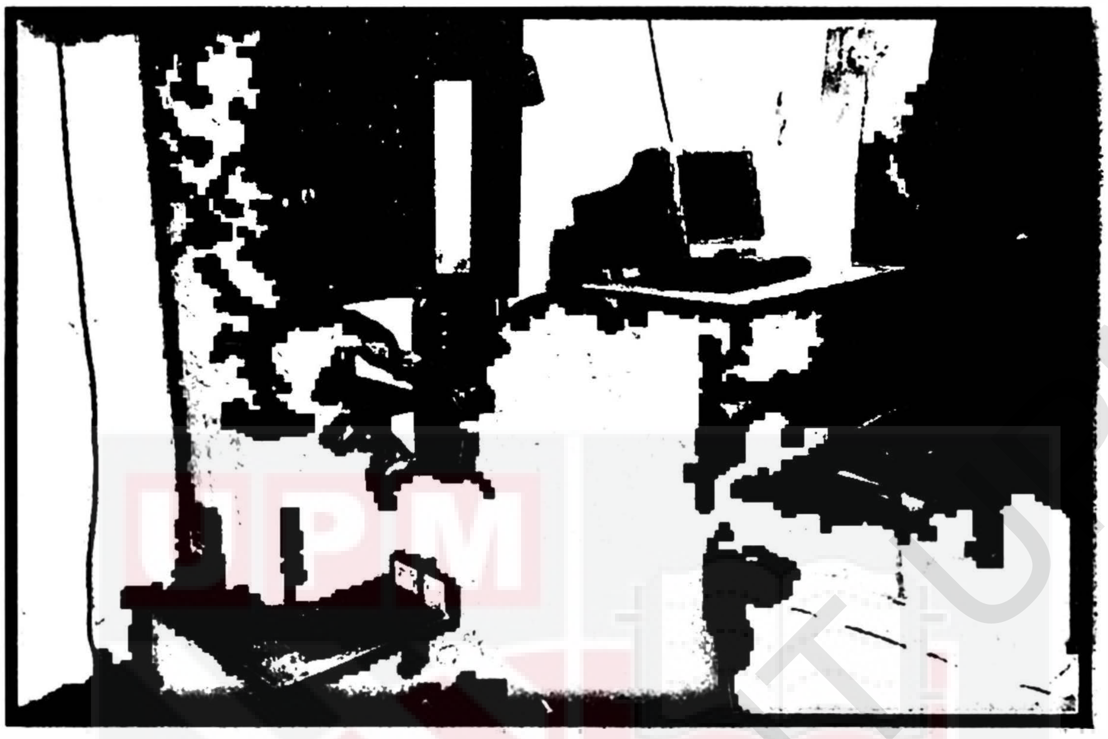


Figure 6.3: The samples are compacted by using compacter machine

Table 6.1: Stability correlation ratio

Volume of Specimen, cm^3	Approximate thickness of specimen, mm	Correlation Ratio
406 to 420	50.8	1.47
421 to 431	52.4	1.39
432 to 443	54.0	1.32
444 to 456	55.6	1.25
457 to 470	57.2	1.19
471 to 482	58.7	1.14
483 to 495	60.3	1.09
496 to 508	61.9	1.04
509 to 522	**63.5**	**1**
523 to 535	65.1	0.96
536 to 546	66.7	0.93
547 to 559	68.3	0.89
560 to 573	69.8	0.86
574 to 585	71.4	0.83
586 to 598	73.0	0.81
599 to 610	74.6	0.78
611 to 625	76.2	0.76

Indirect Tensile Modulus Test

Test method: ASTM D4123-82 / AASHTO TP31 (horiz. lvdts only, assumed Poisson's ratio)
Data file Name: C:\Documents and Settings\UPM\Desktop\FYP BIHA SHELL\4_0% C.D020
Template file name: C:\Documents and Settings\UPM\Desktop\LARRY\150mm SMA sample\TEMPLATE RESILIENT MODULUS SMA14.PD
Test date & time: 5/2/2017 2:01:27 PM
Project: AC14 FYP CS
Operator: SABIHA
Comments: AC 14

Setup Parameters

Target temperature (°C): 25
Loading pulse width (ms): 250
Pulse repetition period (ms): 3000
Conditioning pulse count: 5

Peak loading force (N): 1200
Estimated Poisson's ratio: 0.4

Seating force: AASHTO TP31 (10% of peak)

Specimen Information
Identification: 4.0% C
Remarks:

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev
Length (mm)	60.0						60.0	
Diameter (mm)	101.0						101.0	

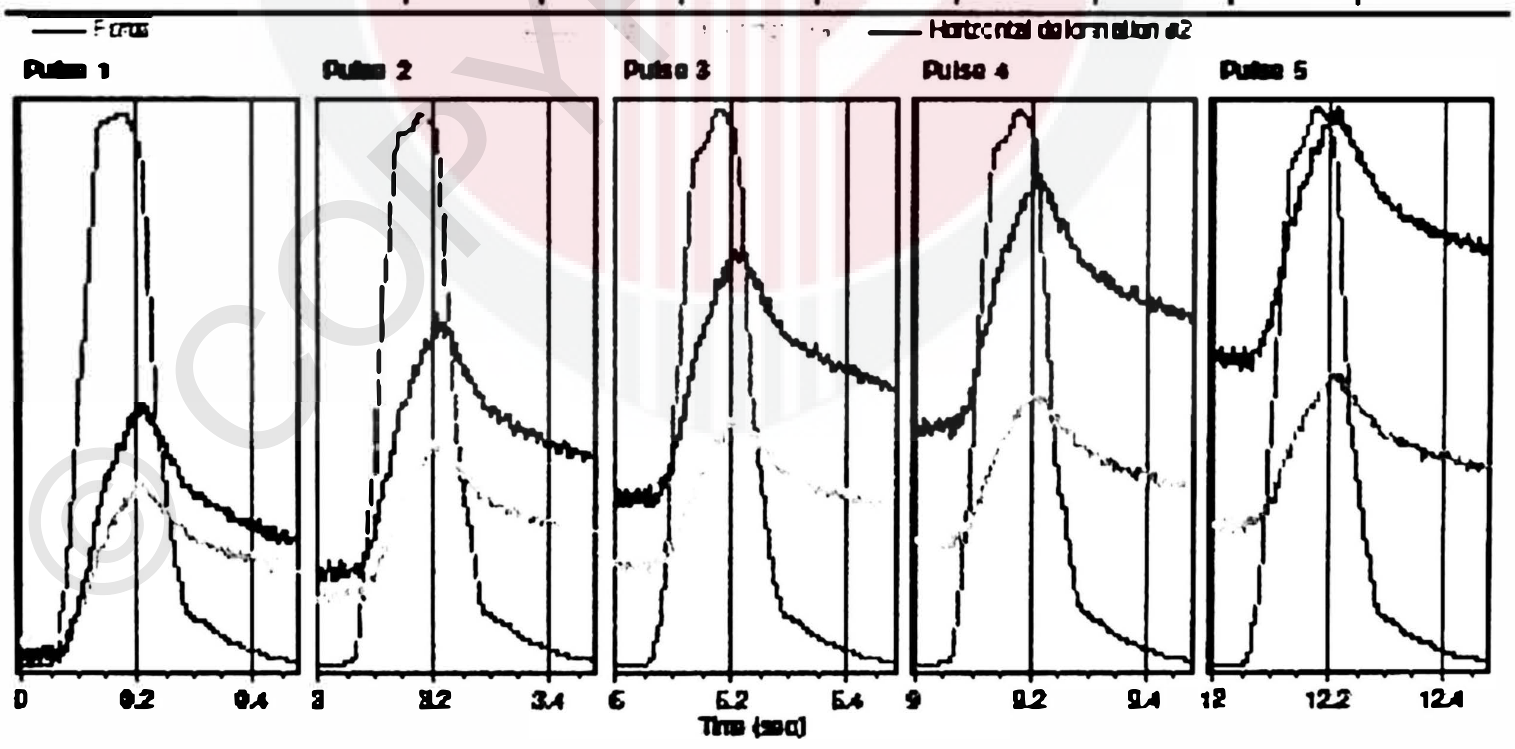
Cross-sectional area (mm²): 8011.8

Test Results

Conditioning pulses: 5
Core temperature (°C): 25.8
Skin temperature (°C): 25.6

Permnt horiz 1 defm/pulse (µm): 2.074000

	Pulse 1	Pulse 2	Pulse 3	Pulse 4	Pulse 5	Mean	Std. Dev.	%CV
Resilient modulus (MPa)	4032	3738	3711	3621	3634	3750	140.77	3.74
Total recoverable horiz. deform. (µm)	2.84	3.07	3.11	3.13	3.19	3.07	0.12	3.97
Peak loading force (N)	1178.2	1182.0	1186.1	1187.8	1193.6	1186.2	5.41	0.46
Recoverable horiz. deform. #1 (µm)	1.10	1.17	1.22	1.31	1.34	1.23	0.09	7.01
Recoverable horiz. deform. #2 (µm)	1.73	1.90	1.89	1.82	1.85	1.84	0.06	3.23
Seating force (N)	118.1	117.2	121.0	117.6	118.9	118.5	1.34	1.13



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Template file name: C:\Documents and Settings\UPM\Desktop\LARRY\150mm SMA sample\TEMPLATE RESILIENT MODULUS SMA
Test date & time: 5/3/2017 2:08:20 PM
Project: AC14 FYP CS
Operator: SASIHA
Comments: AC 14

Setup Parameters

Target temperature (°C): 25
Loading pulse width (ms): 250
Pulse repetition period (ms): 3000
Conditioning pulse count: 5

Peak loading force (N): 1200
Estimated Poissons ratio: 0.4

Seating force: AASHTO TP31 (10% of peak)

Specimen Information
Identification: 4.5% A
Remarks: ...

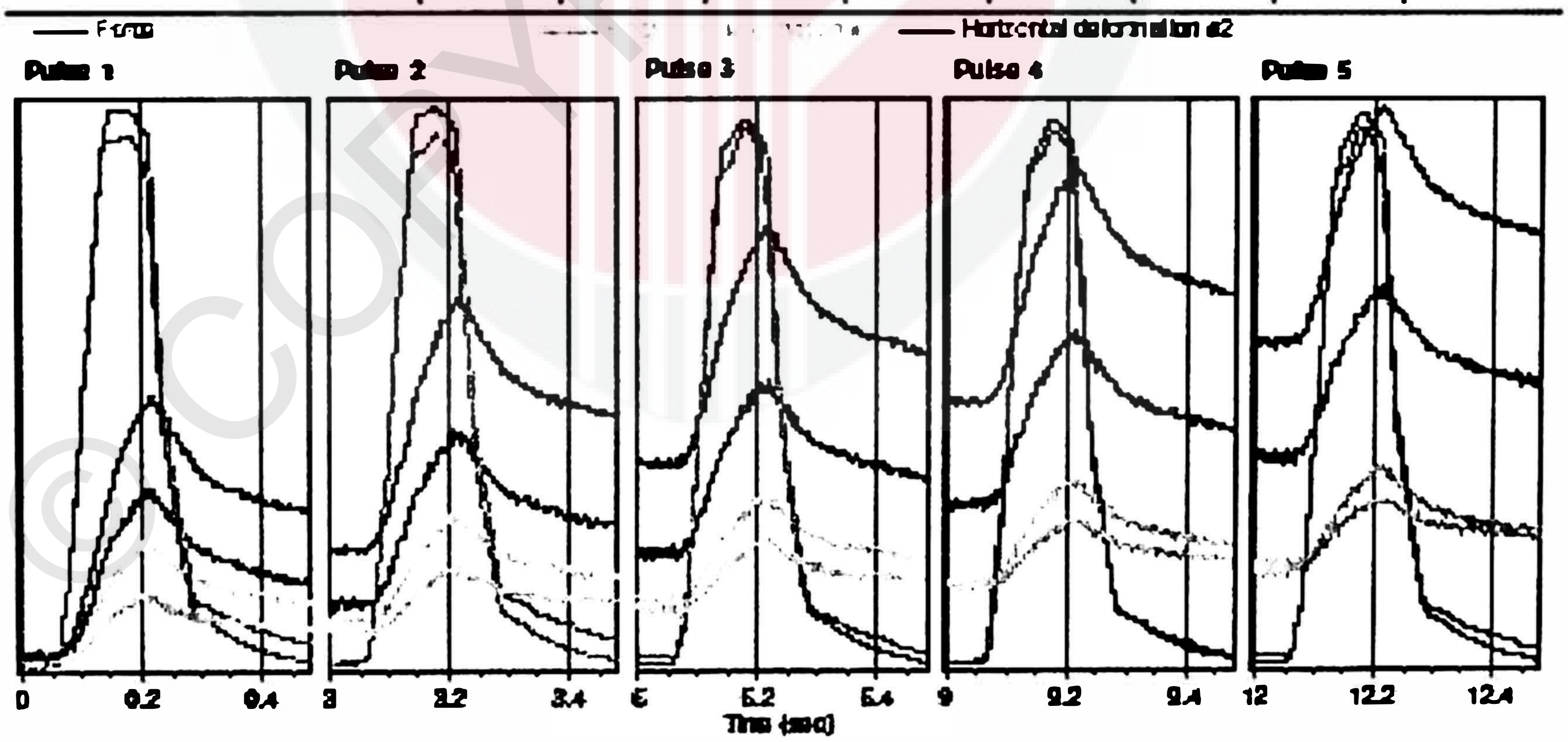
Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev
Length (mm)	68.0						68.0	
Diameter (mm)	101.0						101.0	

Cross-sectional area (mm²): 8011.8

Test Results
Conditioning pulses: 5
Core temperature (°C): 25.3
Skin temperature (°C): 25.5

Percent horiz1 deform/pulse (µm): 2.900000

	Pulse 1	Pulse 2	Pulse 3	Pulse 4	Pulse 5	Mean	Std. Dev.	%CV
Resilient modulus (MPa)	4221	4032	3640	3227	3523	3807	262.38	6.89
Total recoverable horiz. deform. (µm)	2.85	3.06	3.22	3.20	2.38	3.17	0.18	5.56
Peak loading force (N)	1238.5	1238.0	1193.7	1214.7	1208.7	1218.7	17.35	1.42
Recoverable horiz. deform. #1 (µm)	0.56	0.62	0.71	0.63	0.65	0.63	0.05	7.62
Recoverable horiz. deform. #2 (µm)	2.33	2.43	2.51	2.66	2.73	2.53	0.15	5.82
Seating force (N)	113.6	117.4	132.5	113.1	132.2	121.8	8.79	7.22



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Indirect Tensile Modulus Test

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Test date & time: 5/2/2017 4:09:30 PM
Project: AC14 FYP CS
Operator: SABIHA
Comments: AC 14

Setup Parameters

Target temperature (°C): 25
Loading pulse width (ms): 250
Pulse repetition period (ms): 3000
Conditioning pulse count: 5

Peak loading force (N): 1200
Estimated Poisson's ratio: 0.4

Seating force: AASHTO TP31 (10% of peak)

Specimen Information
Identification: 5.5% A
Remarks: _

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev
Length (mm)	60.0						60.0	
Diameter (mm)	101.0						101.0	

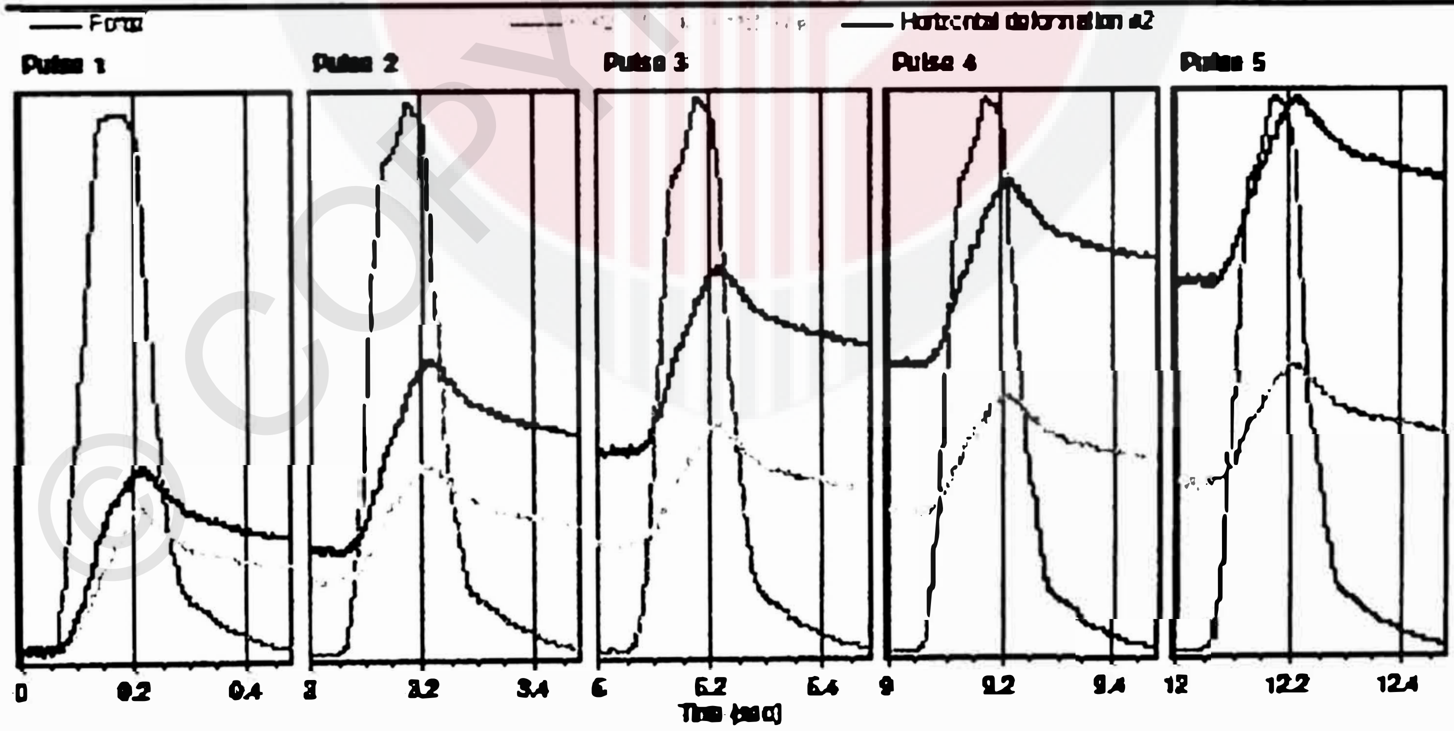
Cross sectional area (mm²): 8011.8

Test Results

Conditioning pulses: 5
Core temperature (°C): 24.8
Skin temperature (°C): 25.0

Param1 horiz 1 defm/pulse (µm): 4.360000

	Pulse 1	Pulse 2	Pulse 3	Pulse 4	Pulse 5	Mean	Std. Dev.	%CV
Resilient modulus (MPa)	4194	3850	3694	3579	3475	3758	250.28	6.68
Total recoverable horiz. deform. (µm)	2.69	2.97	3.12	3.21	3.33	3.07	0.22	7.13
Peak loading force (N)	1183.5	1179.4	1187.3	1185.0	1190.0	1181.1	9.38	0.79
Recoverable horiz. deform. #1 (µm)	1.19	1.45	1.46	1.40	1.52	1.42	0.12	8.26
Recoverable horiz. deform. #2 (µm)	1.50	1.52	1.66	1.73	1.80	1.64	0.12	7.08
Seating force (N)	116.3	120.0	120.4	122.4	119.5	119.7	1.97	1.64



Indirect Tensile Modulus Test

Test method: ASTM D4123-82 / AASHTO TP31 (horiz. lvdts only, assumed Poisson's ratio)
Data fileName: C:\Documents and Settings\UPM\Desktop\FYP BIHA SHELL'S_0% A.D003
Template file name: C:\Documents and Settings\UPM\Desktop\LIBRARY\TEMPLATE RESILIENT MODULUS.P003
Test date & time: 4/5/2017 2:51:18 PM
Project: AC14 FYP CS
Operator: SABIHA
Comments: AC14

Setup Parameters

Target temperature (°C): 25
Loading pulse width (ms): 250
Pulse repetition period (ms): 3000
Conditioning pulse count: 5

Peak loading force (N): 1200
Estimated Poisson's ratio: 0.4

Seating force: AASHTO TP31 (10% of peak)

Specimen Information

Identification: 5.0% A
Remarks:

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev
Length (mm)	72.0						72.0	
Diameter (mm)	101.5						101.5	

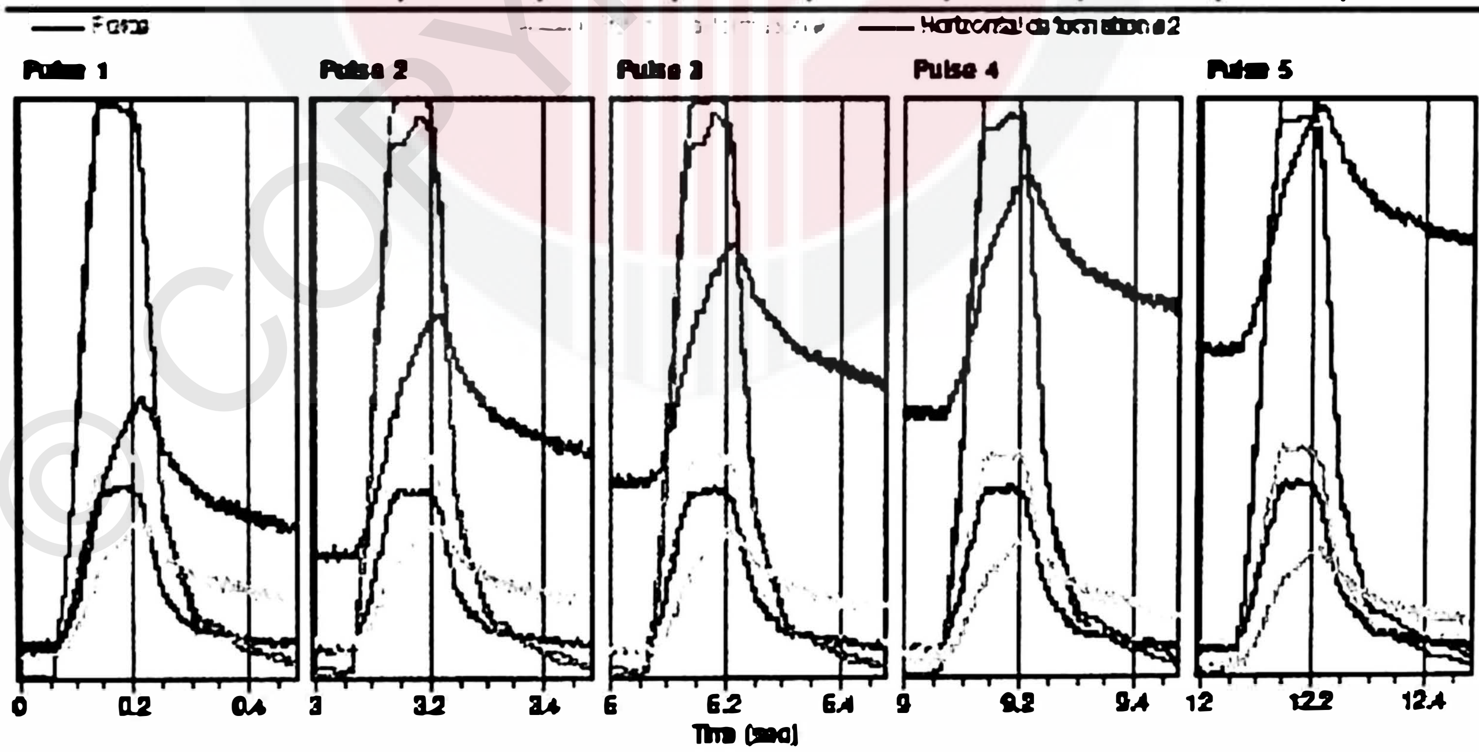
Cross-sectional area (mm²): 8091.4

Test Results

Conditioning pulses: 5
Core temperature (°C): 23.7
Skin temperature (°C): 23.9

Permit horiz1 defm/pulse (µm): 1.281090

	Pulse 1	Pulse 2	Pulse 3	Pulse 4	Pulse 5	Mean	Std. Dev.	%CV
Resilient modulus (MPa)	4225	3664	3837	3796	3597	3884	179.72	4.63
Total recoverable horiz. deform. (µm)	2.64	2.81	2.84	2.90	2.94	2.83	0.10	3.66
Peak loading force (N)	1198.5	1165.7	1160.7	1182.3	1168.4	1177.1	12.02	1.02
Recoverable horiz. deform. #1 (µm)	1.14	1.24	1.20	1.18	1.24	1.20	0.04	3.11
Recoverable horiz. deform. #2 (µm)	1.50	1.57	1.64	1.72	1.70	1.62	0.08	5.07
Seating force (N)	115.5	125.5	125.1	117.8	124.3	121.5	4.24	3.49



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Indirect Tensile Modulus Test

Test method: ASTM D4123-82 / AASHTO TP31 (horiz. lvdts only, assumed Poisson's ratio)
Data file name: C:\Documents and Settings\UPM\Desktop\FYP BIHA SHELL\E_0% B.D003
Template file name: C:\Documents and Settings\UPM\Desktop\LARRY\150mm SMA sample\TEMPLATE RESILIENT MODULUS SMA14
Test date & time: 5/3/2017 2:38:48 PM
Project: AC14 FYP CS
Operator: SABIHA
Comments: AC 14

Setup Parameters

Target temperature (°C): 25
Loading pulse width (ms): 250
Pulse repetition period (ms): 3000
Conditioning pulse count: 5

Peak loading force (N): 1200
Estimated Poisson's ratio: 0.4

Seating force: AASHTO TP31 (10% of peak)

Specimen Information
Identification: 6.0% B
Remarks: _

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev
Length (mm)	65.0						65.0	
Diameter (mm)	101.0						101.0	

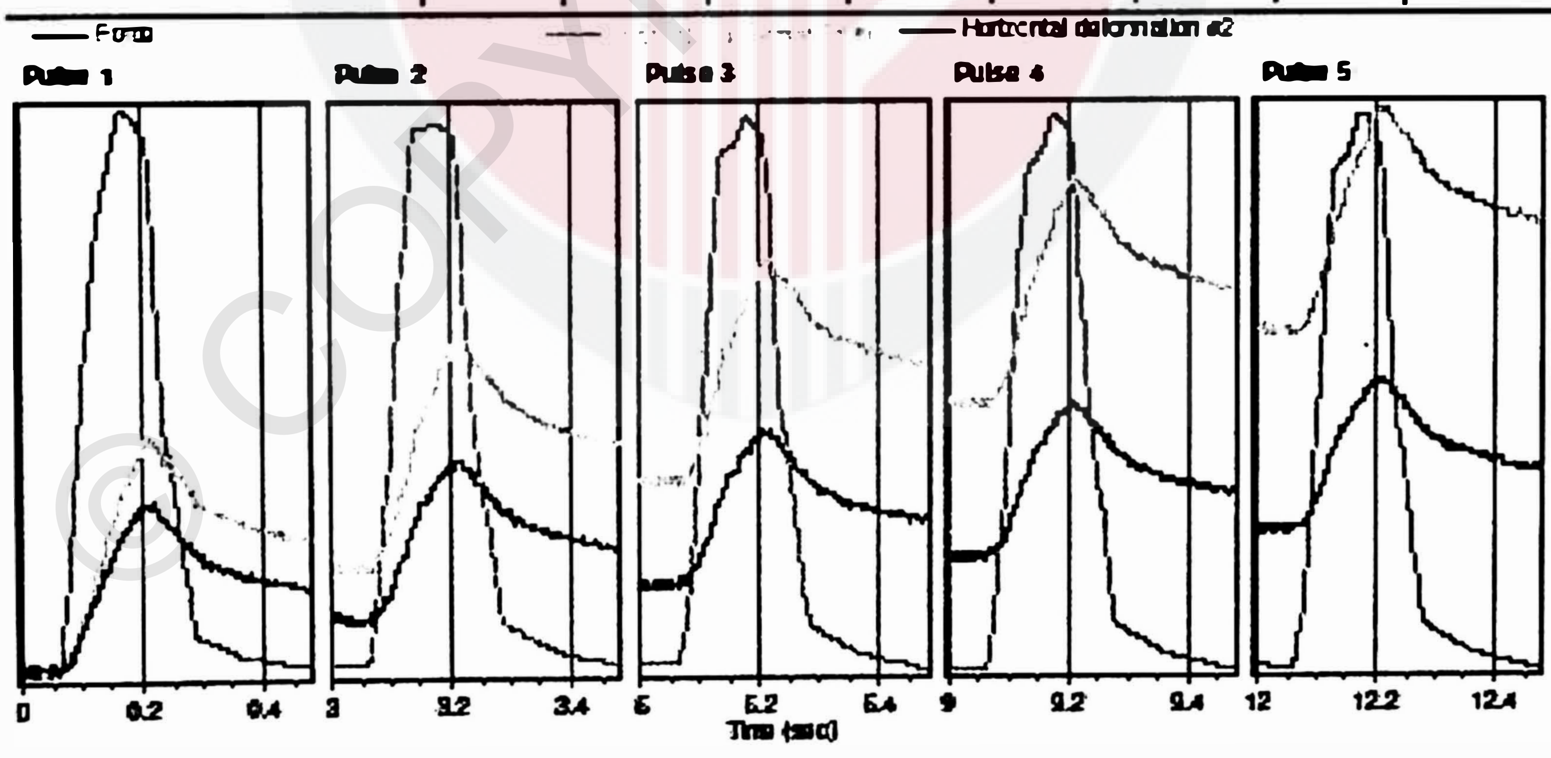
Cross-sectional area (mm²): 8011.8

Test Results

Conditioning pulses: 5
Core temperature (°C): 24.8
Skin temperature (°C): 25.0

Param horiz 1 defm/pulse (µm): 2.578000

	Pulse 1	Pulse 2	Pulse 3	Pulse 4	Pulse 5	Mean	Std Dev.	%CV
Resilient modulus (MPa)	4316	3840	3847	3750	3771	3913	203.52	5.20
Total recoverable horiz. deform. (µm)	2.85	3.10	3.12	3.20	3.22	3.10	0.13	4.14
Peak loading force (N)	1216.0	1174.2	1182.7	1196.5	1195.3	1192.5	14.51	1.22
Recoverable horiz. deform. #1 (µm)	1.51	1.65	1.66	1.75	1.74	1.66	0.09	5.17
Recoverable horiz. deform. #2 (µm)	1.35	1.45	1.46	1.46	1.48	1.44	0.05	3.17
Seating force (N)	111.0	125.8	126.0	117.8	120.1	120.3	5.78	4.81



Industrial Process Controls Global Ltd UTS003 Ver. 1.32 (1.32)

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Indirect Tensile Fatigue Test

Data file name: C:\Documents and Settings\UPM\Desktop\all lab pelajar ugrad FYP SIHA SHELL\FATIGUE\5.2% D CS-1.D013
Template file name: C:\Documents and Settings\UPM\Desktop\FYP FATIGUE 2017\NURFAZIRA PET\default template 1.P013
Test date & time: 5/24/2017 8:04:56 PM
Project: FYP2017 CRUSHED SHELL
Operator: SABIHA
Comments: FATIGUE TEST FOR CRUSHED SHELL

Specimen information
Identification: 5.2% E CS
Remarks:

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev
Length (mm)	67.5						67.5	
Width (mm)	100.0						100.0	
Thickness (mm)	80.0						80.0	

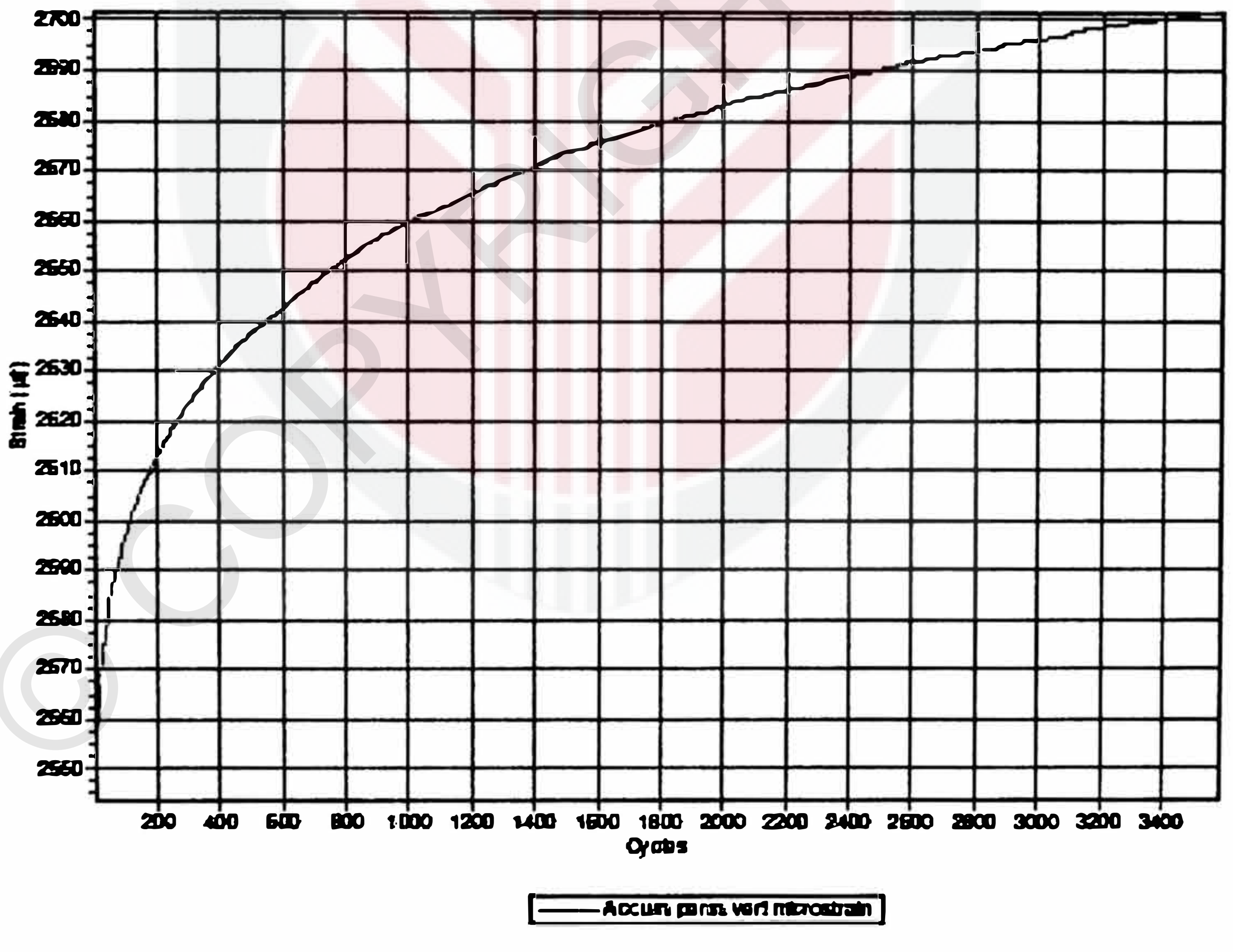
Cross-sectional area (mm²): 801.8

Set up parameters

Transducer configuration: Std IT Jig
Cyclic loading force: 2000 N
Seating force: 100 N
Cycle duration: 100 ms
Cycle repetition time: 500 ms

Poisson ratio: 0.40
Target temperature: 20 °C

Termination cycle count: 3600
Termination max displacement: 9 mm



Asphalt Permanent Deformation Test

Data file name: C:\Documents and Settings\UPM\Desktop\fail lab pelajar ugrad\FYP SIHA SHELL\RUTTING\5.2% C shell.D014
Template file name: C:\Documents and Settings\UPM\Desktop\fail lab pelajar ugrad\FYP17 NURHAYAH COCONUT FIBRE\RUTTING\0.25% S1
Test date & time: 5/15/2017 1:33:42 PM
Project: FYP17 CRUSHED SHELL
Operator: SABIHA
Comments: DETERMINATION OF RUTTING RESISTANCE

Specimen information

Identification: 5.2% C shell
Remarks:

Dimensions	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Average	Std Dev
Length (mm)	98.7						98.7	
Width (mm)	100.0						100.0	
Thickness (mm)	80.0						80.0	

Cross-sectional area (mm²): 8011.8

Set up parameters

Loading function: Haversine
Cyclic loading stress: 200 kPa
Seating stress: 10 kPa
Cycle duration: 100 ms
Cycle repetition time: 500 ms

Preload stress: 10 kPa
Preload time: 60 s
Confine axis control: No
Confine stress: 100 kPa
Termination cycle count: 3600
Termination strain: 10 %

Results

Minimum strain rate: 0.500 µs/cycle
Strain @ min strain rate: 1.021 %
Cycles @ min strain rate: 3332