Modification of Asphalt Binder by Incorporating Coconut Shell Powder

by

Kevindran A/L Shanmugam
15949

Dissertation submitted in partial fulfilment of
the requirement for the
Bachelor of Engineering (Hons)
(Civil Engineering)

JANUARY 2016

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak

CERTIFICATION OF APPROVAL

Modification of Asphalt Binder by Incorporating Coconut Shell Powder

by

Kevindran A/L Shanmugam
15949

A project dissertation submitted to the
Civil Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(CIVIL ENGINEERING)

Approved by,

_____

(Dr. Ibrahim Kamarrudin)

UNIVERSITI TEKNOLOGI PETRONAS
BANDAR SERI ISKANDAR, PERAK
January 2016

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own expect as specified in the references and acknowledgement, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

_____

(KEVINDRAN A/L SHANMUGAM)

ABSTRACT

This research objective is to determine the performance of coconut shell powder with bitumen comparing with base bitumen of grade 60/70 pen and grade 80/100 pen in terms of strength and stability. Coconut shell is chosen because it is a natural waste product which can be recycled and cheaper in cost. Besides, this is also way to reduce the waste product of coconut and to reduce pollution by using natural product. The coconut shell are crushed into powder of ASTM no.100 or 150 micron. Then, the coconut shell powder were added to modify the bitumen of grade 60/70 pen and grade 80/100 pen. The base bitumen and modified bitumen were tested with different test such as Penetration Test, Softening Point Test and Ductility Test. This test were carried out for the virgin bitumen and aged bitumen which were aged using Rolling Thin Film Oven Test (RTFOT) which simulate short term aging process and Pressure Aging Vessel (PAV) Test which simulate long term aging process. The results achieved for base bitumen and modified bitumen are analyzed and compared to determine the rheological properties and physical properties of modified bitumen of grade 60/70 pen and modified bitumen of grade 80/100 pen.

ACKNOWLEDGEMENT

Special thanks go to my supportive supervisor, Associate Professor Dr. Ibrahim Kamaruddin. The supervision and care that he gave truly helped the progress and smoothness of the final year project. The support is much truly respected for all the guidance and worthwhile information he contributed for my report. A huge contribution and hard work from him during these two semester. He has been always answering my doubts about my project and has given me a great encouragement. Moreover, this platform makes me understand the importance of carrying out research work which challenges us every second.

Not to forget, a countless appreciation goes to the lab technician who assisted me from time to time during the research. Without them, I would not have learned or gained this much so far. The entire program really brought us together to appreciate the exact value of friendship and admiration of each other.

Great deals appreciation goes to the support of my friends and family who have helped me directly or indirectly in making the final year project a successful one. In addition, not to forget my university, University Technology PETRONAS (UTP) providing me the chance to expose to the actual atmosphere on research based.

Lastly, I would like to ask for forgiveness to all other unnamed people who assisted me in numerous ways to have a good training. Knowledge is power and unity is strength.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Background Study

Malaysia have a total extent of road network which is about 137220 kilometers of paved road (Razali & Zakaria, 2008). The common type of pavement in Malaysia is flexible pavement. It is known as flexible pavement because this type of pavement deflects and flexes when there is load. This type of pavement consists of several layers which are surface course, base course and sub-base course as shown in figure 1. These multiple types of layers are important for road pavement construction because it will provide a strong, hard and impermeable layer of road pavement. According to Razali and Zakaria (2008) , pavement structures in Malaysia are designed according to the stand of Arahan Teknik (Jalan) 5/85 which is adapted from AASHO (American Association Of State Highway Officials) Road Test. In the early of 2013, the standard was reviewed and new references for pavement structures was published as Arahan Teknik (Jalan) 5/85 (Pindaan 2013) Manual for the Structural Design of Flexible Pavement.

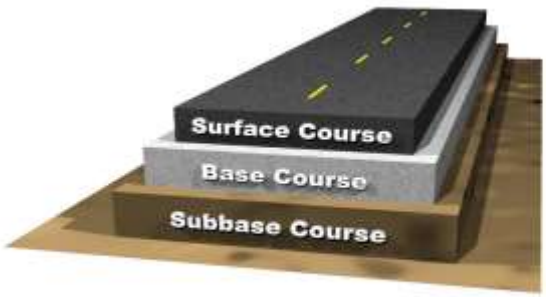


FIGURE 1.1 Course Layer (Wikipedia, 2015)

The material which is required for road pavement is Hot Mix Asphalt (HMA). This HMA was introduced as a bituminous surfacing in 1980's as wearing course and binder course. HMA is a complex material which have multiple and different performance subjecting to the distresses. Occurring distresses are due to environment factor and traffic loads which will eventually reduce the serviceability of the road pavement. Asphaltic layer play a very important role in road pavement since it need to provide a hard and impermeable layer to the road pavement (Razali & Zakaria, 2008). The hard layer prevents deformation in the unbound layer when load is present. The impermeable asphalt bound layer will also prevent water from entering the layer of pavement structure which weakens the layers. Introduction of HMA in Malaysia has come with the problem of extensive quality control test which require a stable mix tolerance.

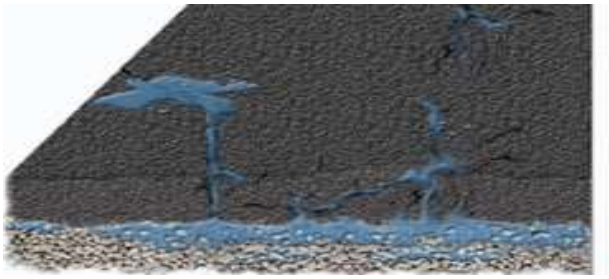


FIGURE 1.2 Penetration of Water in Road Pavement (Wikipedia, 2015)

Road pavements are exposed to thermal cracking, fatigue cracking, rutting, slippage, disintegration, roughness and skid resistance. Even though the HMA is produced according to specifications and standards, high traffic load stresses at most of the area has caused distress to the road pavement and rapid permanent deformation. Since there are many influence of the road pavement, new pavement materials is needed to overcome the problems. The possible solution which is currently being done by many researches is by changing the additives in asphalt mixes. The usage of additives in asphalt mixture is current study and research is carried out to be practice for road pavement construction. As reported by Abiola, Kupolati, Sadiku, and Ndambuki (2014), modification of bitumen is one approach to improve the pavement performance when the asphalt produced does not meet the standard requirement. Selected additives gives advantages such as improvement of thermal cracking, resistance to rutting, fatigue resistance, durability, resistance to water damage and strength of traffic loading.

In this research, coconut shell powder is used as an alternate additive to act as an antioxidant to improve the asphalt performance. Coconut shell powder are preferred because it is a waste disposal material which can be recycled. Besides, if this solution is proved it can be a way of reducing cost of the road maintenance by using natural byproduct. Different proportion of coconut shell powder are added as additives to the bitumen and certain test were carried out to determine the antioxidant performances. This recycling technique is also a solution for coconut disposal problem. Thus, this coconut shell usage is a suitable alternative because the cost for coconut shell powder not needed which reduces cost for road pavement construction.

1.2 Problem Statement

The common failure for HMA pavements are through road cracking and permanent deformation. Environment effect will speed up the deterioration process which reduce the performance of road pavement. Multiple factors also influence the performance of asphalt mix for instance the type of grading, bitumen composition, moisture of permeability and interface between bitumen content and aggregate. The cost of asphalt paving mixtures must also be considered because common maintenance and rehabilitation works will increase the cost.

Coconut shell is a common solid waste since they are commonly disposed by coconut industry. Besides, it is sustainable resource which is environment friendly and safe. The advantage of using waste material will reduce the cost of using other chemical materials. Therefore, coconut shell can be utilized as coconut shell powders as a possible solution for coconut disposal and alternative for modification of asphalt properties.

1.3 Objective

The objective of this paper is to determine the performance of coconut shell powder with bitumen comparing with base bitumen in terms of strength and stability. The aim of this research are as followed:

i. To determine the antioxidant potential of coconut shell powder to control asphalt age hardening according to standards.

ii. To evaluate the performance of coconut shell powder with bitumen on physical and engineering properties.

iii. To evaluate and compare the physical and engineering properties of different bituminous mixtures incorporating coconut shell powder.

1.4 Scope of Study

This research is to study the performance of modified bitumen incorporated with coconut shell powder. The asphalt testing and performance test for bitumen is carried out. Bitumen of Grade 60/70 pen and Grade 80/100 pen were used by following the standard requirements. The samples are tested for their basic asphalt properties by using Penetration Test, Softening Point Test and Ductility Test was carried. The rheology test will be carried out to test the rheological properties of coconut shell powder incorporated with bitumen of different grades. The same procedure of test will be carried again after the aging process through Rolling Film Oven Test (RTFOT) and Pressure Aging Vessel Test (PAV). From the results obtained, we can determine the suitability of this coconut shell powder additives in binder to be used for road construction purpose.

CHAPTER 2

LITERATURE REVIEW

2.1 Asphalt/Bitumen Binder

Bitumen is commonly used in the construction industry for road pavement and water proofing material. They are obtained from fractional distillation of crude petroleum. It acts a binding agent to the aggregates, stabilizers in bituminous mixtures and provides durability to the mix. In Malaysia, the common bitumen grade which is used is grade 80/100 pen (Razali & Zakaria, 2008). However, the ASEAN countries has started adopting the grade 60/70 pen and it is a matter of time before Malaysia start to adopt bitumen of grade 60/70 pen.

According to Kar (2012), this bitumen affects the bituminous mixture behavior are temperature susceptibility, viscoelasticity and aging. This bitumen behavior depends on the temperature and time of loading where at low temperature and short loading it is stiffer and vice versa. Bitumen is a viscoelastic material since it exhibits both viscous and elastic properties at the normal pavement temperature where it is elastic during low temperature and it is viscous fluid at high temperature (Kar, 2012). As time pass, these bitumen which are used for road pavement construction will deteriorate caused by traffic load and condition of the environment.

For this research, both bitumen grade 60/70 pen and grade 80/100 pen are modified with the addition of coconut shell powder. Modification of bitumen or addition of additives to bitumen are done to increase the stabilization of bituminous mix. Additives are also added to the bitumen to control the oxidation process. Due to oxidation, bitumen tend to cause pavement deterioration and cracking.

2.2 Aging of Bitumen

Aging of bitumen is one of the main factors for the significant effect of durability and strength of road pavement. Bitumen will become brittle and ability to withstand loading decreases as it is aging. Eventually the pavement will deteriorate and cause thermal cracking of the road pavement. Harshad and Gundaliya (2014) agreed that ageing is primarily associated with bitumen oxidation and the loss of volatile components from the bitumen to the air and aggregates during asphalt mixture production (short-term aging) and in-place service period (long-term aging).

According to Calabi-Floody and Thenoux (2012), from aging perspective, the aging process is related to a viscosity increase where bitumen turns into a brittle elastic solid. Commonly the hardening process involved are physical hardening and chemical hardening. Calabi-Floody and Thenoux (2012) point of view physical hardening is attributed to molecular reorganization and the slow crystallization of waxes under a specific set of conditions at low temperatures where this process is reversible and bitumen may recover its original rheological properties.

Qin, Schabron, Boysen, and Farrar (2014) reported this aging hardening effects the rheology property of the bitumen due to oxidation. They observed this rheological hardening is directly related to compositional changes of asphalt due to field aging.

Calabi-Floody and Thenoux (2012) investigated that due to oxidation process, these asphalt hardens and increases pavement susceptibility to cracking. Therefore, they carried out study to control these aging process by using additives as antioxidants.

The pattern of aging process varies depending on the combined factors of physical hardening and chemical hardening. Physical hardening is related to the molecular reorganization and slow crystallization of waxes, under a specific low temperature whereas chemical hardening is the combination of oxidation reactions and polymerization (Calabi-Floody & Thenoux, 2012).

Xiang, Cheng, and Kang (2015) examined the performance of Crumb Rubber/SBS Composite Modified Asphalt (CR/SBSCMA) on pre and post aging process where the hardening of matrix asphalt and softening of modifiers interacted and shifted. Thus, they concluded that this modified asphalt has an excellent anti-aging performance.

2.3 Coconut Shell

Coconut shell is environmental friendly and it is also 100% sustainable natural resource. Thus, this will ensure the sustainable development as an important raw material. In Malaysia, coconut is the fourth important industrial crop after oil palm, rubber and paddy in terms of total planted area. According to Gunasekaran, Kumar, and Lakshmipathy (2011), researches have paid attention to some agriculture waste for use as construction material and one of the waste is coconut shell which is a common solid waste in many tropical country.

Coconut shell is an excellent raw material because of it hardness which provides a good strength. Gunasekaran et al. (2011), has described the coconut shell have a good compressive, flexural, tensile strengths and high impact strength which is suitable for construction industry.

Ting, Jaya, Hassan, Yaacob, and Jayanti (2015), explained the coconut shell is suitable for construction materials because it is weather resistance. Besides, its dispose process is costly and considered a waste since it has no economic value. They also stated the composition of coconut shell is 33.61% cellulose, 36.51% lignin, 29.27% pentosans, 0.61% ash and high volatile matter of 65% to 75%. The coconut shell is also well known since the resistance toward crushing and impact is better than granite aggregate.

Al-Mansob, Ismail, Algorafi, Hafezi, and Baghini (2013), explored the use of coconut shell as an evolution of alternative material for more robust performance of asphalt mix and specially tailored for Malaysia condition. This practice leads to a potential economical and improved usage of waste material to mitigate an expensive disposal of waste material.

Commonly the coconut shell is thrown away after being scraped out. The amount of waste is large since coconut is used daily especially for food industry. The utilization of coconut waste is an important way of reducing environmental pollution. Besides, the demand of coconut is abundantly needed which also increases the waste product of coconut. The addition of natural material as additives is a method of recycling. Since the coconut shell powder is a waste product, the cost of using these waste product is manageable.

2.4 Previous Research on Natural Materials as Additives

Xue et.al (2014) used biomass ashes and wood sawdust ash as additives to modify the asphalt binder of grade 60/70. It was found that these additives are possible to control the aging process of these bitumen. Based on researches observation, the polymer modified bitumen provides a better performance (Xue, Wu, Cai, Zhou, & Zha, 2014).

Abiola et al. (2014), used natural fiber to improve the performance of asphalt mixtures against permanent deformation and fatigue cracking. They found that fibers have the potential to change the viscoelasticity of modified asphalt, rutting resistance and moisture susceptibility. In certain case, the fiber length and content have a major effect to the stability and volumetric properties.

Oda, Leomar Fernandes Jr, and Ildefonso (2012), studied the effect of natural fiber and asphalt rubber binder in asphalt. The results showed the blend of natural fiber have high resistance towards tensile strength and modulus of resilience. The modified bitumen also holds up oxidation, dampness penetration and cracking.

Al-Mansob et al. (2013), researched on the performance of Hot Mix Asphalt (HMA) with the addition of palm oil shell and coconut shell as additives. Since the response of coconut shell for rutting characteristics is more positive, coconut shell acts as a better additive compared to palm oil shell. The results of physical properties of asphalt mix has indicated coconut shell has the ability to be an antioxidant for the modified bitumen.

CHAPTER 3

METHODOLOGY

3.1 Research Procedure

As for every project, a proper methodology or procedure will be required to ensure this project objective is achieved. Hence, the methodology or procedure below was used:

1. The bitumen of grade 60/70 pen and grade 80/100 pen are tested before and after aging by carrying out few test according to standards such as Penetration Test, Ductility Test and Softening Point Test.
2. The coconut shell is placed into incinerator of 40 °C for five to seven days.
3. The coconut shell are crushed into powder by using Los Angeles Abrasion Test to crush the coconut shell.
4. Sieving test is carried out to achieve ASTM no 100 or 150micron coconut shell powder.
5. The bitumen of both grade 60/70 pen and grade 80/100 pen are modified by adding the coconut shell powder.
6. The modified bitumen of grade 60/70 pen and grade 80/100 pen are tested before and after aging by carrying out few test according to standards such as Penetration Test, Ductility Test and Softening Point Test.
7. Results and data from the test are recorded and tabulated.
8. The results of pure bitumen and modified bitumen are compared to identify the advantage and disadvantage of modified bitumen.

3.2 Binder/ Bitumen

Bitumen acts as binding agent to the coarse and fine aggregates and stabilizers in HMA mixtures. Properties of bitumen depend on temperature. Bitumen shows viscous as well as elastic property. Bitumen used for the experiment is grade 60/70 pen and grade 80/100 pen. Standard properties test were carried out such as penetration test, softening point test and ductility test.

3.2.1. Penetration Test

This test is to determine the penetration of semi-solid and solid bituminous materials. In this test, a needle is allowed to penetrate into the bitumen sample under a load of 100g bitumen at a fixed temperature of 25 degree Celsius for five seconds. The distance of penetration will determine the classification of bitumen.

FIGURE 3.1 Penetration Test

3.2.2 Softening Point Test

This test is done to determine the softening point of bituminous binder. In this test, the ring and ball test is carried out to determine the softening point. Two steel ball will be placed on a sample of bitumen contained in two brass ring which is suspended in water bath. The bath temperature is raised five degree Celsius per minute and slowly the bitumen softens and eventually deforms slowly with ball moving

through the ring. The moment the first ball touches the base plate 25mm below the ring, the temperature is recorded. The second ball to touch the base plate must not be more than one degree Celsius.

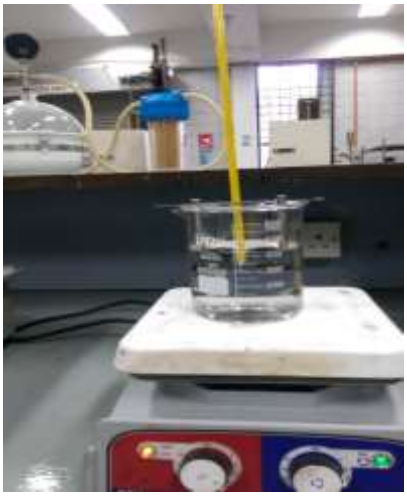


FIGURE 3.2 Softening Point Test

3.2.3 Ductility Test

This test is done to determine the ductility distillation residue of cutback bitumen. The bitumen is placed in a brass plate and moulded. The rings of the brass plate is attached to the hook of testing machine which is known as Ductilometer. The sample is placed 25mm below in a water bath. Then, the hook is pulled until the bitumen breaks. The ductility is measured by distance in centimeter where it will elongate until it breaks.

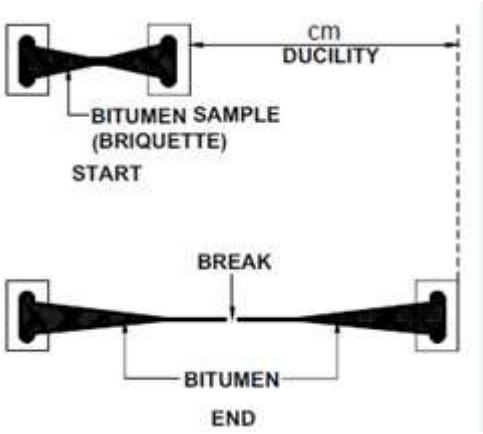


FIGURE 3.3 Ductility Test

FIGURE 3.4 Ductilometer

3.2.4 Rolling Thin Film Oven (RTFO) Test

It is a process to determine the short term aging. This test is done to measure the effect of heat and air on a moving film of a semi solid asphaltic materials. A total of eight cylindrical glass cup is placed into the oven for a total of 85 minutes in condition of 163 degree Celsius. Once the test is done, it will be placed into the Pressure Aging Vessel test to determine the long term aging.

FIGURE 3.5 Rolling Thin Film Oven (RTFO)

3.2.5 Pressure Aging Vessel (PAV) Test

It is a process to determine the long term aging process. This test is done to simulate in-service oxidative aging of bitumen by exposing to an elevated temperature in a pressurized environment. A total of six round pans are placed into the oven for a total of 20 hours in condition of 95 degree Celsius. Once the test is done, the aged bitumen will be tested and results of virgin bitumen and aged bitumen are compared.

FIGURE 3.6 Pressure Aging Vessel (PAV)

3.3 Production of Coconut Shell Powder

Since the production of coconut shell powder is very important, a standard of procedure is prepared to produce coconut shell powder:

1. The coconut shell is left to dry at 40 degree for seven to nine days.
2. The dried coconut shell are then placed in the Los Angeles Abrasion Test and left in rotation of 1000 to be crushed into powder.
3. Sieving is finally done in an ASTM No.100 or 150 micron sieve to get the fine powder which is applied as additives to the bitumen.
4. After sieving, the coconut shell powder is tested for the specific gravity (Gs).

FIGURE 3.7 Dried Coconut Shell

FIGURE 3.8 Crushed Coconut Shell

3.4 Addition of Coconut Shell Powder to Bitumen

1. A cup of 500g bitumen is prepared and addition of coconut shell powder are done separately.
2. The amount of coconut shell powder to be added are shown below:

TABLE 3.1 Amount of Coconut Shell Powder Used

Percentage	2%	4%	6%	8%
Amount (g)	10	20	30	40

3. A high shear mixer is used to mix the binder with coconut shell powder at a rotation per second of 3500rps for 45 minutes.

FIGURE 3.9 High Shear Mixer

3.5 Key Milestone

There are a few major activities that was done to determine my success towards completion of this project. For the first two weeks, brainstorming to search a proper topic and finalizing the topic with my supervisor was the first activity. This is important so that I would have topic which is relevant and feasible during this two semesters. Second activity is my part to study and understand literature review using multiple sources. Next, the lab test activities will be carried out by comparing the base binder results and coconut shell powder bitumen. Experimental work is carried out to determine the performance of modified bitumen with standard bitumen. The data for each experiment is collected and analyzed to discover the advantage of modified bitumen. The conclusion of experiment is concluded. Lastly, the most important milestone is to complete this project according to the requirement which is set by UTP.

3.6 Gantt Chart

TABLE 3.2 Gantt Chart

Project Activities	Weeks													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
FYP 1														
Selection of Project Topic	■	■												
Literature Review			■	■	■	■	■	■	■	■	■	■	■	■
Extended Proposal						★								
Proposal Defense									★					
Experiment Material Preparation Preliminary Test							■	■	■	■	■	■	■	
Submission of Interim Report														★
FYP 2														
Experiment Test of Modified Bitumen	■	■	■	■	■	■	■							
Data and Analysis Interpretation						■	■	■	■	■	■	■		
Viva													★	
Report Writing (continuation from FYP 1)	■	■	■	■	■	■	■	■	■	■	■	■	■	★

■	Progress
★	Task to be done

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Results

4.1.1 Coconut Shell Powder Preparation

The coconut shell that was crushed into powder by using LA Abrasion Test was sieved by using the following sieve sizes. Then, the sieve analysis graph was plotted to show the how fine the powder is. From current results, the chosen material will be powder from ASTM no. 100 or 150 micron sieve.

TABLE 4.1 Sieve Analysis of Coconut Shell Powder

Sieve Size	**Mass Of Pan (G)**	**Mass Of Pan + Sieve (G)**	**Mass Of Sieve (G)**	**Percent Passing (%)**
1.18 mm	960	4000	3040	84.40%
600 µm	913	1195	282	7.80%
425 µm	854.5	908	48	1.30%
150 µm	862	1047.4	185.4	5.00%
75 µm	826	849	23	0.64%
Pan	778	796	18	0.50%

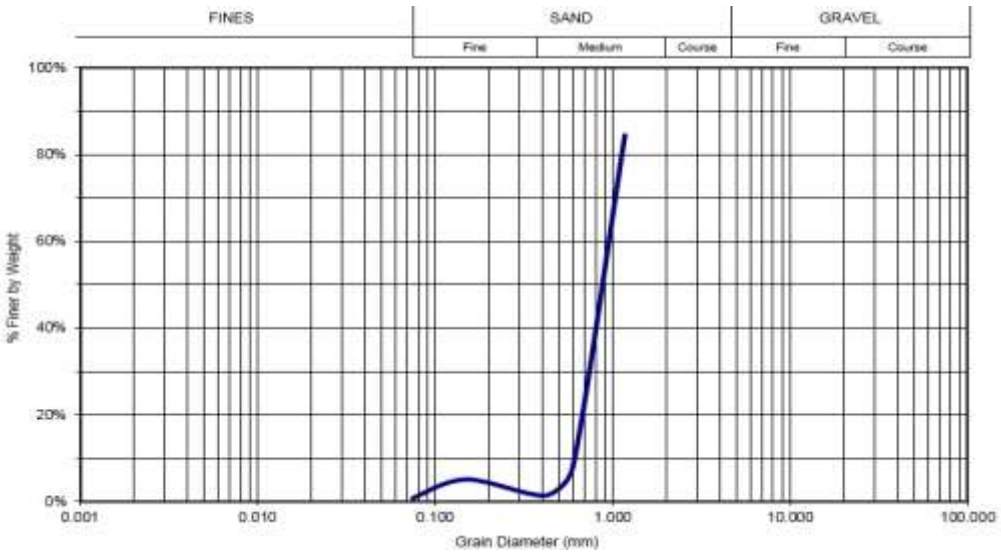


FIGURE 4.1 Sieve Analysis Graph

After the sieving is completed, the samples are tested for the specific gravity (Gs). Table 4 below shows the results of the specific gravity of coconut shell powder which is 1.68.

TABLE 4.2 Specific Gravity of Coconut Shell Powder

Experiment No	**1**	**2**
W1, weight of empty clean and dry pycnometer (g)	38.4	37.8
W2, weight of pycnometer containing sample (g)	84.4	87.6
W3, weight of pycnometer containing sample and distilled water (g)	155.6	158.3
W4, weight of pycnometer containing distilled water (g)	138.1	137.2
Specific Gravity (Gs)	1.61	1.74
Average Specific Gravity (Gs)	**1.68**	

4.1.2 Base/ Virgin Bitumen

The base bitumen of both grade were tested to obtain their properties. The table below shows the physical properties of both bitumen grade 60/70 pen and grade 80/100 pen after the experiment are carried out. They are tested before and after aging process where the aging process is done by undergoing RTFOT for short term aging and PAV test for long term aging simulation. The results obtained will be compared later on with the results of modified bitumen to determine whether the coconut shell powder manage to control the oxidation process which occur during the road pavement application.

TABLE 4.3 Physical Properties of Bitumen Grade 60/70 Penetration Before and After Aging Process

Properties	**Before**	**After**	**Specifications Used**
Penetration (25 °C , 100g, 5s, dmm)	64.5mm	44mm	ASTM D 5
Softening Point (°C)	45.5	51.0	ASTM D 36
Ductility (25 °C, 5cm/min)	150cm	141cm	ASTM D 113

TABLE 4.4 Physical Properties of Bitumen Grade 80/100 Penetration Before and After Aging Process

Properties	**Before**	**After**	**Specifications Used**
Penetration (25 °C , 100g, 5s, dmm)	93mm	75.5mm	ASTM D 5
Softening Point (°C)	43.0	48.0	ASTM D 36
Ductility (25 °C, 5cm/min)	150cm	142cm	ASTM D 113

4.1.3 Modified Bitumen

The addition of coconut shell powder for 2%, 4%, 6% and 8% are carried out to study the difference of modified bitumen. The addition are done for every 500g of bitumen grade 80/100 pen and grade 60/70 pen. From table 1 which was shown earlier, the amount need to be added are known where for 2% is 10g, 4% is 20g, 6% is 30g

and 8% is 40g. Then, the mixing process are carried out by High Shear Mixer for 45 minutes of all the sample. Once the modified bitumen are prepared, the experiment were carried out to compare the results of modified bitumen with base bitumen before and after aging.

TABLE 4.5 Physical Properties of Modified Bitumen Grade 80/100 Penetration by addition of 2% of Coconut Shell Powder Before and After Aging Process

Properties	**Before**	**After**	**Specifications Used**
Penetration (25 °C , 100g, 5s, dmm)	84.3mm	68.8mm	ASTM D 5
Softening Point (°C)	45.5	52.0	ASTM D 36
Ductility (25 °C, 5cm/min)	150cm	138cm	ASTM D 113

TABLE 4.6 Physical Properties of Modified Bitumen Grade 80/100 Penetration by addition of 4% of Coconut Shell Powder Before and After Aging Process

Properties	**Before**	**After**	**Specifications Used**
Penetration (25 °C , 100g, 5s, dmm)	78.7mm	66.5mm	ASTM D 5
Softening Point (°C)	48.0	53.5	ASTM D 36
Ductility (25 °C, 5cm/min)	142cm	125cm	ASTM D 113

TABLE 4.7 Physical Properties of Modified Bitumen Grade 80/100 Penetration by addition of 6% of Coconut Shell Powder Before and After Aging Process

Properties	**Before**	**After**	**Specifications Used**
Penetration (25 °C , 100g, 5s, dmm)	82.6mm	70.0mm	ASTM D 5
Softening Point (°C)	50.0	52.5	ASTM D 36
Ductility (25 °C, 5cm/min)	150cm	132m	ASTM D 113

TABLE 4.8 Physical Properties of Modified Bitumen Grade 80/100 Penetration by addition of 8% of Coconut Shell Powder Before and After Aging Process

Properties	**Before**	**After**	**Specifications Used**
Penetration (25 °C , 100g, 5s, dmm)	86.2.mm	74.6mm	ASTM D 5
Softening Point (°C)	49.5	51.0	ASTM D 36
Ductility (25 °C, 5cm/min)	147cm	120cm	ASTM D 113

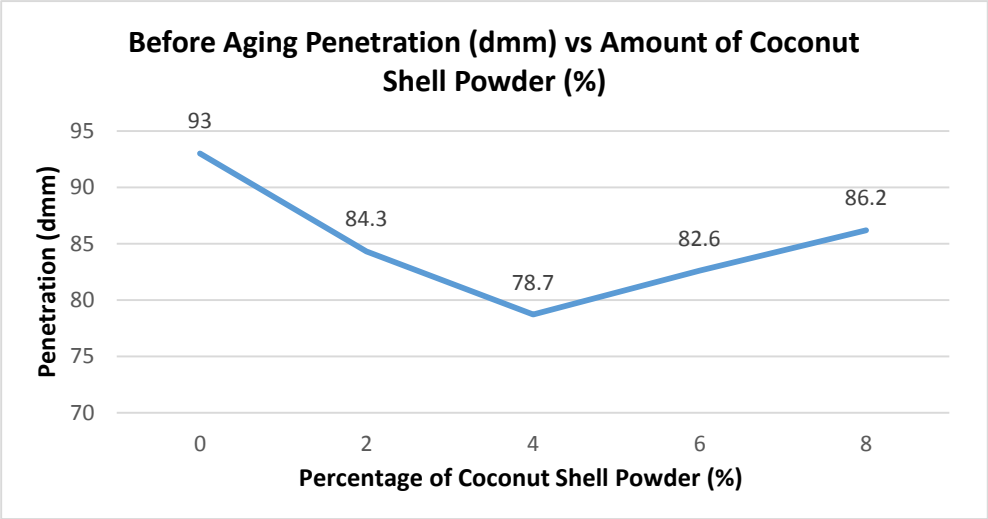


FIGURE 4.2 Before Aging Penetration (dmm) vs Amount of Coconut Shell Powder (%) Graph of Bitumen Grade 80/100 Pen

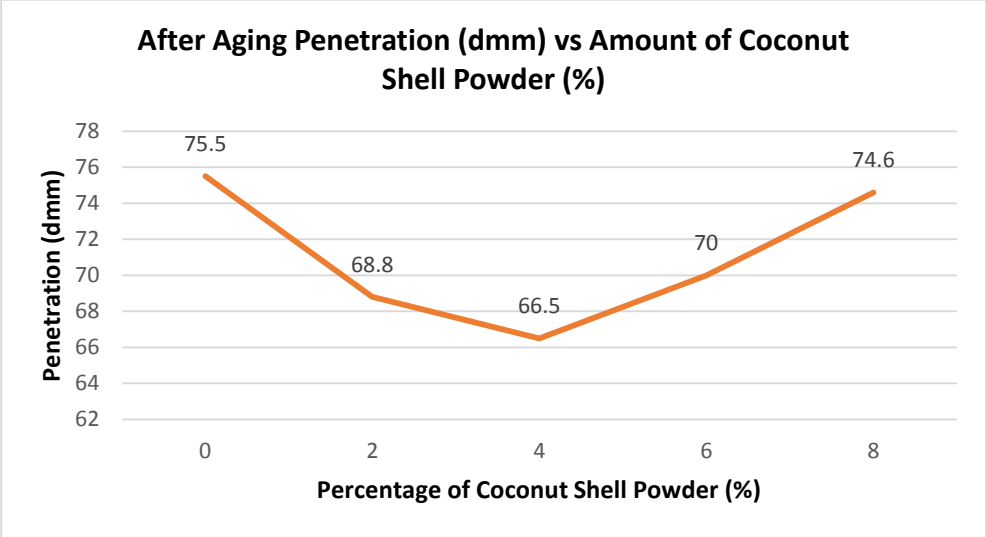


FIGURE 4.3 After Aging Penetration (dmm) vs Amount of Coconut Shell Powder (%) Graph of Bitumen Grade 80/100 Pen

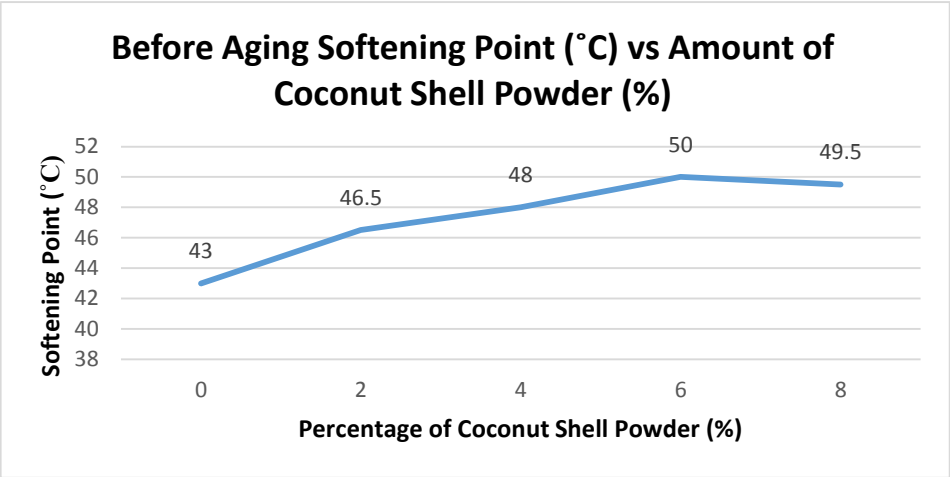


FIGURE 4.4 Before Aging Softening Point (°C) vs Amount of Coconut Shell Powder (%) Graph of Bitumen Grade 80/100 Pen

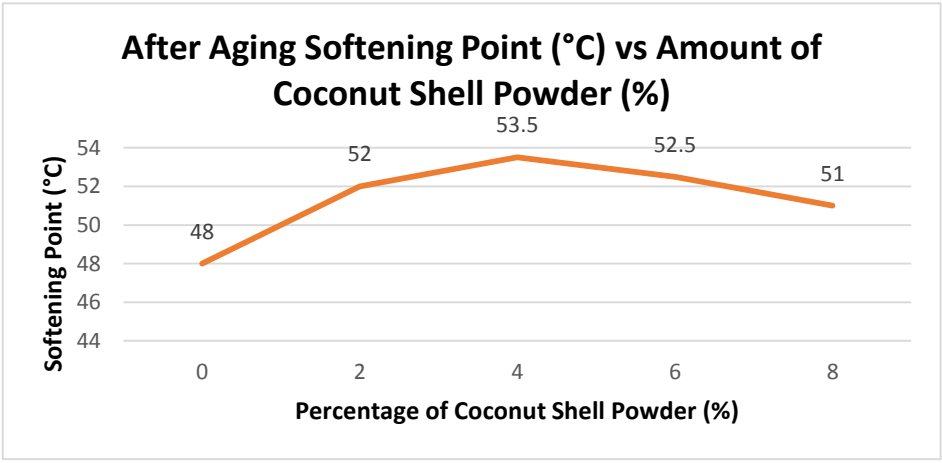


FIGURE 4.5 After Aging Softening Point (°C) vs Amount of Coconut Shell Powder (%) Graph of Bitumen Grade 80/100 Pen

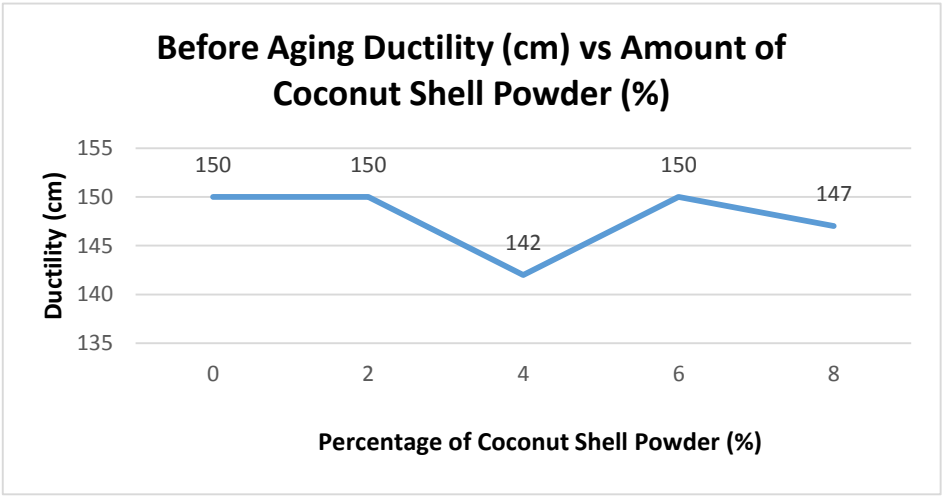


FIGURE 4.6 Before Aging Ductility (cm) vs Amount of Coconut Shell Powder (%) Graph of Bitumen Grade 80/100 Pen

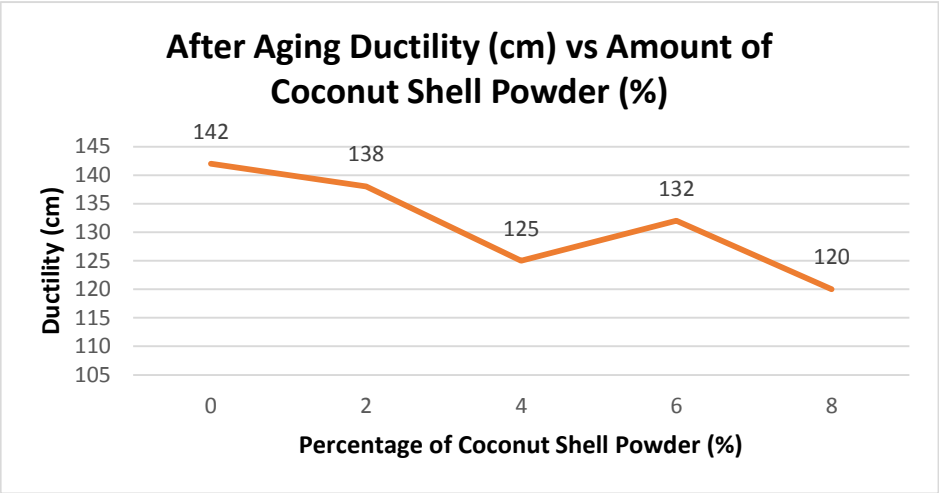


FIGURE 4.7 After Aging Ductility (cm) vs Amount of Coconut Shell Powder (%) Graph of Bitumen Grade 80/100 Pen

TABLE 4.9 Physical Properties of Modified Bitumen Grade 60/70 Penetration by Addition of 2% of Coconut Shell Powder Before and After Aging Process

Properties	**Before**	**After**	**Specifications Used**
Penetration (25 °C , 100g, 5s, dmm)	61.5mm	46mm	ASTM D 5
Softening Point (°C)	47.5	50.0	ASTM D 36
Ductility (25 °C, 5cm/min)	147cm	138cm	ASTM D 113

TABLE 4.10 Physical Properties of Modified Bitumen Grade 60/70 Penetration by Addition of 4% of Coconut Shell Powder Before and After Aging Process

Properties	**Before**	**After**	**Specifications Used**
Penetration (25 °C , 100g, 5s, dmm)	63.0mm	44.5mm	ASTM D 5
Softening Point (°C)	49.5	52.0	ASTM D 36
Ductility (25 °C, 5cm/min)	150cm	142cm	ASTM D 113

TABLE 4.11 Physical Properties of Modified Bitumen Grade 60/70 Penetration by Addition of 6% of Coconut Shell Powder Before and After Aging Process

Properties	**Before**	**After**	**Specifications Used**
Penetration (25 °C , 100g, 5s, dmm)	62.0mm	48.0mm	ASTM D 5
Softening Point (°C)	49.0	51.5	ASTM D 36
Ductility (25 °C, 5cm/min)	146cm	132cm	ASTM D 113

TABLE 4.12 Physical Properties of Modified Bitumen Grade 60/70 Penetration by Addition of 8% of Coconut Shell Powder Before and After Aging Process

Properties	**Before**	**After**	**Specifications Used**
Penetration (25 °C , 100g, 5s, dmm)	65.5mm	47.5mm	ASTM D 5
Softening Point (°C)	50.5	53.0	ASTM D 36
Ductility (25 °C, 5cm/min)	150cm	128cm	ASTM D 113

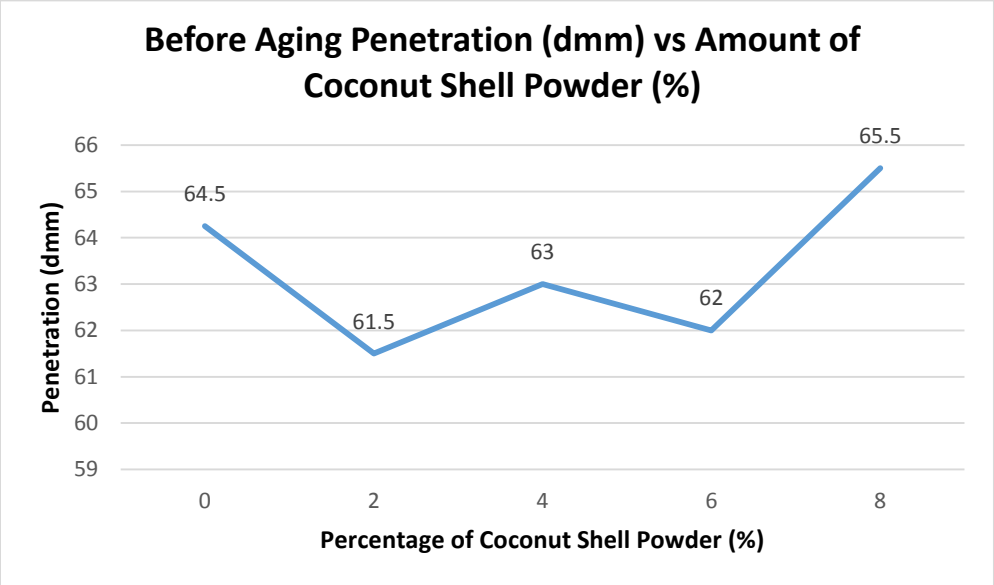


FIGURE 4.8 Before Aging Penetration (dmm) vs Amount of Coconut Shell Powder (%) Graph of Bitumen Grade 60/70 Pen

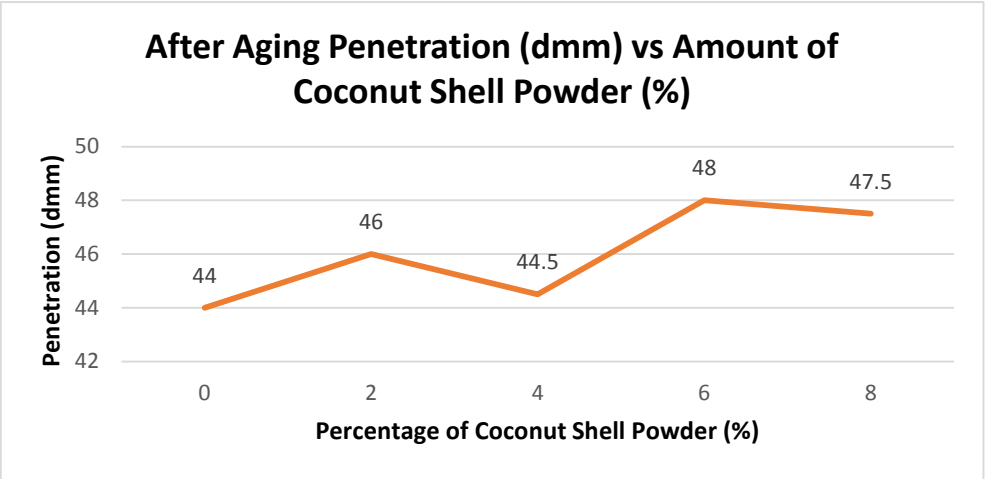


FIGURE 4.9 After Aging Penetration (dmm) vs Amount of Coconut Shell Powder (%) Graph of Bitumen Grade 60/70 Pen

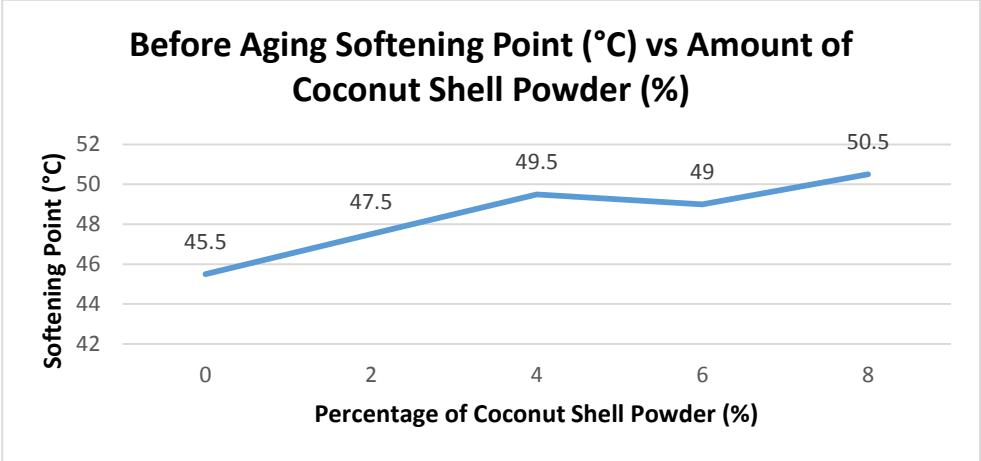


Figure 4.10 Before Aging Softening Point (°C) vs Amount of Coconut Shell Powder (%) Graph of Bitumen Grade 60/70 Pen

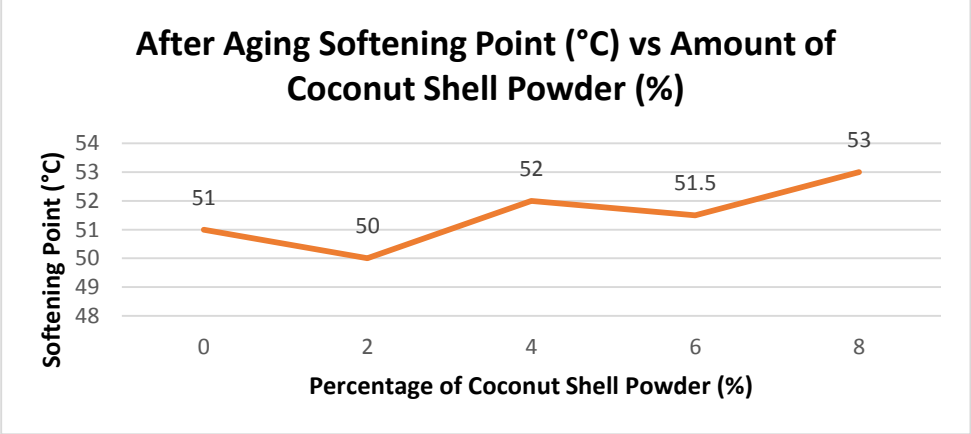


FIGURE 4.11 After Aging Softening Point (°C) vs Amount of Coconut Shell Powder (%) Graph of Bitumen Grade 60/70 Pen

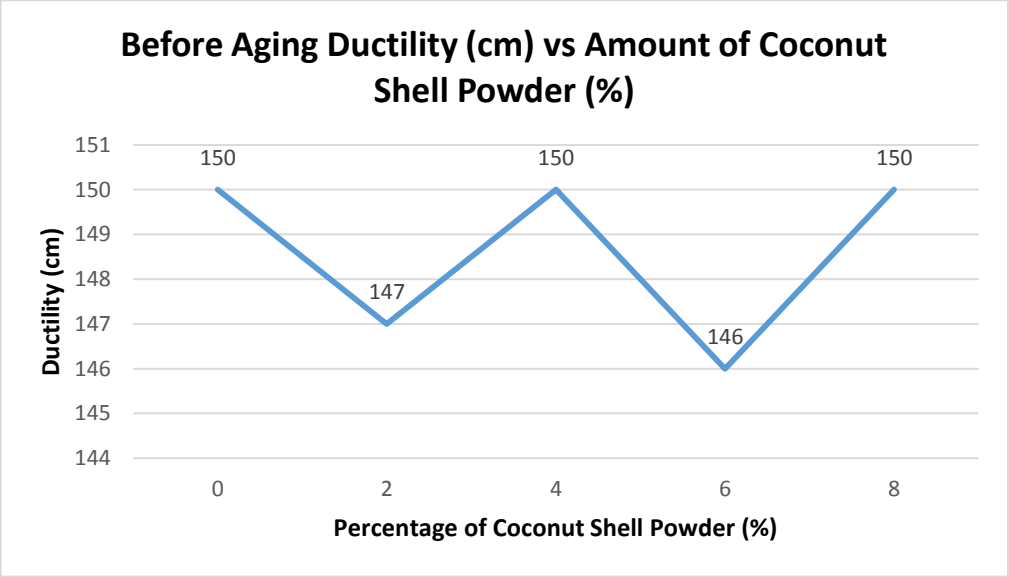


FIGURE 4.12 Before Aging Ductility (cm) vs Amount of Coconut Shell Powder (%) Graph of Bitumen Grade 60/70 Pen

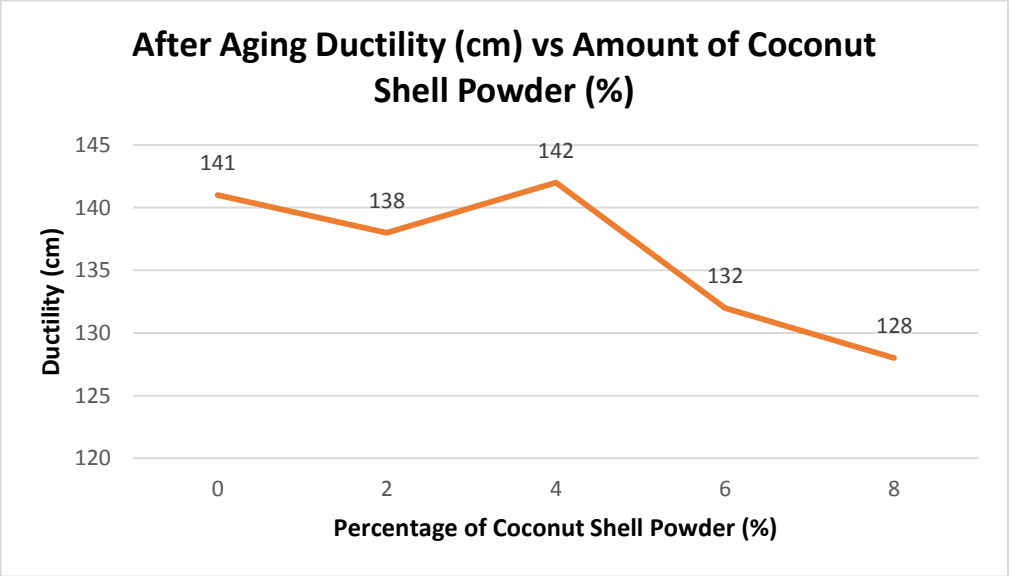


FIGURE 4.13 After Aging Ductility (cm) vs Amount of Coconut Shell Powder (%) Graph of Bitumen Grade 60/70 Pen

4.2 Discussion

Based from the results obtained, there are changes in the properties of bitumen after the addition of coconut shell powder. These results were validated by comparing the virgin bitumen with modified bitumen of 2%, 4%, 6%, and 8% before aging and after aging process of bitumen from grade 80/100 pen and grade 60/70 pen. The physical test of both bitumen grade 60/70 pen and grade 80/100 pen indicates there are reaction when coconut shell powder is added.

From the penetration test it can be observed the modified bitumen tends to harden before aging at 2%, 4%, 6% and 8% for both bitumen grade 60/70 pen and grade 80/100 pen. First for the bitumen grade 80/100 pen, the graph of figure 11 indicates the virgin bitumen of before aging is at 93dmm which is higher compared to the modified bitumen. The same results of graph can be observed from figure 12 of after aging process of the bitumen where the virgin bitumen is at 75.5dmm higher compared to the modified bitumen of 2%, 4%, 6% and 8%. By comparing the graph of both before and after aging from figure 13 and figure 14, the difference of results for virgin bitumen is 17.5dmm, 2% is 15.5dmm, 4% is 12.2dmm, 6% is 12.6dmm and 8% is 11.6dmm. Whereas from the results of bitumen grade 60/70 pen, the graph of figure 19 shows the virgin bitumen penetration is 64.5dmm which is higher than the modified bitumen up to 6% except for 8% which has a penetration of 65.5dmm. As for the graph of after aging of bitumen grade 60/70 pen from figure 20, the virgin bitumen penetration is 44dmm which is lesser than the modified bitumen up to 8%. Again by comparing the graph of both before and after aging from figure 19 and figure 20, the difference of results for virgin bitumen is 20.5dmm, 2% is 15.5dmm, 4% is 18.5dmm, 6% is 14.0dmm and 8% is 18.0dmm. These results from penetration of both bitumen of grade 80/100 pen and grade 60/70 pen also showed the coconut shell powder was able to act as an antioxidant for the modified bitumen since the difference of modified bitumen is lesser than the virgin bitumen. Hence, it can be deduced there are changes due to chemical reactivity by the addition of coconut shell powder on the consistency and hardness of bitumen but probably due to some technical error the results of bitumen grade 60/70 pen are not very desirable.

As for the softening point test, for bitumen grade 80/100 pen it can be observed from figure 15 the temperature for softening point before aging of virgin bitumen is 43 °C and for modified bitumen of 2%, 4%, 6% and 8% the temperature are higher than the virgin bitumen. The same flow of results can be observed from figure 16 which is after aging where virgin bitumen is 48 °C and the modified bitumen temperature are higher. While, for bitumen grade 60/70 pen before aging from figure 21 it can be observed the virgin bitumen have a temperature of 45.5 °C and the modified bitumen have a higher reading than the virgin bitumen. However, after aging as in figure 22 shows a different results where there is an increase of temperature for softening point for 4%, 6% and 8% as compared to the virgin bitumen temperature of 51 °C from figure 22. Thus, based from the observed softening point results it can be deduced the bitumen tends to become harder and need a higher temperature to reach a desired softening point temperature.

Finally from the ductility test results, for bitumen of grade 80/100 pen before aging of figure 17 shows the elongation is 150cm for virgin bitumen, 2% and 6% of modified bitumen. The 4% elongates up to 142cm and 8% up to 147cm. From figure 18, the bitumen tends to become more brittle which show the results of modified binder breaks earlier than the virgin bitumen reading of 142cm after aging. The lowest reading was shown for modified bitumen of 4% at 125cm and 8%. For bitumen of grade 60/70 pen, figure 23 the before aging bitumen shows a reading where it was able to elongate an average length of 145cm for virgin and modified bitumen. After aging results based from figure 24 shows the lowest reading for modified bitumen which breaks at 132cm for 6% and 128cm for 8%. Therefore, this ductility results indicates the brittleness increases for both modified bitumen after aging process.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

Based from this study, we have understand and determined the potential performance of coconut shell powder incorporated with bitumen of grade 60/70 and grade 80/100. Since coconut shell is a sustainable waste product, the cost is cheaper and can be attained easily. Hence, it can be used as a possible additive for bitumen to enhance the performance of bitumen. The expected goal is to develop a modified binder which can produce a possible solution to act as antioxidant and provide a better characteristics for the binder. Based on the results obtained, it can be observed there is a controlled aging process for the modified bitumen of grade 60/70 pen and grade 80/100 pen. The coconut shell powder used as an antioxidant was able to reduce the age hardening after short term and long term aging process. It was observed the changes in terms of improvement towards cracking and rutting resistance for the modified bitumen. In conclusion, from both grade of bitumen tested with all aging conditions with respects to control, there are slight difference in results of modified bitumen 2%, 4%, 6% and 8% compared to virgin bitumen but a definite suitable results for modified bitumen can be concluded with a more detailed experiment.

As for recommendation, I would suggest to continue the test up to 20% of addition to study and achieve a better results. However, due to time constraint results was complete up to 8% of addition. More research is also required to understand the effect and implication of modified bitumen on the pavement behavior.

REFERENCES

Abiola, O. S., Kupolati, W. K., Sadiku, E. R., & Ndambuki, J. M. (2014). Utilisation of natural fibre as modifier in bituminous mixes: A review. *Construction and Building Materials, 54*, 305-312.

Al-Mansob, R. A., Ismail, A., Algorafi, M. A., Hafezi, M. H., & Baghini, M. S. (2013). <Comparison between Mixtures of Asphalt with Palm Oil Shells and Coconut Shells as Additives>.

Calabi-Floody, A., & Thenoux, G. (2012). Controlling asphalt aging by inclusion of byproducts from red wine industry. *Construction and Building Materials, 28*(1), 616-623. doi: 10.1016/j.conbuildmat.2011.08.092

Gunasekaran, K., Kumar, P. S., & Lakshmipathy, M. (2011). Mechanical and bond properties of coconut shell concrete. *Construction and Building Materials, 25*(1), 92-98.

Harshad, P., & Gundaliya, D. P. J. (2014). Review on Effect of Aging on Paving Grade Bitumen using Different Filler Material.pdf. *4*(3).

Kar, D. (2012). A LABORATORY STUDY OF BITUMINOUS MIXES USING A NATURAL FIBRE.pdf. 85.

Oda, S., Leomar Fernandes Jr, J., & Ildefonso, J. S. (2012). Analysis of use of natural fibers and asphalt rubber binder in discontinuous asphalt mixtures. *Construction and Building Materials, 26*(1), 13-20.

Qin, Q., Schabron, J. F., Boysen, R. B., & Farrar, M. J. (2014). Field aging effect on chemistry and rheology of asphalt binders and rheological predictions for field aging. *Fuel, 121*, 86-94.

Razali, R., & Zakaria, S. (2008). IMPROVING ROAD DURABILITY USING MODIFIED ASPHALT IN MALAYSIA HOW ITS WORKS.pdf.

Ting, T. L., Jaya, R. P., Hassan, N. A., Yaacob, H., & Jayanti, D. S. (2015). <A REVIEW OF UTILIZATION OF COCONUT SHELL AND COCONUT FIBER IN ROAD CONSTRUCTION>.

Xiang, L., Cheng, J., & Kang, S. (2015). Thermal oxidative aging mechanism of crumb rubber/SBS composite modified asphalt. *Construction and Building Materials, 75*, 169-175.

Xue, Y., Wu, S., Cai, J., Zhou, M., & Zha, J. (2014). Effects of two biomass ashes on asphalt binder: Dynamic shear rheological characteristic analysis. *Construction and Building Materials, 56*, 7-15.

Chui-Te Chiu and Li-Cheng Lu (2007), "A Laboratory study on Stone Matrix Asphalt using Ground Tire Rubber", *Construction and Building Materials, Volume 21, Issue 5, pp 1027-1033*

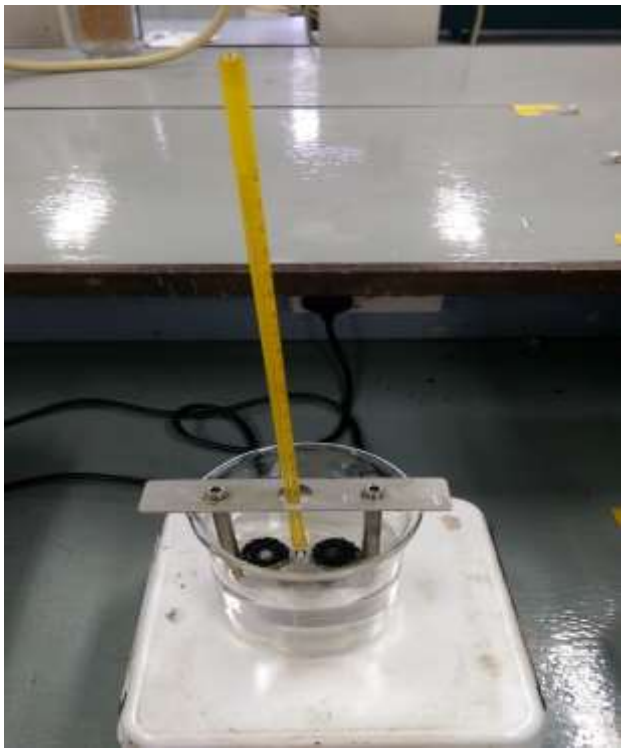
APPENDICES

a. Sieving Machine

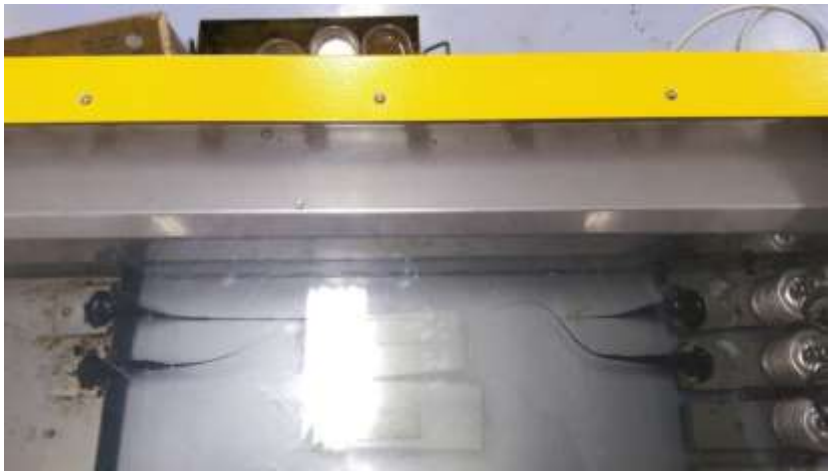
b. Los Angeles Abrasion Machine

c. Rheometer Test

d. Softening Point Test



e. Ductility Test



f. Specific Gravity Calculation

The determination of theoretical density of coconut shell powder

Gs = [(W2-W1) / {(W4-W1) – (W3-W2)}]

W1, weight of empty clean and dry pycnometer

W2, weight of pycnometer containing sample

W3, weight of pycnometer containing sample and distilled water

W4, weight of pycnometer containing distilled water

Experiment No	1	2
W1, weight of empty clean and dry pycnometer (g)	38.4	37.8
W2, weight of pycnometer containing sample (g)	84.4	87.6
W3, weight of pycnometer containing sample and distilled water (g)	155.6	158.3
W4, weight of pycnometer containing distilled water (g)	138.1	137.2
Specific Gravity (Gs)	1.61	1.74
Average Specific Gravity (Gs)	1.68	

Calculation:

1) Gs = [(84.4-38.4) / {(138.1-38.4) – (155.6-84.4)}]
Gs = 1.61

2) Gs = [(87.6-37.8) / {(137.2-37.8) – (158.3-87.6)}]
Gs = 1.74

Hence, the average results of Specific Gravity is Gs=1.68