The Physical and Engineering Properties of 60/70 Bitumen with Carbon Black Additives

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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 except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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Khalida binti Khalid

Abstract

The increasing of human population has increases the needs for them to travel from one place to another. Due to this, the use of vehicles has increase which also increases the loadings on the flexible pavement. Due to that, the demand for better pavement to withstand all the harsh condition also increased. In this report, one of the constituent of the flexible pavement i.e. the bitumen is being focused on to be improved. The selected bitumen grade is 60/70 bitumen.

Bitumen is a result of the petroleum condensation process. Its grade is determined based on their properties. On the other hand, carbon black is a black pigment of rubber which produced from either furnace or thermal black processes. In this project, by adding carbon black into the bitumen, the bitumen's physical and engineering properties are investigated after mixing it with 2 types of carbon blacks with different percentages according to the weight of the bitumen.

The bitumen with carbon black additives are tested using penetration and softening point tests in the laboratory. As the result, both additives improve the virgin bitumen's performance. The details of the results are described in Result and Discussion section.

As the conclusion, the presence of carbon black in the bitumen does improve the properties of the bitumen. Hence, the bitumen helps in resistance upon problems such as rutting and cracking. The increment value of Penetration Index (PI) also further confirms the improvement of bitumen after added with carbon black. However, several recommendations are recommended in order to obtain better results and to have further results to be in the specification ranges of standard.

Acknowledgement

I would like to express fullest appreciation to all who involved and made the possibilities for me to complete my fourteen (14) weeks duration of Final Year Project (FYP).

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Chapter 1

INTRODUCTION

1.1 Background

Since long ago, roads are the means for humans to connect their region of territories as they migrate between them. In present days, roads are paved as flexible or rigid pavement (Figure 1) accordingly by considering its usage, maintenance purposes and costs.

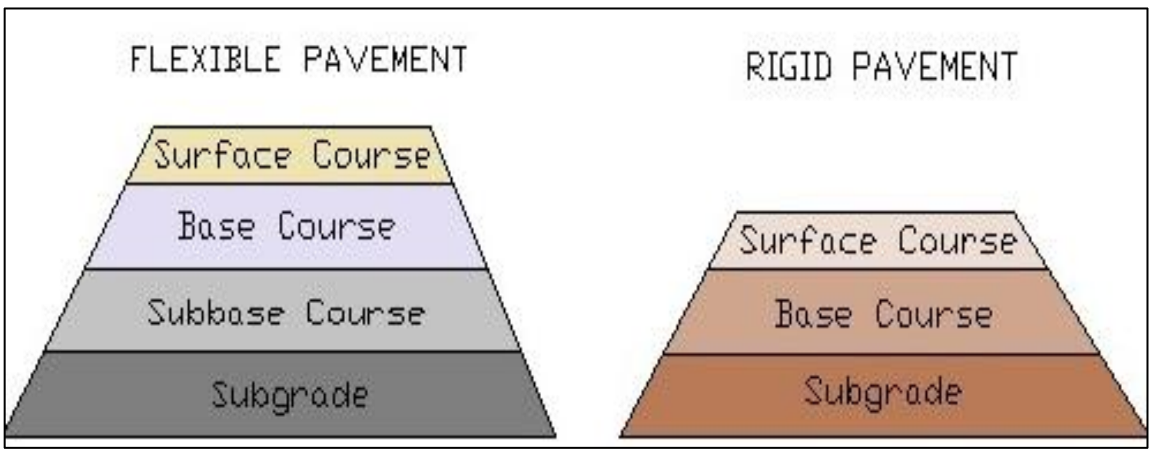

Figure 1: Flexible Pavement vs. Rigid Pavement

Flexible pavement is a road paving method where bitumen is used as its binder unlike rigid pavement where concrete is used as its binder. In designing pavement, four major contributes are consider the main subject in designing a pavement namely, course aggregate, fine aggregate, filler and the binder itself. Increasing demand in roads especially highway's construction, engineers studied many ways in enhancing the performance of the bituminous pavement. Thus, simple modifications also can be made in order to solve problems such as creep (permanent deformation) and fatigue of the road can be minimized by altering the materials used to design the bituminous mixture.

1.2 Problem Statement

As the world evolved, human population increased incrementally with time. Human's mobility involves road networks and vehicles such as cars, motorcycles, buses and other heavy vehicles for their daily activities. As such, these activities caused the road paving technology to experience challenges where problems such as creep (permanent deformation) and fatigue of the road to happen due to the loads exposed. Besides that, environmental changes in Malaysia, which having hot weather and heavy rain all year can cause damages to the roads as well. Thus, repetitive traffic loads at high temperature causes creep or rutting to occur (Figure 2). Exposure to repetitive traffic loads also explain the fatigue experienced by the road where repeated cycles of loadings are imposed that create cracks on the road (Figure 3)

Time also affect the bituminous pavement in which as time goes by, the pavement will aged. Aging of the pavement is almost an impossible problem to overcome forever. These faulty may disturb activities needed to be done by the user in a period of time and even may damage vehicles in a way that too much exposure to the uneven and destroyed road surfaces. Therefore, studies are taken in order to solve problems arising especially to have better performance with possible maintenance for the roads with the two main distresses of creep and fatigue failure by doing some modifications on the Malaysia's current binder used for bituminous pavement.

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Figure 2: Rutting

Figure 3: Fatigue Cracks

1.3 Objectives

The main objective for this study is to specify the engineering properties of 60/70 bitumen by adding additives of carbon black, which is different than the current binder used in Malaysia's roads.

1.4 Scope of Study

The study is focused on 60/70 bitumen as the base bitumen. The engineering properties of the 60/70 bitumen added with carbon black additives are determined.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

Bitumen is widely used in highway construction. They are hydrocarbons that are found in the natural deposits of the distillation of crude petroleum. In the next sections of this report, further explains characteristics of bitumen and their properties. Carbon black is used as the additive for this study for modifications made on asphalt. By adding additives, the bitumen either may strengthen as agreed by Cong, Chen and Chen (2011), which proven that diatomite added in the asphalt binder improves the resistance against deformation at high temperature and even against the thermal cracking at low temperature. Besides that, proved by Zhang, Xi, Zhang, Zhang and Zhang (2008), the addition of a polymer, styrene-butadiene-rubber/montmorillonite (SBR/MMT) to asphalt has decreased the softening and viscosity at high temperature which helps in enhancing the resistance to rutting at high temperature. The characteristics and properties of carbon black will be discussed later in the section coming.

2.2 Bitumen

Oxford Dictionaries defined bitumen as a black viscous mixture of hydrocarbons obtained naturally or as a residue from petroleum distillation. Hindustan Petroleum Corporation Limited Bitumen Handbook defined bitumen as a viscous liquid, or a solid, consisting essentially of hydrocarbons and their derivatives, which is soluble in trichloro-ethyelene and is substantially nonvolatile and softens gradually when heated. Lesuer (2008) generally defined bitumen as a virtually in volatile, passive and waterproofing material derived from crude petroleum, or present in natural asphalt. As the conclusion, bitumen is a black colored viscous hydrocarbon that softens gradually when heated and obtained naturally or as a product of petroleum distillation (Figure 4).

Figure 4: Bitumen

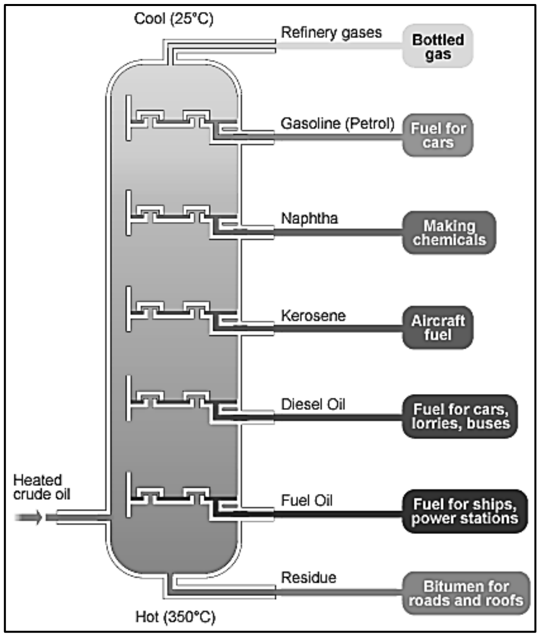

Figure 5: Fractional Distillation of Crude Petroleum

However bitumen also one of the products obtained from the distillation of crude petroleum. Asphalt is the heaviest residual material in the fractional distillation of crude petroleum separation process (Figure 5).

Asphalt is categorized into asphalt cements, asphalt cutbacks and asphalt emulsions. Asphalt cements are cementing agents that are semi-solid hydrocarbons with certain physiochemical characteristics. Usually, asphalt cements are used as the binder in the bituminous mixtures. They are viscous and as a binder, they are required to be heated and mixed together with aggregates and filler. As a result, mixing process is important which agreed by Hasmi (2008) where it may result in creep deformation due to the effect of high bitumen content from improper mixing other than exposure to high temperature, successive stress and insufficient compaction during road construction. Besides that, these asphalt cements are available in grades which vary from soft to hard according to its penetration values. The softest one is with the penetration value of 200 to 300. However, bitumen 60/70 is actually asphalt with grades of 60 to70 penetration which is categorized as one of the hardest in the asphalt cements. The other types of asphalts such as cutbacks and emulsified asphalts are usually used for surfacing proposes.

2.3 Properties of Bitumen

Bitumen is mainly consisting of hydrogen and carbon. Its density at room temperature usually lies between 1.01 to 1.04 g/cm^3. Bitumen is black or brown in colors. They are substantially non-volatile and soften gradually when heated. It is water resistant and possesses adhesive properties which made them the ideal candidate as binders in road constructions. Bitumen is mostly graded according to their penetration. Through the penetration test, the bitumen is classified either it is soft or hard.

Pfeiffer and Van (1936) developed an equation on penetration index which define the bitumen's consistency changes to temperature. Equation below is assuming PT for a penetration test temperature of 25˚C.

$$PI = \frac{1952 - 500 \log \text{Pen25} - 20\,\text{SP}}{50 \log \text{Pen25} - \text{SP} - 120}$$

This explain the ductility properties, the ability to elongate without breaking of the bitumen where varies the change of viscosity with different temperature.

Bitumen is also a visco-elastic material. At high temperature, it behaves like liquid where viscosity is exhibited. However during low temperature, bitumen behaves like solid where solid properties for stress and strain become relevant. Due to this properties, when it comes to repetitive loadings, a phase lag occurred in stress and strain and may lead to fatigue and creep problems . A softening point test or ring-and-ball test can be conducted in order to identify the temperatures that when bitumen changes from solid to liquid which giving the softening point of a bitumen specimen.

Adhesion is one of the properties that bitumen holds. Bitumen has an excellent adhesive quality. However with the presence of water, bitumen loses its adhesion to aggregate due to highly polarized water that strongly attached to the aggregate and displacing the bitumen coating. As the result, stripping which according to Hefer and Little (2005) as an exhibition of interfacial tension relation between aggregate and bitumen with the presence of water happened to the bituminous mixture. However, more factors are considered in influencing the bitumen adhesion properties.

Table 1 shows the minimum requirement for each tested properties for different penetration grade of bitumen based on Malaysian Standard MS124 1973.

Table 1: Standard Properties of 60/70 Penetration Grade Bitumen

INSPECTION	TEST METHOD	LIMITS
Penetration, 0.1 mm	ASTM D5	60 to 70
Softening Point, ˚C	ASTM D36	46.0 to 57.0

2.4 Carbon Black

International Carbon Black Association (ICBA) defined carbon black as virtually pure elemental carbon in the form of colloidal particles that are produced by incomplete combustion or thermal decomposition of gaseous or liquid hydrocarbons under controlled conditions. According to Hjelm, Wampler and Gerspacher (1986), carbon black, the fine powdery 'soot' formed by the burning of hydrocarbons under oxygen-depleted conditions. IARC Monographs defined carbon black as a form of elemental carbon manufactured by the controlled vapor-phase pyrolysis and partial combustion of hydrocarbons. As a conclusion, carbon black is literally a black colored pure carbon of colloidal particles that are produced by burning under insufficient oxygen of hydrocarbons (Figure 6).

Figure 6: Carbon Black

Carbon black is produced in two ways which are the furnace black and the thermal black processes. In the furnace black process, it uses the heavy aromatic oils as the feedstock. It uses a closed reactor to atomize the heavy aromatic oils under carefully controlled conditions such as temperature and pressure (Figure 7). The primary feedstock oil then introduced into a hot gas stream which achieved by burning a secondary feedstock such as natural gas or oil where it vaporizes and then pyrolyzes in the vapor phase to form microscopic carbon particles. Most of the furnace reactors have the reaction rate that is controlled by steam or water sprays. The carbon black is produced and conveyed through the reactor, cooled and collected in bag filters in a continuous process. And most of the furnace black plants use a portion of the residual gas to produce heat, steam or electric power.

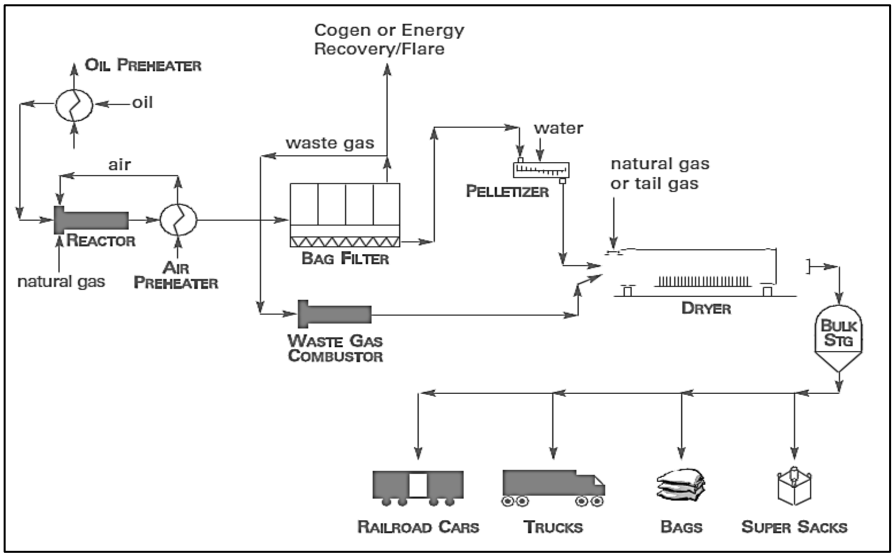

Figure 7: The Furnace Black Process

On the other hand, the thermal black process uses natural which primarily consist of methane or heavy aromatic oils as the feedstock material (Figure 8). This process uses a pair of furnaces that alternate approximately every five minutes between reheating and carbon black production. Then, the natural gas is injected into the hot refractory lined furnace with the absence of air; the heat from the refractory material decomposes the natural gas into carbon black and hydrogen. Water sprays quenches the aerosol material stream and filtered in a bag house. The product of carbon black may be further processed to remove impurities, pelletized, screened and then packaged for shipment while the hydrogen off-gas is burned in air to preheat the second furnace.

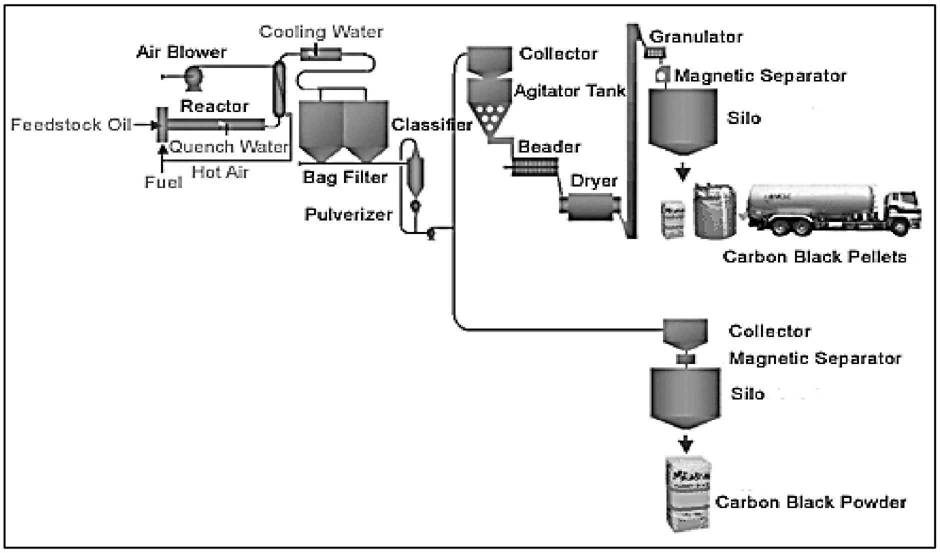

Figure 8: The Thermal Black Process

2.5 Properties of Carbon Black

According to McCunney (2001), carbon black is a powdered form of elemental carbon composed of particles and fused particle aggregates. It possessed an amorphous quasi-graphitic molecular structure. According to Wang (2003), the primary carbon black particle, also known as the nodule, is approximately 10 to 500 nm in diameter. The significant areas of different between a carbon black from furnace black and thermal black process are particle size and structure. Carbon black from thermal black process has the larger particle or nodule size that has mean diameter of 240 to 320 nm hence have lower surface area at 7-11 m^2/g. Whereas nodule size from furnace black process three to twenty times smaller which has mean diameter of 15-80 nm providing surface area from 27-145 m^2/g. Figure 9 below shows the visual comparison of the particle sizes.

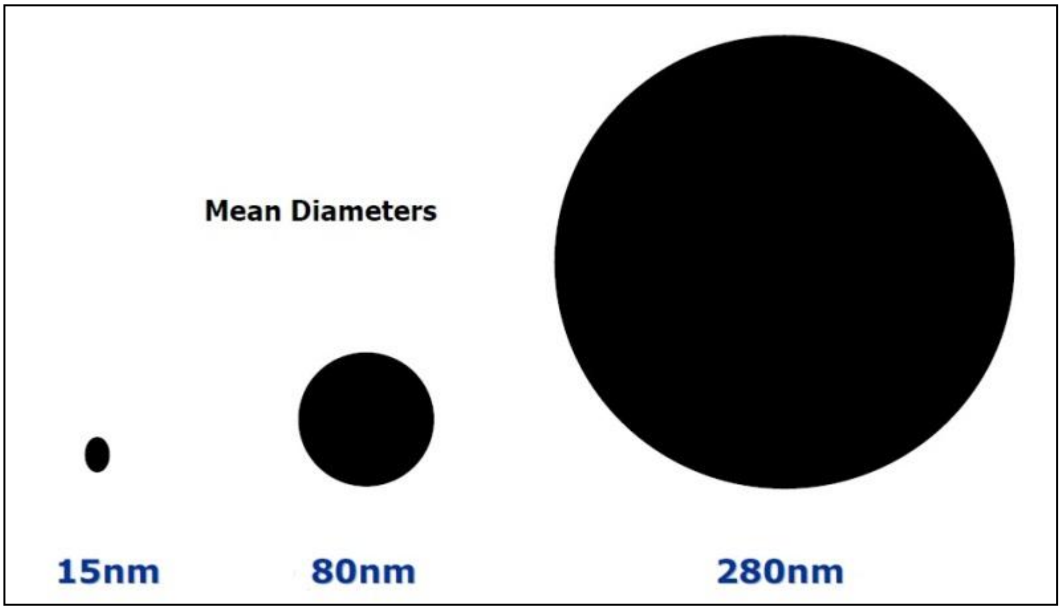

Figure 9: Carbon Particle Sizes Comparison

The nodule is the primary particle. It is made up of condensed aromatic ring system of carbon atoms arranged in large sheets of variable size and alignment. According to Wang (2003), these sheets are randomly stacked around an axis, held together by Van der Waals forces, and overlaid to form structures called nodules. Figure 10 below shows how carbon black particle's molecular arrangement.

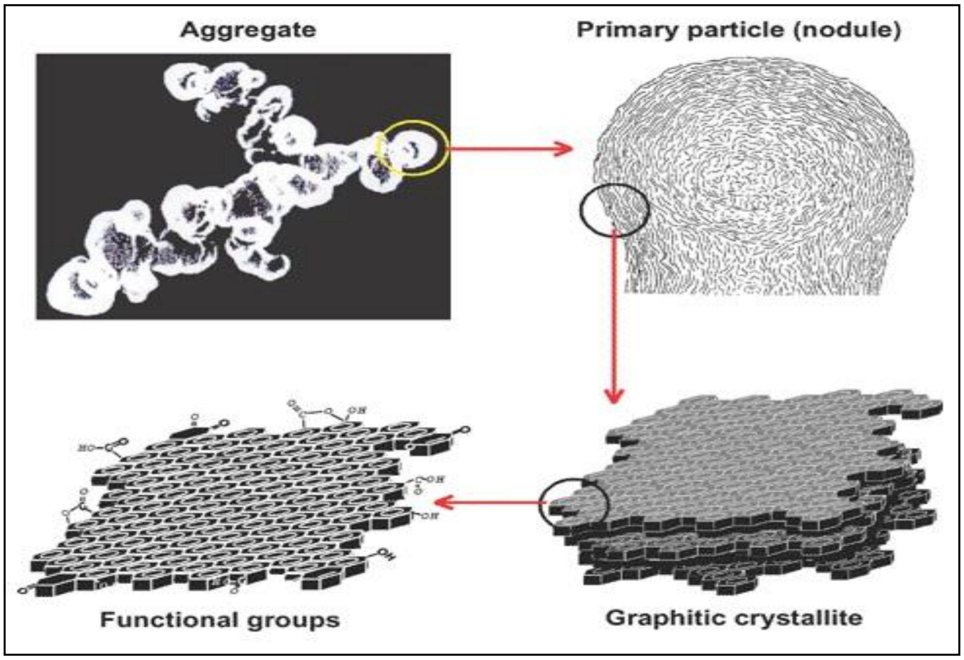

Figure 10: Structure of Carbon Black

The influence on carbon properties on the applications performance are summarized in the Figure 11 below.

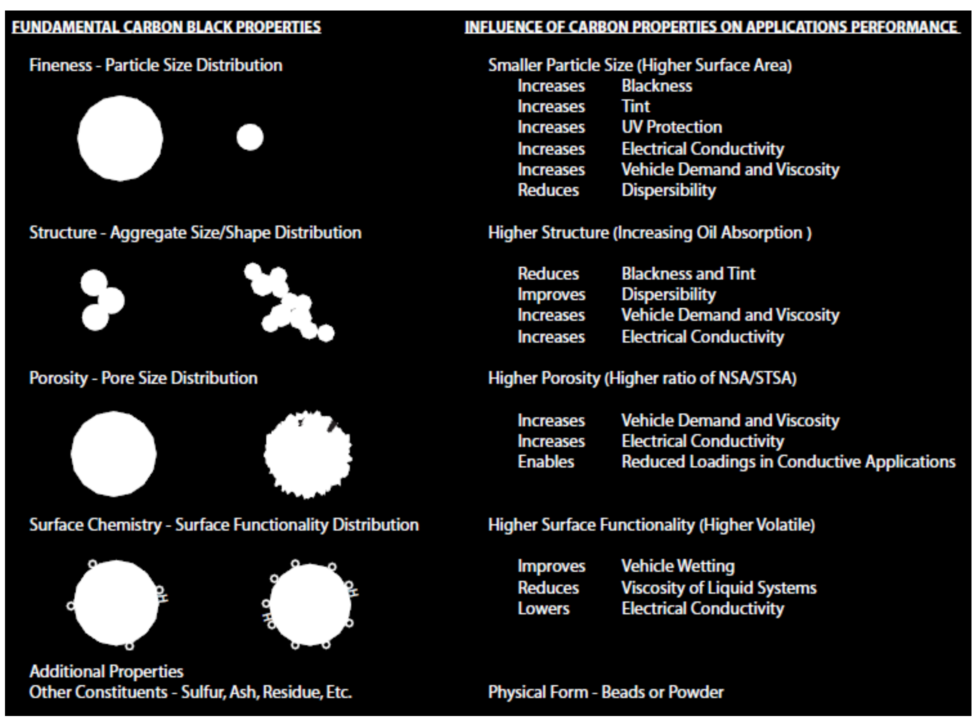

Figure 11: Summarized Influence of Carbon Black on Application Performance

Table 2 and 3 below are the physical and chemical properties of carbon black and the typical ranges of 4 types of carbon black respectively obtained from Environment Canada (2007).

Table 2: The Physical and Chemical Properties of Carbon Black

Property	Type	Value	Temperature (°C)	Reference
Physical state	Experimental	Solid: powder	-	ICBA 2004
Melting point (°C)	Experimental	3 652 -3 697 (sublimation)	-	Weast 1983
Primary particle size (nm)	See Table 3			
Surface area (m^2/g)	See Table 3			
Boiling point (°C)	Not available			
Density (kg/m^3)	Experimental	1 800-1 860 (Relative density: 1.80-1.86)	Not indicated	Kotlensky and Walker 1960; US EPA 1980
Vapour pressure (Pa)	Professional judgement	Negligible	Not indicated	OECD 2006
Henry's Law constant ($Pa{\cdot}m^3/mol$)	Professional judgement	Negligible	-	-
Log K_{ow} (octanol-water partition coefficient) (dimensionless)	Not applicable			
Log K_{oc} (organic carbon-water partition coefficient) (dimensionless)	Not applicable			
Water solubility (mg/L)	Experimental	Insoluble	Not indicated	IARC 1996
Organic solvents solubility	Experimental	Insoluble	-	Hawley 1981 ; ITII 1988

Table 3: Typical Ranges of 4 Types of Carbon Black

Property	Acetylene Black	Furnace Black	Lampblack	Thermal Black	Gas Black
Average aggregate diameter	Not reported	80-500 nm	Not reported	300-810 nm	Not reported
Average primary particle diameter	35-50 nm	17-70 nm	50-100 nm	150-500 nm	13-29 nm
Surface area (m^2/g)	60-70	20-200	20-95	6-15	90-320
Oil absorption (mL/g)	3.0-3.5	0.67-1.95	1.05-1.65	0.30-0.46	2.8-9.2
pH	5-7	5-9.5	3-7	7-8	2.5-4.5
Volatile matter (%)	0.4	0.3-2.8	0.4-9	0.10-0.50	5-6
Hydrogen (%)	0.05-0.10	0.45-0.710	Not reported	0.3-0.5	Not reported
Oxygen (%)	0.10-0.15	0.19-1.2	Not reported	0.00-0.12	Not reported
Benzene extract (%)	0.1	0.01-0.18	0.00-1.4	0.02-1.7	<0.1-0.3 (toluene)
Ash (%)	0.00	0.1-1.0	0.00-0.16	0.02-0.38	0.02
Sulfur (%)	0.02	0.05-1.5	Not reported	0.00-0.25	0.3-0.5
Density (g/mL)	Not reported	1.80	1.77	Not reported	1.20-1.80

Chapter 3

METHODOLOGY/PROJECT WORK

3.1 Introduction

In order achieve the objective of this study, a certain procedure is planned in order to be able to finish the research in the given period of time. Every activities are planned and noted as per scheduled so that none of the process is forgotten.

3.2 Research Methodology

As to precede the project, firstly the problem must be identified in order to gain the purposes to carry out the project. In this project, problems regarding pavement such as rutting, cracking and road deformed have been identified as the purpose of having modified bitumen as to solve only a part of flexible pavement constituents. Thus, some ideas were brainstormed and discussed with the supervisor so that the project can be realized through experiments on modifying bitumen. After the ideas are obtained, the project framework on objectives and scope of project where the project only focuses on one part of the flexible pavement: the binder. By modifying the bitumen using carbon black additives in this case, the virgin bitumen chosen to be tested on is the 60/70 bitumen.

After all important ideas and scope of the project has been narrowed down, the project commenced by starting some researches on properties of virgin bitumen and carbon blacks. Some literature review has been done by collecting some of other narrator’s work papers on many researches made on properties of modifying bitumen with many other fillers and modifiers. After diligent studies on other's outcome, data is collected and experiments are carried out. Comparisons were made after results are obtained and analyzed.

Lastly, after all the analysis and discussion are made, conclusion is made and some recommendations are stated so that in the future, if any study regarding modifying bitumen is carried out, this paper may help in improving the results that may have obtained.

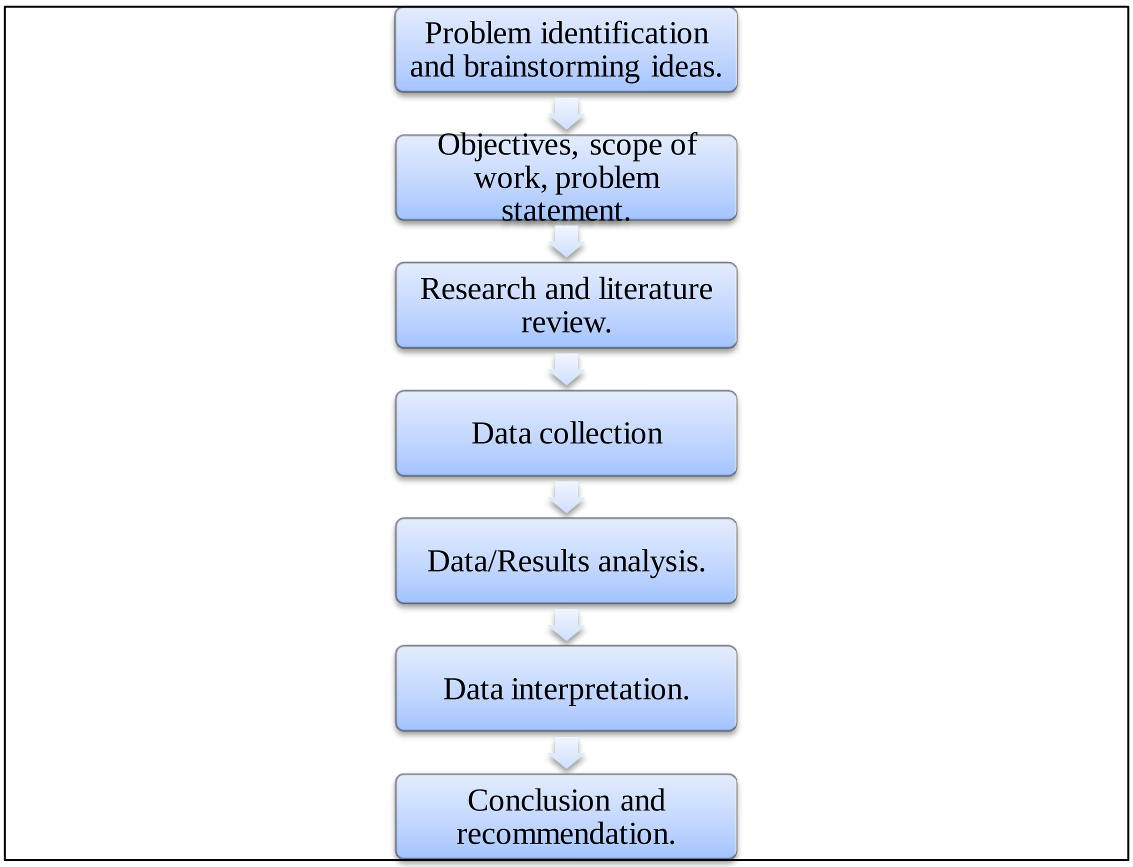

Figure 11: Flow Chart and Research Methodology

3.3 Project Work

3.3.1 Key Milestone

Key milestone is important in determining target achievability of the project. It is the target of completion for all the project work against time of the project ends. Thus, by having the target tabulated, the project will proceed without delays and is carried out smoothly.

Table 4 below shows the project deliverables and target date for the project work:

Table 4: Key Milestone

Event or Deliverable	Target Date	Responsibility
Project works continues	Week 1-12	Continue searching and produces results and conclusion for the project.
Submission of progress report	Week 8	Complete the progress report and hand it to supervisor.
Pre-SEDEX	Week 11	Sharpens the student's skill in poster preparation (exhibition style) and communication skills.
Submission of draft reports	Week 12	Students must submit the draft to the supervisor.
Submission of Dissertation report (soft bound)	Week 13	Students must submit the final report to the supervisor.
Submission of Technical report	Week 13	Students must submit the technical report to the supervisor.
Oral presentation	Week 14	Students must present their project to the supervisor and the examiner.
Submission of Dissertation report (hard bound)	Week 15	Students must submit the hard bounded final report to the supervisor.

3.3.2 Gantt Chart

No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14	15
1	Project Work Continues	■	■	■	■	■	■	■	Mid-Semester Break								
2	Submission of Progress Report									■							
3	Project Work Continues									■	■	■	■	■			
4	Pre-SEDEX												■				
5	Submission of Draft Report													■			
6	Submission of Dissertation (soft bound)														■		
7	Submission of Technical Paper														■		
8	Oral Presentation															■	
9	Submission of Project Dissertation (Hard Bound)																■

Figure 12: Gantt chart

3.3.3 Materials

The materials used in this study are listed as Table 5 below:

Table 5: Materials Used

Binder	**Additive**
Bitumen 60/70	Carbon Black -Raven 3500 -N220

3.3.4 Laboratory Tests

The tests conducted in this study are summarized as Table 6 below:

Table 6: Tests Conducted and it's Function

Test Conducted	**Function**	
Standard Penetration Test	• To determines the consistency of the penetration bitumen.	
Ring and Ball Test (Softening Point)	• To determine the consistency of the bitumen which represent the temperature at which a change of phase from solid to liquid occur.	

Penetration Test is used to determine the bitumen's consistency. The penetration is defined as the distance of the needle penetration into the bitumen which was measured in tenths of decimillimetre, dmm. The value of the penetration indicates the stiffness of the bitumen. Thus, the higher the penetration value, the softer the bitumen.

The Penetration Test achievable by allowing a needle of specified dimension to penetrate into a sample of bitumen under a known load (100g), at a fixed temperature of 25^{o}C for 5 seconds. However, the penetration is allowed only to a certain range of specification which is as stated in BS2000-49:2007 in Table 7 below. The table is tabulated for maximum allowable ranges for standard penetration ranges as according to the BS2000-49:2007 standard.

Table 7: Standard Penetration Ranges According to BS2000-49:2007

Penetration	**0 – 49**	**50 – 149**	**150 – 249**	**>250**
Maximum difference between highest and lowest determination	2	4	6	8

The table above indicates the maximum permissible ranges of penetration values for all samples tested. If the range is not satisfied, the test needs to be repeated. For each test, at least three trials of penetration are made. The differences of three penetrations should not differ by more than the amounts shown in the table above.

Ring and Ball Test is the standard test to determine the softening point at which of temperature that bitumen changes its state from solid to liquid occurs. By having this property of state changes helps in improving pavement performance against rutting through proper bitumen selection. Thus the higher the softening point, the more difficult for the bitumen to melt and allow rutting to occur.

The Ring and Ball Test is achievable by using a steel ball weighing approximately 3.5g that is placed on a sample of bitumen contained in a brass ring which will be suspended in a water or glycerol bath. The bitumen sample and the steel ball are placed in a water bath at a temperature of 5^{o}C for about 15 minutes before the test undergone. The bath temperature is raised at 5˚C per minute the specimen softens and eventually deforms slowly with the ball through the ring. At the moment the specimen and steel ball touched a base plate 25 mm below the ring, the temperature of the water is recorded. However, the softening values are allowed only to a certain range of specification which is as stated in BS2000-58:2007 in Table 8 below.

Table 8: Standard Softening Point Ranges According to BS2000-58:2007

Bath Liquid	**Type of Bitumen**	**Repeatability (˚C)**	**Reproducibility (˚C)**
Water	Unmodified	1 , 0	2 , 0
Water	Polymer modified	1 , 5	3 , 5
Glycerol	Oxidised	1 , 5	5 , 5

The table above indicates the maximum permissible differences of a set of softening point values for all samples tested. If the range is not satisfied, the test needs to be repeated. Therefore, differences between the 2 rings must satisfy the requirement as tabulated above.

Chapter 4

RESULT AND DISCUSSION

4.1 Introduction

Two 5L cans were used to mix the virgin bitumen with two types of carbon black namely N220 and Raven 3500. Approximately, 2kg virgin bitumen was used to be mixed with both types of carbon black respectively. The virgin bitumen was filled to a height of about a quarter from the height of the can, so that the mixer blade will be submerged completely during mixing. Thus, the intrusion of air into the mixture is minimized.

Mixing is required to be carried out carefully. In order to have well-mixed bitumen-carbon black mixture, bitumen mixing temperature is predetermined before mixing. The mixing temperature is determined by using Bitumen Test Data Chart (BTDC). After plotting the penetration and softening point values at25^{o}C, a line is made by joining these plots. The joined line is extrapolated to touch the line indicating viscosity value of 0.2Pa.s which is ideal viscosity for mixing. The process is illustrated as Figure 13 below.

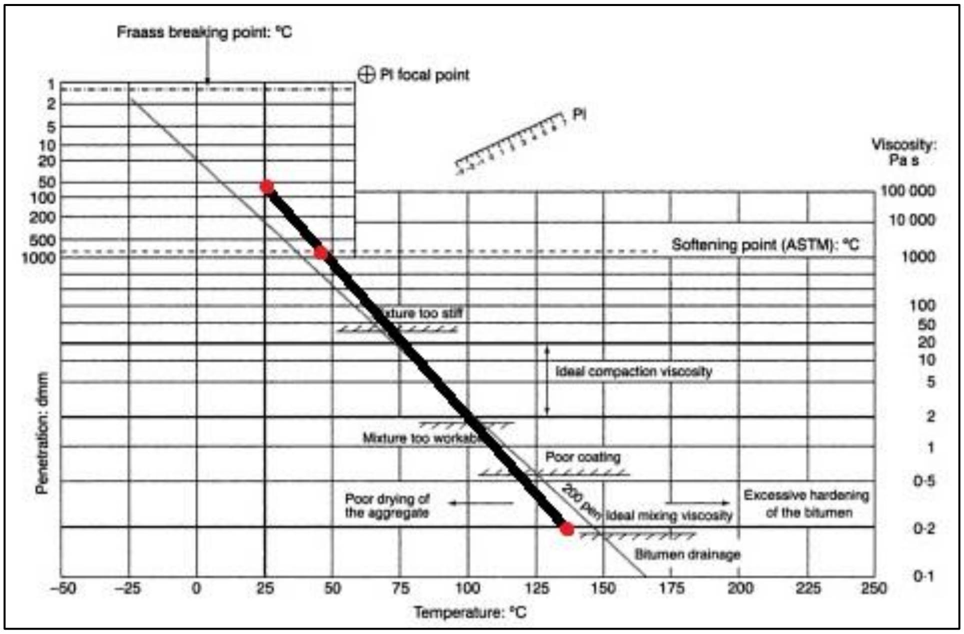

Figure 13: Bitumen Test Data Chart showing 'ideal' bitumen viscosities for optimal mixing and compaction of a dense bitumen macadam (The Shell Bitumen Handbook Fifth Edition, 2003)

From the plot, the minimum temperature needed to achieve for mixing (for viscosity of 0.2Pa.s) is about 135^{o}C. Therefore, the bitumen was preheated about 1 hour to the temperature at about 140^{o}C in the oven to make sure the whole volume of the bitumen is at the desired mixing temperature. The bitumen is also being placed on a hot plate during mixing in order to maintain the temperature hence maintained the desired viscosity.

The carbon black is measured to be 4% of the bitumen weight, is poured little by little by using spatula into the mixer containing bitumen. After each pouring of carbon black, the mixer is turned on slowly to avoid the carbon black powder to escape from the mixture due to its lightweight. The mixing is done slowly until the whole amount of carbon black is completely mixed with the bitumen which took about 1 hour and 30 minutes.

Table 9 below is the amount of bitumen and carbon black used.

Table 9: Amount of Bitumen and Carbon Blacks used

Can (Carbon Black Type)	**Empty can weight (kg)**	**Bitumen + can weight (kg)**	**Bitumen weight (kg)**	**4% weight of bitumen (kg)**
N220	0.3563	2.3161	1.9598	0.07839
Raven 3500	0.3589	2.3203	1.9616	0.07846

The table 10 following is the table showing the actual percentage value achieved of carbon black in the mix.

Table 10: Actual Percentage of Carbon Blacks achieved

Can (Carbon Black Type)	**Theoretical mixture weight (kg)**	**Measured mixture weight (kg)**	**Weight Loss of carbon black (kg)**	**Actual percentage of carbon black**
N220	2.0382	2.0299	0.0083	3.56 %
Raven 3500	2.0399	2.017	0.0229	2.83 %

The sample from both cans then was poured into 3 small cans (comply with BS 2000-49:2007 requirement) each for penetration test. The sample then will be heated to use it for softening point test.

4.2 Results

Penetration Test results:

Table 11 shows the virgin bitumen's penetration values and Table 12 shows the penetration test results for 60/70 bitumen with carbon black additives of N220 and Raven 3500 respectively.

Table 11: Virgin Bitumen's Penetration Values

Bitumen	Penetration Values (pen.)				
	Trial 1	Trial 2	Trial 3	Trial 4	Average
60/70 bitumen	64.5	65.0	66.0	66.5	65.5

Table 12: Penetration Test Results for 60/70 Bitumen with Carbon Black Additives

Carbon black	Cup	Penetration Values (pen.)				
		Trial 1	Trial 2	Trial 3	Trial 4	Average
3.56% N220	A	49.0	48.0	46.0	48.0	47.8
	B	46.0	44.0	48.0	49.0	46.8
	C	44.0	46.0	45.0	46.0	45.3
2.83% Raven 3500	A	50.5	52.0	50.0	52.0	51.1
	B	54.0	50.0	53.0	50.0	51.8
	C	52.5	50.0	52.0	51.0	51.4

Softening Point Test results:

Table 13 shows the virgin bitumen's softening point values and Table 14 shows the softening point results for 60/70 bitumen with carbon black additives of N220 and Raven 3500 respectively.

Table 13: Virgin Bitumen's Softening Point Values

Bitumen	**Set**	**Temperature (C°)**	
		Right	Left
60/70 bitumen	1	46.5	46.5
	2	47.5	47.5
	3	46.5	46.5

Table 14: Softening Point Test Results for 60/70 Bitumen with Carbon Black Addtives

Carbon black	**Set**	**Temperature (°C)**	
		Right	Left
3.56% N220	A	54.4	54.4
	B	54.5	54.3
	C	54.4	54.4
2.83% Raven 3500	A	54.0	54.1
	B	54.0	53.9
	C	54.3	54.0

The PI is calculated as follow:

For virgin bitumen:

1. Penetration Value: 65.5 pen.
2. Softening Point: 46.8°**C**

$$PI = \frac{1952 - 500 \log(65.5) - 20(46.8)}{50 \log(65.5) - (46.8) - 120}$$

$$= -1.42$$

For bitumen with 3.56% N220:

3. Penetration Value: 46.6 pen.
4. Softening Point: 54.4˚**C**

$$PI = \frac{1952 - 500 \log (46.6) - 20 (54.4)}{50 \log (46.6) - (54.4) - 120}$$

$= -0.33$

For bitumen with 2.83% Raven 3500:

1. Penetration Value: 51.4 pen.
2. Softening Point: 54.1˚**C**

$$PI = \frac{1952 - 500 \log (51.4) - 20 (54.1)}{50 \log (51.4) - (54.1) - 120}$$

$= -0.16$

4.3 Discussion

Based on the values of the percentage measured of the carbon black after mixing, both samples fail to achieve 4% by weight of the bitumen. This is because, during mixing, due to its super lightweight properties, the carbon black easily escapes to the air when the mixer is running. With the same method of mixing, the Raven 3500 carbon black losses more if compared to N220 carbon black. This is because the Raven 3500 is lighter in weight if compared to N220.

Even though precautions had been taken, the air bubble still formed inside the mix which visible when it cools down. This might be caused by the moisture from the carbon black itself. Second possible cause is the bitumen temperature is not enough to achieve ideal viscosity because there is no precaution was done to determine the accurate bitumen temperature other than referring to the temperature display on the oven.

Based on the Table 12, bitumen with N220 carbon black additives have average of 45 - 47 penetration values for all the three cups of samples. In contrast, for bitumen with Raven 3500 as additive, all the cups have the penetration values of about 51.0 pen..

All the pen values of the highest and the lowest do not exceed maximum allowable differences as required according to BS2000-49:2007 standard. However, penetration values for bitumen with both additives are lower than the penetration values obtained from the virgin bitumen as tabulated in Table 11. Thus, by adding carbon black either N220 or Raven 3500, they do improve the penetration values of the virgin bitumen hence increase the bitumen's performance.

On the other hand, based on the Table 14, the softening point of bitumen with N220 carbon black additive is about 54.4 ˚C and 54.1 ˚C for bitumen with Raven 3500 carbon black additive.

All the values for each set do not exceed the maximum allowable differences between the set of rings as required by the BS2000-58:2007 standard. However, the softening points obtained are higher than the virgin bitumen softening point which is about 46.5 ˚C as tabulated in Table 13. Thus, by adding carbon black either N220 or Raven 3500, they do improve the softening point values of the virgin bitumen.

Based on the PI of the virgin bitumen calculated before, the PI value is - 1.42. After mixing the bitumen with both types of carbon black, the PI values are - 0.33 and - 0.16 respectively for N220 and Raven 3500. From the PI values obtained, bitumen with additives gives higher values if compared to bitumen without additives. However, bitumen with N220 carbon black additive has lower value of PI if compared to the bitumen with Raven 3500 carbon black additive. Higher PI values indicate that the bitumen is resistance towards low temperature cracking and permanent deformation. Thus, by adding both carbon black additives, the bitumen's property is upgraded in its resistance upon low temperature cracking and permanent deformation.

4.4 Recommendation

Most of the carbon black content was disturbed during the mixing process. Thus the percentage of the carbon black added into the virgin bitumen was lesser than the firstly determined. This problem was probably due to the poor handling of carbon black. Since the carbon black was so light weight, it tends to fly out of the mixer during the mixing due to the speed in the bitumen. Thus, the mixer is required to be closed or the mixing should be carried out using a mixer with lid. This is to ensure that the carbon black will not fly out of the mixer during mixing.

Besides that, air bubble is visible during the mixing is done. Air bubble presence in samples may disturb the accuracy and precision of the results. Thus, temperature plays an important role in ensuring the samples were not having any air bubbles. Bitumen's temperature must be kept at the ideal temperature for mixing so that no air bubbles appear during mixing. Carbon black also plays an important role to have no air bubbles in the samples. Thus, by preheating the carbon black also helps in air bubble removal since it removes its moisture before mixing. If the air bubbles presence after the mixing, it is advisable that the mixed samples should be heated in the oven again for about an hour to allow the air bubble to move out of the sample.

Lastly, the current results are based on only 1 percentage of carbon black. Thus, in the future, it is required that to have multiple values of percentages so that the penetration values for both bitumen with carbon black additive to be within the standards as the virgin bitumen.

Chapter 5

CONCLUSION

As the conclusion, the virgin bitumen is successfully added and mixed with carbon black with their respective percentages. The properties of the bitumen with carbon black additives are determined. Both penetration and softening point test have proved that by adding carbon black additives, the values are improved better than the values obtained from the virgin bitumen. Thus, by using carbon black additives, bitumen’s resistance upon rutting and cracking is improved.

Lastly, due to difficulty in handling carbon black handling, the mixing process is disturbed. Besides that, bitumen’s viscosity also contributed to the problem in handling mixing process. Thus, some precautions must be made in order to obtain result as accurate as possible.

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Appendices

Mixed bitumen in cans

Bitumen after removing air bubble by heating in oven

Bitumen cooled down ready for penetration test

Penetration test

Softening point test