The Physical and Engineering Properties of 80/100 Bitumen with Carbon Black Additive

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Approved by,

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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.

MUHAMMAD FAKHRUR RAZI BIN AHMAD FAIZUL

ABSTRACT

Nowadays, the road pavement faced more challenging environment i.e. increase in loadings and temperature. Due to that, the demand for better pavement to withstand all the harsh condition also is increasing. 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 80/100 bitumen. Further elaboration of project including the background, problem statement, objective and scope of study will be explained in the Introduction section. The bitumen's physical and engineering properties are investigated after mixing it with 4 types of carbon blacks with different concentration (measured by percentage by weight of the bitumen). The properties of bitumen and carbon blacks are described in Literature Review section. The laboratory tests done to complete this project are penetration test and softening point test and further describe in Methodology section. The result for penetration and softening point test, in summary, shows increment on the softening point values (still within specification range) with the same penetration value as penetration value of the virgin bitumen. The details of the results are described in Result and Discussion section. For the conclusion, the presence of carbon black in the bitumen does improve the properties of the bitumen i.e. the increment of softening point values which indicates that the bitumen can improvise its defense against the problem such as rutting. The increment value of Penetration Index (PI) also further confirms the improvement of bitumen after added with carbon black. Several recommendations to make this research better are also given in Conclusion and Recommendation section.

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Table of Contents

List of Figures

List of Tables

CHAPTER 1

INTRODUCTION

1.1 Background

Road, is one of the medium used by human since long ago to connect between one place to another, apart from river and sea. At present time, road usually constructed and categorized into two type namely flexible pavement and rigid pavement as shown in figure below.

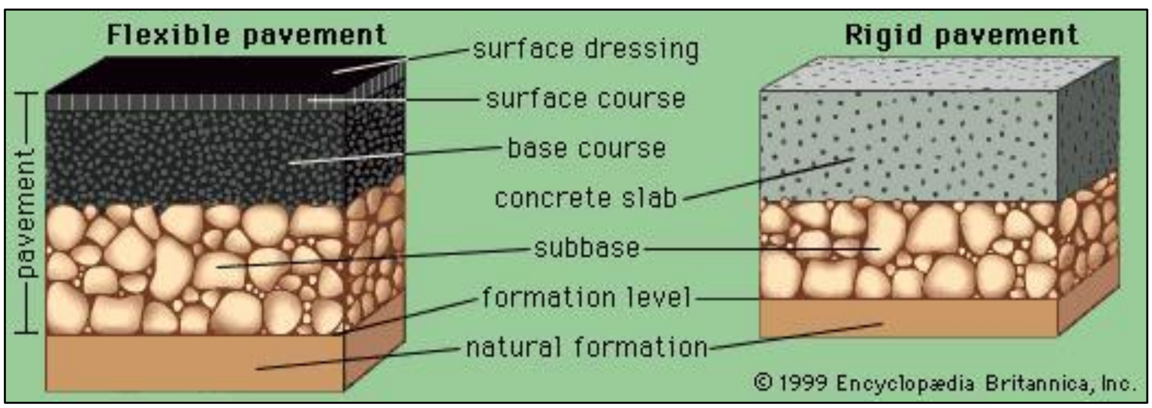


Figure 1: Flexible Pavement vs. Rigid Pavement

The bitumen, the material that will be studied in this report, only appear in flexible pavement. Flexible pavement made up of 5 layers namely surface course, binder course, base course, subbase and subgrade (natural formation). From these 5 layers, bitumen are present only at the surface (or wearing) course and binder course, but sometimes also appear in base course. The bitumen is the binder which binds the aggregates in the wearing and base course. The filler, commonly to be Ordinary Portland Cement (OPC), is used to enhance the adhesion of bitumen and aggregates.

1.2 Problem Statement

The human population is growing exponentially. Due to that, a lot of people nowadays travel much frequent than before as they need to moves quicker e.g. the person work in the big concentrated city, goes back and forth from their house located out from the city, which caused the road now experience challenging situation such as creep (permanent deformation) and fatigue as it needs to bear more load from day to day. 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).

Figure 2: Rutting

Figure 3: Fatigue Cracks

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.

1.3 Objectives

The main objective for this study is to specify Malaysia's flexible pavement performance by using different type of additives of the bitumen, which are the four types of carbon blacks namely N220, N774, Raven 2500, and Raven 3500.

1.4 Scope of Study

The study is focused on 80/100 bitumen as the base bitumen. The engineering properties of the 80/100 bitumen added with four types of carbon black are determined.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

From the different layers of flexible pavement namely surface course, base course, subbase course and subgrade course, the layer that contains bituminous mixture or asphaltic concrete is only at the surface course layer. Asphaltic concrete consists of course aggregates, fine aggregates, binder and filler which will be discussed in the following sections. Binder used in this research are 80/100 Grade Penetration Bitumen.

2.2 Penetration Grade Bitumen 80/100

Bitumen, also known as asphalt, is a material mainly consists of hydrocarbon and its derivative. It is substantially non-volatile and softens gradually when heated. It is also black in color, water resistant and possesses adhesive properties hence it is an ideal material to act as the binders in highway and road constructions. In today’s world, the need of improved bitumen properties is needed. According to Napiah, Kamaruddin, and Gasm (2010), with an increasing demand in highway’s construction, scientists and engineers are constantly trying to improve the performance of bitumen pavement. Bitumen can be obtained either from refinery process of fractional distillation of petroleum or from natural deposit such as in the Asphalt Lake in Trinidad and Tobago.

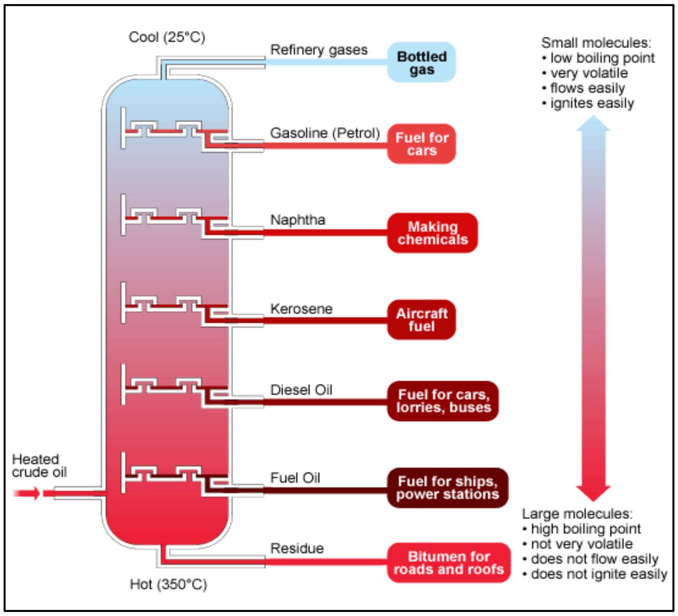


Figure 4: Petroleum Fractional Distillation Process

2.2.1 Bitumen Manufacturing Process from Petroleum Fractional Distillation

The petroleum or the crude oil is a material formed in the earth crust. It is the mixture of hydrocarbons of difference carbon chain lump together inside it hence difference in the molecular weight and boiling points. According to Whiteoak (1990), the crude oil originates from the remains of marine organisms and vegetable matter deposited with mud and fragments of rock on the ocean bed. The process of fractional distillation make use of the characteristic of the crude oil in which the crude oil is heated and the hydrocarbon chain which vaporizes after reaches their respective boiling points later will be cooled down in order to get different product such as naphtha and kerosene.

The higher boiling points fractions which are not vaporized are then drawn-off via a heat exchanger and enter a vacuum distillation column. This process produces a material called “short residue” that is used to manufacture several grades of bitumen namely Penetration Grade, Oxidized, Hard Grade, Cutback, Emulsion, and Polymer Modified bitumen. The hardness of the short residue is depending on the pressure and temperature conditions within the vacuum process.

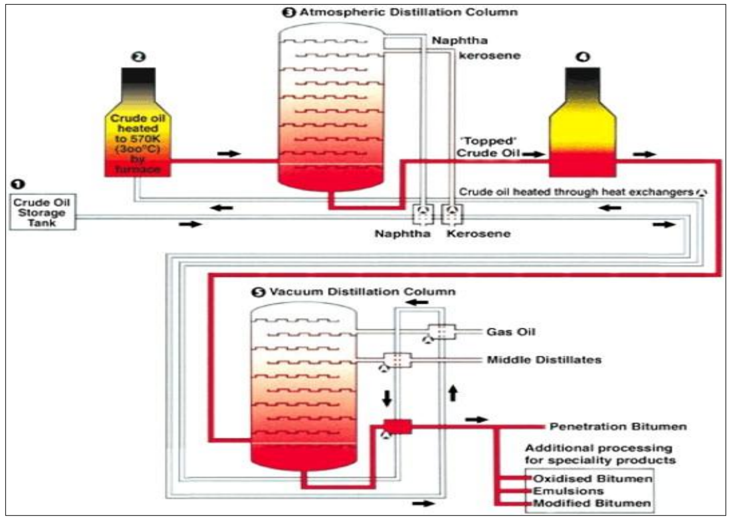


Figure 5: Distillation of Bitumen

2.2.2 Bitumen Properties

Bitumen is a hydrocarbon material which means it major molecule constituent is carbon and hydrogen. According to Lesueur (2008), its density lies typically between 1.01 and 1.04 g/cm3, depending on the crude source and paving grade. It is a viscous material and also possesses a thermoplastic behavior which means up to a certain temperature, it becomes moldable and returns to a solid state upon cooling. It is also insoluble in water. Chemically, they are inert material and oxidize slowly.

There are two empirical tests used to characterize bitumen which are penetration test and softening point test. For penetration grade bitumen, it is determined by the penetration test which will classify it into several grades namely 60/70, 80/100 or 100/120. Penetration grades greater than 40 are mostly used in road construction.

The softening point of the bitumen is also has to be determined. This is achieved by conducting a softening point test or also known as ring-and-ball test. Softening point is the temperature at which bitumen changes its states from semi solid to semi liquid.

Many important properties of bitumen such as the specific gravity, ductility, and viscosity can be determined by other empirical tests.

Ductility can be defined as the ability of the bitumen to elongate without breaking. The temperature susceptibility of bitumen indicates variation of viscosity with change in temperature. This property is called Penetration Index which is calculated either from 2 or more penetration results at different temperatures or from one penetration and softening point. Pfeiffer and Van (1936) developed the equation to define the way that consistency changes with temperature which is the penetration index. The equation below is developed for the penetration test temperature at 25^{o}C.

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

The penetration index (PI) indicates temperature susceptibility of bitumen. Typically, PI values are ranging from around -3 (high temperature susceptible bitumen) to around +7 for highly blown low temperature susceptible bitumen.

Below is table of several bitumen properties according to American Society for Testing and Materials (ASTM) Standards, which is also applied by British Standards (BS) in BS2000: Part 49.

PROPERTY / UNIT	SPECIFICATION	TEST METHOD
Penetration at 25°C	80-100	ASTM D5
Ductility at 25°C CMS	100 Min	ASTM D113
Softening point (°C)	45-52	ASTM D36
Loss on heating PCT WT	0.5 Max	ASTM D6
Drop in Penetration after heating (%)	20 Max	ASTM D5
Flash Point (°C)	250 Min	ASTM D92
Solubility in CS2 PCT WT	99.5 Max	ASTM D4
Density / S.G. at 25°C	1.00 / 1.05	ASTM D70
Organic matter insoluble in CS2 PCT WT	0.2 Max	ASTM D4
Spot Test	Negative	AASHTO

Table 1: Specification Requirement for Bitumen

2.3 Carbon Black

Carbon black is a material made up of pure elemental carbon in colloidal particles that are produced by incomplete combustion or thermal decomposition of gaseous or liquid hydrocarbon under controlled conditions. According to Fabry, Flamant and Fulcheri (2000), Carbon nanoparticles are named `Carbon black' which is actually a generic term for a family of products, which are usually referred according to the methods (or raw materials) used in their manufacture. Carbon black is mainly used in tires as excellent rubber reinforcement. It is also widely used for printing inks, resin coloring, paints and toners as it can be used as black pigment. Furthermore, carbon black is used in various other applications as an electric conductive agent, including antistatic films, fibers, and floppy disks.

Figure 6: Carbon Black

2.3.1 Carbon Black Manufacturing Process

Carbon black mainly produced by two methods which are Furnace Black Process and Thermal Black Process. Between these two methods, Furnace Black is the major method used worldwide.

Furnace Black uses heavy aromatic crude oil as its primary feedstock. A closed reactor used by production furnace to atomize the feedstock oil under controlled conditions (primarily temperature and pressure). The primary feedstock is introduced into a hot gas stream which is achieved by burning natural gas or oil which acts the secondary feedstock where it vaporizes and then pyrolyzes in the vapor phase to form microscopic carbon particles. According to International Carbon Black Association (2006), in most furnace reactors, the reaction rate is controlled by steam or water sprays. The carbon produced is conveyed through the reactor to be cooled, and collected in bag filters in a continuous process. The residual gas, or also known as the tail gas, from a furnace reactor contains a variety of gases such as carbon monoxide and hydrogen. In many cases, the furnace black plant uses a portion of this residual gas to produce heat, steam, or electric power.

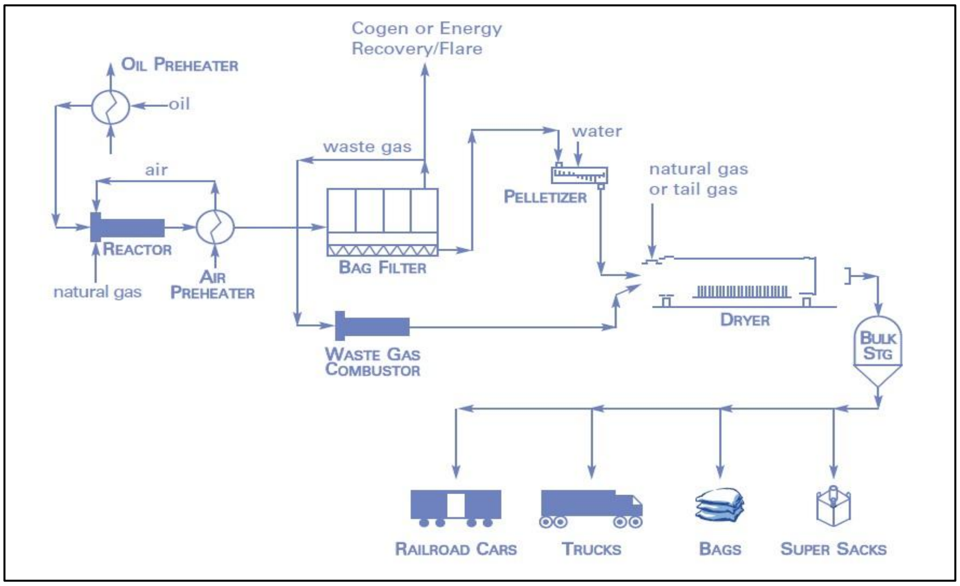


Figure 7: Furnace Black Production Process Flow

For the Thermal Black process, it uses natural gas which consisting primarily of methane or heavy aromatic oil as its feedstock material. This process uses a pair of furnaces that alternating approximately at five minutes interval between preheating and carbon black production. Natural gas is decomposed into carbon black and hydrogen by the heat from refractory material which comes from the injection of natural gas into hot refractory lined surface in the absence of air. The aerosol, which is suspended carbon black in the hydrogen gas, is further quenched with water sprays and filtered in the bag house. The carbon black may be further processed to remove impurities, pelletized, screened and then package for shipment while the hydrogen off-gas is burned in air to preheat the second furnace.

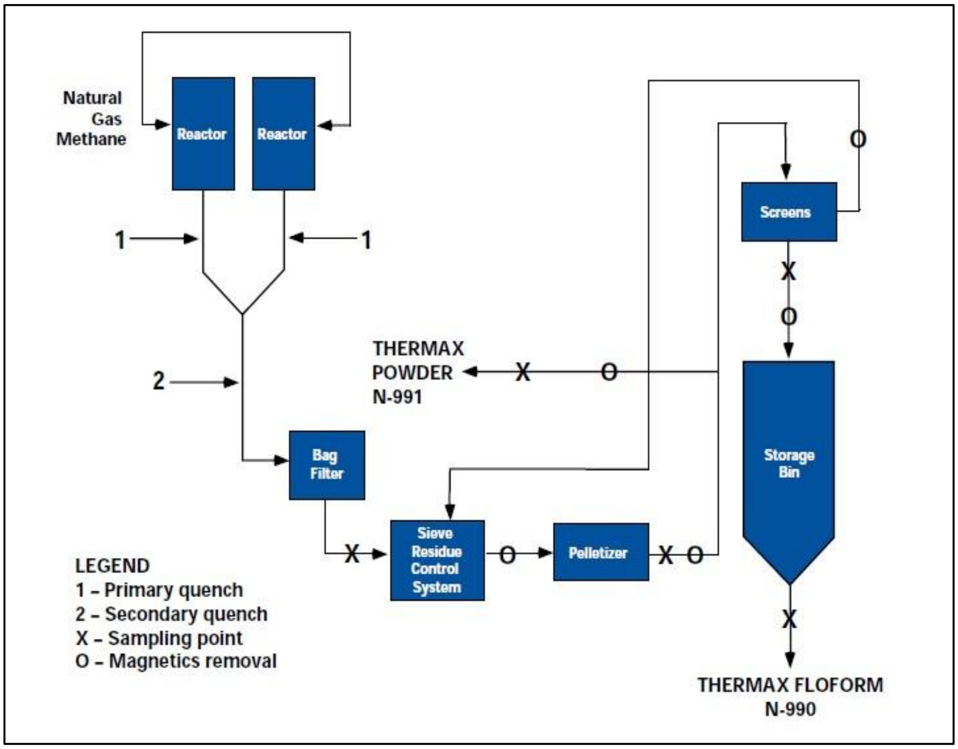


Figure 8: Thermal Black Production Process Flow

2.3.2 Carbon Black Properties

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 below shows the visual comparison of the particle sizes.

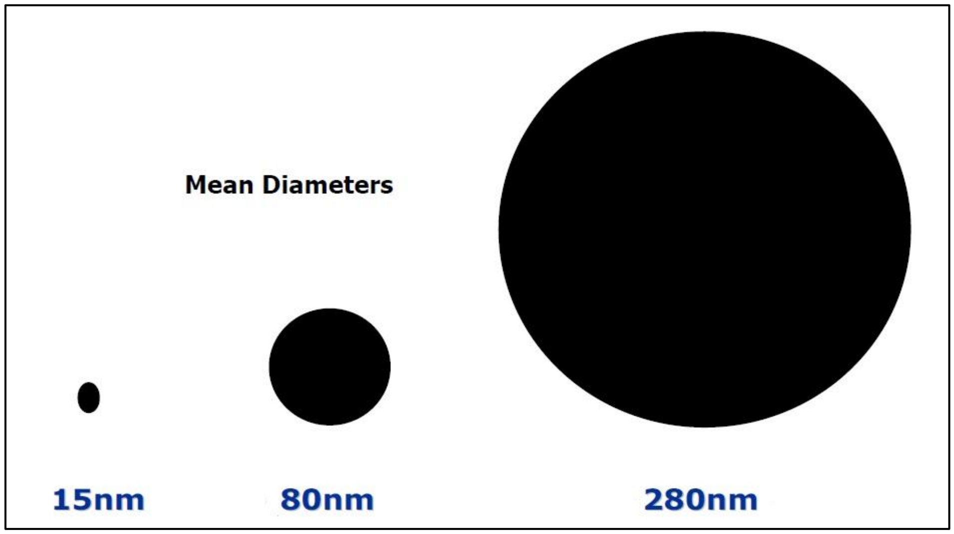


Figure 9: Carbon Particle Sizes Comparison

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 below shows how carbon black particle's molecular arrangement.

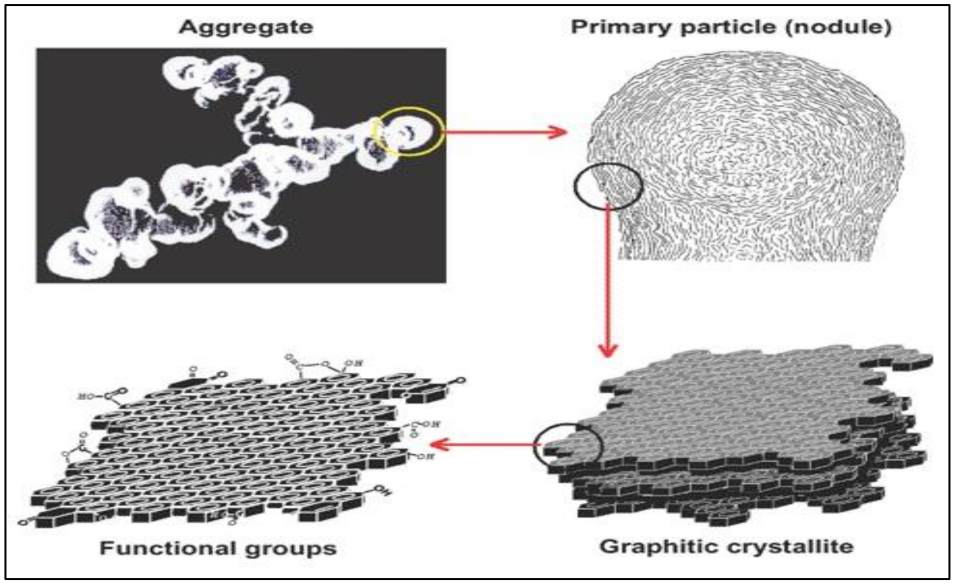


Figure 10: Structure of Carbon Black (from Wang, 2003)

Table below is the physical and chemical properties of carbon black obtained from Environment Canada (2007).

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 2: Physical and Chemical Properties 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

Table 3: Typical Ranges of Four Types of Carbon Black

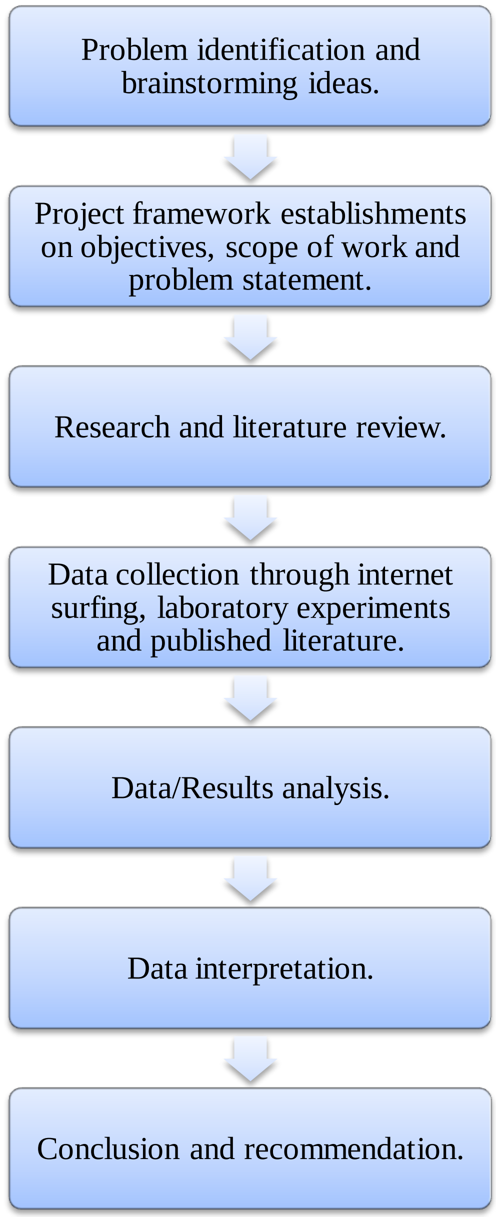
CHAPTER 3

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



3.3 Project Work

3.3.1 Key Milestone

Table below shows the targeted timeline of project deliverables.

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 14	Students must submit the hard bounded final report to the supervisor.

Table 4: Key Milestone

3.3.2 Gantt Chart

No.	Detail/ Week	1	2	3	4	5	6	7	Mid-Semester Break	8	9	10	11	12	13	14	15
1	Project Work Continues	■	■	■	■	■	■	■									
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)																■

Table 5: Gantt chart

3.3.3 Materials

The materials used in this study are listed as table below:

Binder	**Additive**
Bitumen 80/100	Carbon Black - N220 - Raven 2500 - N774 - Raven 3500

Table 6: Materials Used

3.3.4 Laboratory Tests

The tests conducted in this study are summarized as table below:

Test Conducted	Function	Figure
Standard Penetration Test	• To measure the grade of the bitumen which is based on its softness (the higher penetration number, the softer the bitumen). E.g. grade 80/100 is softer then grade 60/70.	
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 to occur.	

Table 7: Test Conducted and its Function

Penetration Test is used to determine the bitumen's consistency. This is achieves 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. The penetration ranges specification is determined by performing penetration test for every specimen.

The penetration is defined as the distance travelled by the needle into the bitumen measured in tenths of decimillimetre, dmm. The higher the value of penetration indicates the softer the bitumen is.

The following is the table of maximum allowable ranges for standard penetration ranges as in BS2000-49:2007 standard.

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

Table 8: The Maximum Difference for Standard Penetration Range from BS2000-49:2007

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 individual measurements of penetration are made. The differences of three penetrations should not differ by more than the amounts shown in the table.

Ring and ball (softening point test) is also a standard test to determine bitumen consistency by determining the temperature at which a change of phase from solid to liquid (equi-viscous state) occurs. A steel ball weighing approximately 3.5g 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^oC for about 15 minutes before the test undergone. The bath temperature is raised at 5˚C per minute. The bitumen softens and eventually deforms slowly with the ball through the ring. The temperature of water is recorded as soon as the bitumen and steel ball touches a base plate 25mm below the ring.

Softening point, as a transition temperature between a more solid and a more liquid like consistency, may be considered to mark the end of the service temperature range (Kamaruddin, 2010). Softening point also related to the rutting resistance of bituminous mix.

CHAPTER 4

RESULTS AND DISCUSSIONS

The standard ranges for penetration and softening point value of 80/100 bitumen based on Malaysian Standard MS124 1973 is tabulated as in the following table.

INSPECTION	TEST METHOD	LIMITS
Penetration, 0.1 mm	ASTM D5	80-100
Softening Point, ˚C	ASTM D36	45-52

Table 9: 80/100 Bitumen specifications based on MS124:1973

Before the mixing is done, the mixing temperature has to be determined first. This is achieved by using Bitumen Test Data Chart (BTDC). The principle is that the two dots indicating the penetration and softening point value will be connected and extrapolates to intersect at a point where the temperature will produce ideal viscosity of mixing of 0.2 Pa.s. The following shows the BTDC diagram.

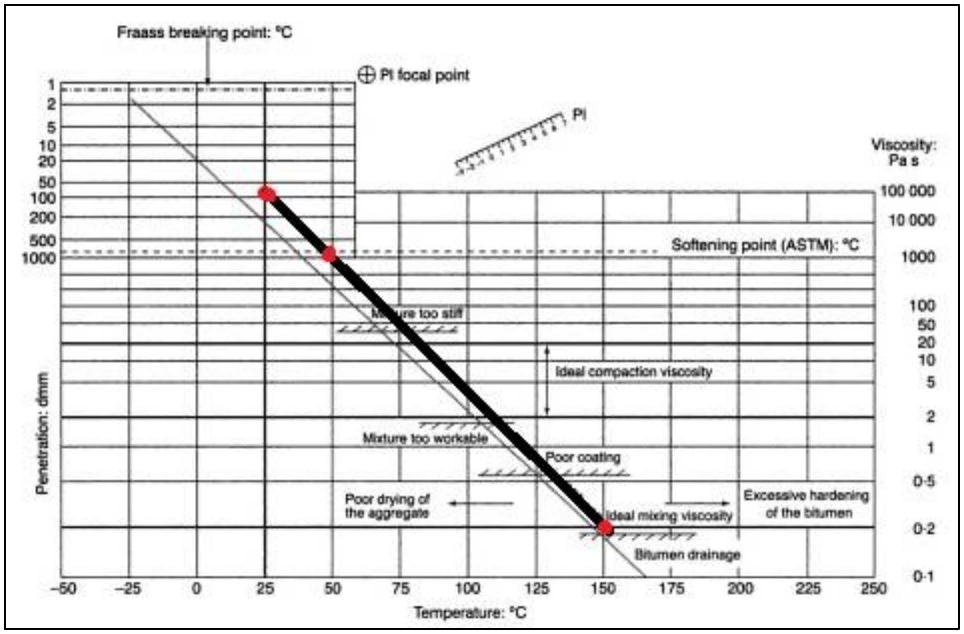


Figure 11: Bitumen Test Data Chart showing 'ideal' bitumen viscosities for optimal mixing and compaction of a dense bitumen macadam (The Shell Bitumen Handbook Fifth Edition, 2003)

From the BTDC plots above, the minimum temperature to achieve the ideal viscosity is about 150^{o}C.

Approximately 1.5 kg of virgin bitumen was prepared into 4 cans (size: 5L). Each can was mixed with different types of carbon blacks namely N220, Raven 2500, N774, and Raven 3500. Each type possesses different properties, especially its individual particle size. The Raven carbon black has smaller particle size than the N type. The mixing was done and the sequence is shown in table below. The weight measurement shown is combination of can, bitumen and carbon black weight. The initial weight measurement has 4% concentration by weight of carbon black.

		N220	Raven 2500	N774	Raven 3500
1	Initial weight (g)	1979.2	1998.1	1965.8	1974.5
2	- 2 penetration cups (g)	1875.9	1874.9	1849.9	1850.3
3	+ additional bitumen (g)	2388.3	2376.5	2356.3	2379.5
4	- 2 penetration cups (g)	2276.8	2255.7	2233.4	2259.3
5	+ additional bitumen (g)	2808.7	2784.5	2743.1	2798.9
6	- 2 penetration cups (g)	2702.9	2669.1	2626.9	2665.6
7	+ additional bitumen (g)	3220.4	3171.0	3129.2	3188.2
8	- 2 penetration cups (g)	3106.4	3042.8	3007.7	3077.3
9	+ additional bitumen (g)	3614.8	3705.9	3509.4	3578.9

Table 10: Sequence of Mixing of Bitumen with Carbon Blacks

The following is the table which shows calculated concentration expressed as percentage of each carbon black in the bitumen (percentage by weight).

Concentration (%)	N220	Raven 2500	N774	Raven 3500
Initial	4.00 %	4.00 %	4.00 %	4.00 %
1st dilution	3.14 %	3.15 %	3.14 %	3.11 %
2nd dilution	2.55 %	2.56 %	2.56 %	2.51 %
3rd dilution	2.14 %	2.15 %	2.15 %	2.10 %
4th dilution	1.84 %	1.77 %	1.84 %	1.81 %

Table 11: Calculated concentration percentage of Carbon Black in the Bitumen

The calculation details on obtaining the resultant carbon black's percentage will be shown in Appendix I in Appendices section.

The virgin bitumen used to mix with the carbon blacks is not the same as in the interim reports. This bitumen was newly ordered to be used for this project. Hence, the virgin bitumen also had been tested in penetration and softening point to check its repeatability. The results are as in the following table.

1) For Virgin Bitumen

Penetration Test values

Sample	Test 1	Test 2	Test 3	Test 4	Average
1	83	84	85	85	
2	82	85	81	87	
3	80	85	81	85	
4	79	85	81	89	
5	79	88	86	90	84

Table 12: Penetration Test result for Virgin Bitumen

Softening Point Test values

Sample	Right (^oC)	Left (^oC)	Average
1	43	43.5	
2	43.5	43	
3	43	43	
4	43.5	43	43

Table 13: Softening Point Test result for Virgin Bitumen

The value of Penetration Index (PI) of virgin is calculated as follows by using PI equation developed by Pfeiffer and Van (1936).

$$PI = \frac{1952 - 500 \text{ Log}(84) - (20*43)}{50 \text{ Log}(84) - 43 - 120} = -1.9$$

As the value shown above, in order to improve the bitumen against rutting, means the temperature susceptibility of the bitumen is targeted to be lower down for the usage of the bitumen sample in hot climate region. Therefore, the outcome of this project is to obtain PI value of higher than PI value for virgin bitumen.

After the mixing work was completed, the entire sample was tested for its penetration and softening point value. The results are shown in the tables below.

1) Mixing with N220

Penetration Test values

Sample	Test 1	Test 2	Test 3	Average
1A (4%)	83	81	76	
1B (4%)	79	77	78	79.0
2A (3.14%)	80	78	79	
2B (3.14%)	88	86	75	81.0
3A (2.55%)	83	82	83	
3B (2.55%)	81	83	86	83.0
4A (2.14%)	85	86	86	
4B (2.14%)	86	86	85	85.7
5A (1.84%)	84	84	84	
5B (1.84%)	91	82	90	85.8

Table 14: Penetration Test result for Bitumen mixed with N220

Softening Point Test and PI values

Sample	Right (^oC)	Left (^oC)	Average	PI
1A (4%)	44.5	44		
1B (4%)	44	44.5	44.3	null
2A (3.14%)	45.5	45		
2B (3.14%)	44.5	45	45.0	-1.40505

Table 15: Softening Point Test result and PI value for Bitumen mixed with N220

PI value for Bitumen added with N220 carbon black only can be measured for N220 concentration of 3.14% because only the softening point value at this concentration is available. And the PI value for concentration at 4% cannot be measured because its corresponding penetration test value fell out of acceptable range.

2) Mixing with Raven 2500

Penetration Test values

Sample	Test 1	Test 2	Test 3	Average
1A (4%)	88	86	85	
1B (4%)	82	87	81	84.8
2A (3.15%)	84	86	81	
2B (3.15%)	81	85	80	82.8
3A (2.56%)	85	83	78	
3B (2.56%)	85	83	77	81.8
4A (2.15%)	86	84	82	
4B (2.15%)	84	82	81	83.2
5A (1.77%)	81	79	80	
5B (1.77%)	81	81	81	80.5

Table 16: Penetration Test result for Bitumen mixed with Raven 2500

Softening Point Test and PI values

Sample	Right (^{o}C)	Left (^{o}C)	Average	PI
1A (4%)	45.2	45.4		
1B (4%)	45.2	45.6	45.4	-1.17114

Table 17: Softening Point Test result and PI value for Bitumen mixed with Raven 2500

3) Mixing with N774

Penetration Test values

Sample	Test 1	Test 2	Test 3	Average
1A (4%)	75	74	83	
1B (4%)	75	72	79	76.3
2A (3.14%)	73	71	75	
2B (3.14%)	74	70	79	73.7
3A (2.56%)	78	73	78	
3B (2.56%)	77	72	80	76.3
4A (2.15%)	70	69	75	
4B (2.15%)	74	71	72	71.8
5A (1.84%)	72	71	72	
5B (1.84%)	73	72	79	73.2

Table 18: Penetration Test result for Bitumen mixed with N774

Softening Point Test values

Sample	Right (^{o}C)	Left (^{o}C)	Average
1A (4%)	44.8	44.5	
1B (4%)	45.6	45.8	45.2
2A (3.14%)	46.2	46.8	
2B (3.14%)	46.6	47	46.7

Table 19: Softening Point Test result for Bitumen mixed with N774

4) Mixing with Raven 3500

Penetration Test values

Sample	Test 1	Test 2	Test 3	Average
1A (4%)	88	85	87	
1B (4%)	86	82	84	85.3
2A (3.11%)	83	86	85	
2B (3.11%)	85	85	85	84.8
3A (2.51%)	85	86	84	
3B (2.51%)	86	83	86	85.0
4A (2.10%)	81	84	84	
4B (2.10%)	81	77	85	82.0
5A (1.81%)	85	79	82	
5B (1.81%)	80	80	82	81.3

Table 20: Penetration Test result for Bitumen mixed with Raven 3500

Softening Point Test and PI values

Sample	Right (^oC)	Left (^oC)	Average	PI
1A (4%)	43	43.5		
1B (4%)	44	44.5	43.8	-1.65849
2A (3.11%)	44.8	45.6		
2B (3.11%)	44.2	44.6	44.8	-1.34144

Table 21: Softening Point Test result and PI value for Bitumen mixed with Raven 3500

The average values of penetration for each type of carbon black are plotted in the following graph.

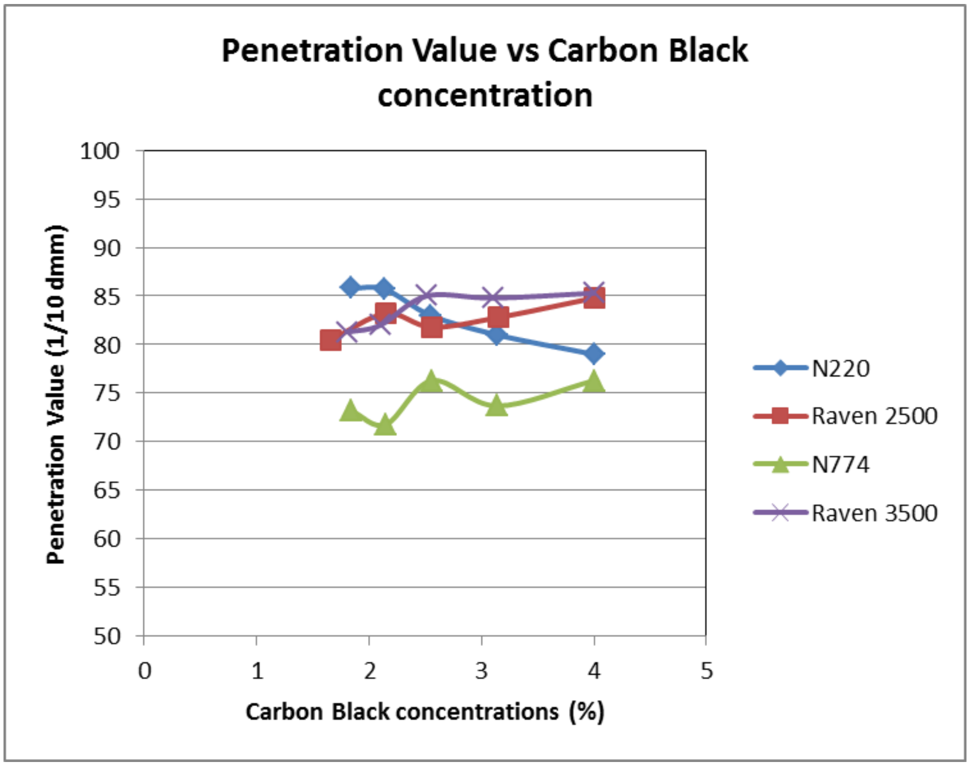


Figure 12: Plot of Penetration Value vs. Carbon Black concentrations

4.1 Discussion

After addition of carbon black into the bitumen, the expected penetration value will be lower compared to virgin bitumen penetration value which shows the bitumen become hardened. This shows that by adding the carbon black, the bitumen is hardened and the stiffness of the bitumen also increase hence increasing the bitumen performance. Also expected, the higher the concentration of carbon black, the lower the penetration value which means, the dilution process is expected to gives increasing value of penetration.

The virgin bitumen is the new bitumen ordered specifically for this project. Different from the existing virgin bitumen sample in the lab, the new bitumen can be said as still fresh i.e. not damaged or oxidized. Therefore the result of the penetration and softening point test are expected to be according to the standard values. However, based on the result obtained for penetration test for the new virgin bitumen, the maximum range value for sample 2, 3, 4, and 5 is more than 4 dmm which surpassing the limit as specified in BS 2000-49:2007. Furthermore, the result also failed to comply with the repeatability required for precision which in 20 readings, there are more than once the penetration value are more than 4% of the average value.

For softening point test result for virgin bitumen, each sample passed the requirement specified in BS 2000-58:2007 which the softening point difference between two rings not exceeding 1^oC. For the repeatability, all 8 rings tested complied with the standard of not exceeding 1^oC which in the standard says that only once are allowed to exceed 1^oC out of 20 readings.

From the two code checks for penetration and softening point test, only the result for penetration test failed to comply with the requirement. But not for softening point test which is as expected as the sample is new, undamaged and qualified to be used in this project. Therefore, it can be deduced that the operator might have conducted the penetration test wrongly e.g. the temperature of the water bath is not at 25^oC, the needle used is not perfectly straight and the penetrometer movement is not smooth which can contribute to inaccurate loading applied to the bitumen which is 100 gram for 5 seconds.

For the penetration test results for the mixed sample, only the bitumen mixed with N220 carbon black shows the predicted trend which is the more concentrate of carbon black, the lower the number of penetration hence harder mixture is produced. But for the other types of carbon black, the trend is not constant. And for N774 carbon black, this can be said that this type of carbon black is not suitable to be used with this bitumen as all the results are out of the limit of penetration allowed for 80/100 bitumen. However, due to the possible fault of conducting the experiment discussed in relation with penetration result of virgin bitumen, it cannot be certain that these results are reliable until some recommendations for improvement are taken for usage in the future experiment.

The softening point results show the results which is expected earlier before conducting the softening point test. The addition of carbon blacks produce higher value of softening point compared to softening point for virgin bitumen. The increased value of softening points means increase the threshold temperature for the bitumen to become equi-viscous state hence improve the rutting resistance of the resulting pavement.

The value of Penetration Index (PI) also shows the increment compared to PI value for virgin bitumen. This indicates the bitumen susceptibility to temperature is lesser which means it become less sensitive i.e. change its properties hence improve the problem such as rutting and fatigue problem in hot climate region.

4.2 Recommendation

As for recommendation, based on the results for penetration test, the equipment needs to be maintained or replace with a new one to ensure the accurate result can be obtained. The softening point test equipment should be added because;

1) Can make the experiment faster, especially when dealing with a lot of sample during experimenting with different percentage of carbon black powder content,
2) Can produce better accuracy.

CHAPTER 5

CONCLUSION

The objective stated is achieved. The addition of carbon black in the bitumen proved to be a good idea since the results show the bitumen properties of bitumen is improved.

The new virgin bitumen ordered for this project is approved to be use i.e. the result of penetration and softening point test is eligible enough to be use. However, some improvement needs to be made fast i.e. the improvement of the penetration test equipment (the penetrometer and the needle) to make the result for penetration test of the mixed sample to be more reliable. The softening point test equipment is proved to be eligible for usage, but to avoid shortage of time available to complete the tests, in the future, the equipment needs to be increase in number.

CHAPTER 6

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CHAPTER 7

APPENDICES

7.1 Appendix I

<u>Concentration of Carbon black after dilution calculation (shown is the first dilution)</u>

Sample Weight = A

A = Weight of Can + Bitumen + Carbon Black

Weight of carbon black = B

B = A * 0.04

Weight of Sample after some are poured into penetration cups = C

Weight of Sample before some are poured into penetration cups = D

Ratio of loss carbon black weight = E

E = C/D

Remaining carbon black weight = F

F= B * (1- E)

Weight of Sample after Bitumen Added (for dilution) = G

Diluted carbon black percentage = H

H = F/G

7.2 Appendix II

Laboratory test pictures

Figure 13: Cans used to Mix the Bitumen with Carbon Blacks

Figure 14: Penetration Test of the sample

Figure 15: Softening point test of the sample