CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

Nowadays, country all over the world have faced big difficulties on maintaining their existing road networks due to high traffic volume, higher axle loads and increased of tire pressure. Most of the main road in Malaysia got system paved with dense graded failed essentially through fatigue cracking. Public Works Department (PWD) and other research institutions had carried out a study related to the most common modes of pavement distress. They stated that cracking and rutting happened to the pavement due to the traffic loading and climate factors; temperature and moisture. According to Abdullahi A,(2007) stated that bitumen under the hot tropical sun, oxidative ageing of asphalt layers leads to the phenomenon of surface down crocodile cracking.

According to PDRM (2004), the Malaysian vehicle population in 1987 and 2004 was 3.6 and 13.9 million respectively. Therefore, over 18years the number of registered vehicles becomes more than doubled. **Figure 1.1** has shown an increasing vehicle population based on Malaysia gears toward an industry. Not just that, the increasing of vehicles proportionally has risen up the allocated fund for road construction and needed more upgrading within five year development plan as shown in **figure 1.2**.

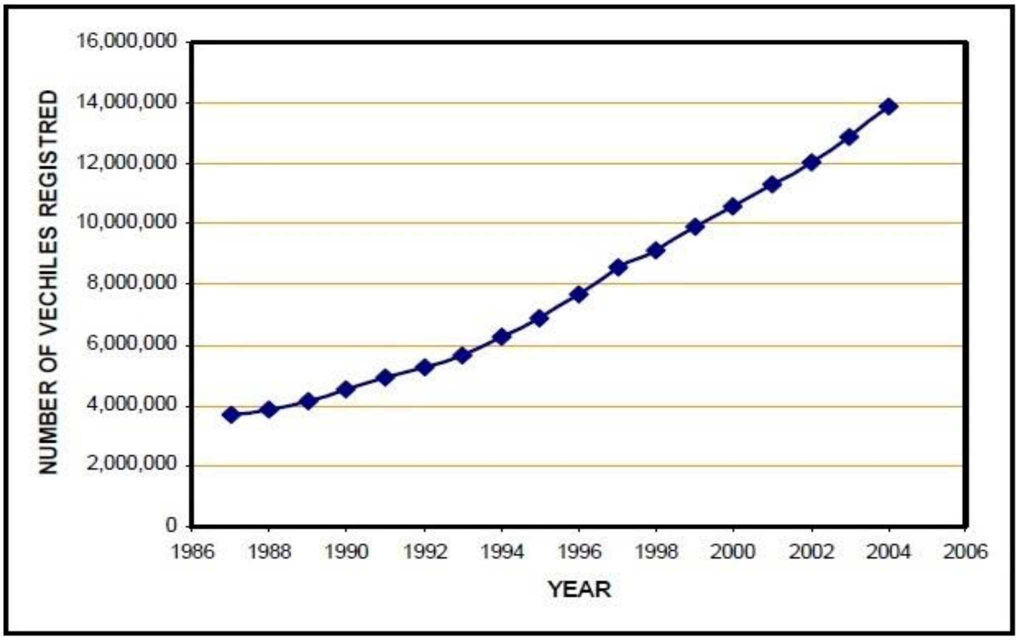


Figure 1.1: Trend in Motor Vehicle Registration
(Source: PDRM, 2004)

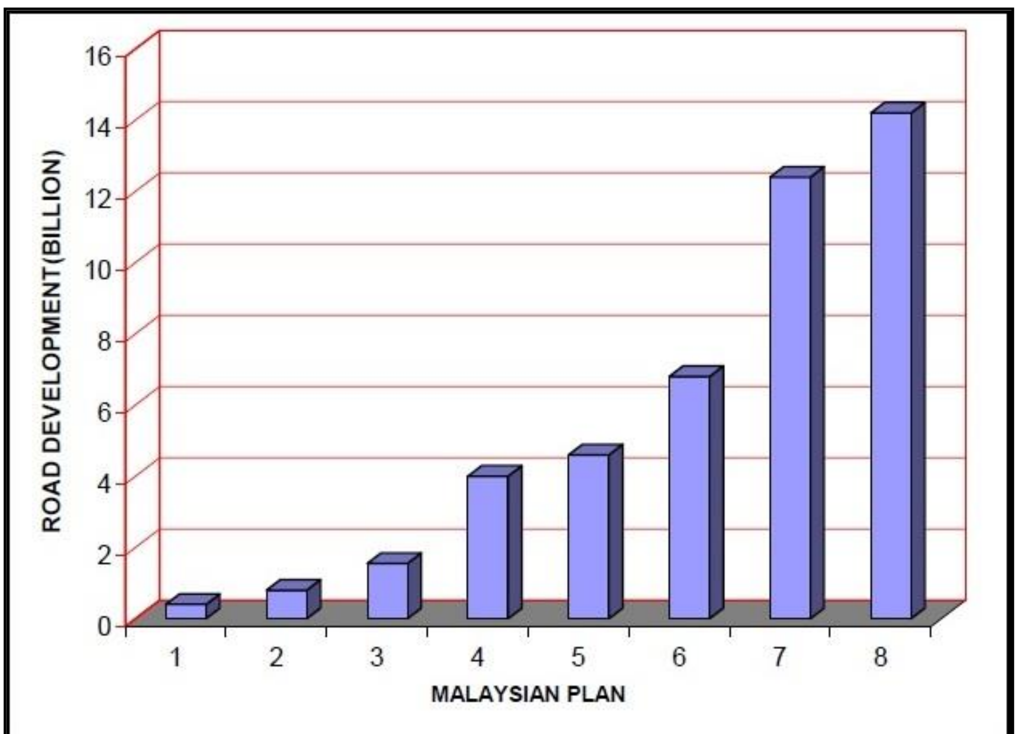


Figure 1.2: Road Development Allocation According to the Malaysian Plan
(Source: Razali, 2002)

Environmental changes between hot and cold temperature over a year had influenced the durability of asphaltic bitumen. Bitumen can be soften when high temperature and it can reduce the stiffness of asphaltic concrete and cause the mix more susceptible to rutting. In contrast, the stiffness of the bitumen can be increase when the temperature is low and it can reduce the elasticity of the asphaltic bitumen, hence it may cause fatigue failure. Thus, cracking on the surface of pavement may develop badly affects the performance of the asphaltic. Hence, high temperature stiffness and low temperature flexibility become significant properties in bituminous mixture respectively to avoid rutting and cracking (Roberts et al., 1990).

Last seven decades, few studies have been carried out to get more understanding on factor that will contribute to long term aging and short term aging. Hardening is principally related to loss of volatile component in bitumen while mixing and construction phase, and progressive oxidation of the in-placed material in field. According to Roberts et al. (1990), the former is described as short term aging whilst the latter is referred to as long term aging. Both short and long term aging can cause increasing in viscosity of the bitumen and a consequent stiffening of the mixtures. The mixture may become brittle and susceptible to disintegration and cracking. It become a necessary to study the bitumen aging process, facts that lead to aging, properties of bitumen that are susceptible to bitumen aging as well as finding the correct combination antioxidant properties of lignin into virgin bitumen to create a new type of aging resistive modified bitumen.

Hence, wide-ranging research on modified bitumen properties can be completely helpful in term of securing a place in the promising global bitumen market. Previous and continuing studies state that current bitumen used for road and pavement are vulnerable to **aging** problem. **Aging** (Oxidation) is caused by **external** to surroundings (as shown in Figure 1.3 and 1.4) like the existence of atmospheric oxygen, Ultra-violet radiation from the sun, temperature changes, traffic loadings, and the formation of free radicals (Kanabar,A.,2010)(Lu, X, 2008). Thus, the bitumen finally gets brittle and prone to cracking (**Figure 1.4**). However, the current conventional pavement construction nowadays still cannot cope with other problems of pavement failure such as rutting (permanent deformation as shown in **Figure 1.3**), moisture damage or stripping failure (lack of adhesion and cohesion between bitumen binder and aggregates), and thermal cracking (when thermal stresses exceed the materials strength)(Kanabar,A., 2010). In short, the conventional bitumen will eventually face aging problems that shorten its service life.

Figure 1.3: *Rutting on the surface road*

Figure 1.4: *Block cracking*

In this project, investigation on the physical and rheological properties of two types of grade penetration which are bitumen grade penetration 60/70 and 80/100 will be carried out. For this project, the performance of both grade penetrations will be tested depending on the condition of the equipment in the lab, time consuming and the laboratory test will be following the scheduled FYP timeframe. The only focus of the project outcome is to find the result of rheological properties and physical properties of both grade penetrations. At the end of this project, the performance both bitumen can be assessed. This objective can be achieved by comparing the result of physical properties and rheological properties of both samples. The physical properties of bitumen can be measured via Physical test which are Penetration test and Softening Point test. For

Softening point test, it will be conducted as per standard in ASTM D5. However, for Penetration test, there will be three different temperature of bitumen that will be test; 25°C, 35°C and 45°C. The laboratory aging test will be conducted by using Rolling thin film oven (RTFO) test that simulates short term aging and Pressure Air Vessel (PAV) that simulates long term aging. Other than that, this project also being conducted to identify which grade penetration bitumen is better and applicable in the construction of highway between grades 60/70 and 80/100.

1.1 PROBLEM STATEMENT

Throughout the years, demands made upon roads increase year by year. Ever increasing numbers of commercial vehicles with super single tires and increased axle loads take their toll and it is clear that this trend will continue in the future. The critical problem that needs to face is, which grade penetration bitumen is the best to be used in the construction of highway. To assist the Highway Engineer to meet this growing challenge, they need to find out the best bitumen penetration grade that should be used by the Highway Engineer. Thus, the comparison of bitumen rheological properties between 60/70 and 80/100 grade penetration bitumen need to be done. Regarding this comparison, the best grade of penetration bitumen will be notified.

1.2 OBJECTIVES

The objectives of this research are:

- To **determine of physical properties** of virgin bitumen grade 60/70 and 80/100 by performing physical test; Penetration and Softening Point.
- To understand the **aging mechanism** between bitumen grade 60/70 and 80/100 by performing Rolling Thin Film Oven test and Pressure Aging Vessel test.
- To c**ompare** the penetration and softening point before and after aging between 60/70 and 80/100 grade.

1.3 SCOPES OF STUDY

The scopes of study cover three major aspect; literature review, laboratory tests, and advantages of using bitumen 60/70 and 80/100 grade penetration. There are age old traditional/conventional tests as well as new generation tests to help in framing the specifications for bituminous binders. This study will be focused on the comparison of bitumen rheological properties between 60/70 and 80/100 grade penetration bitumen..

Generally, few experiments will be carried out in order achieving the objectives stated. The experiments that will be carried out is the physical test which include the penetration test, ring and ball test (softening point) on bitumen. During this experiment, the sample used are 60/70 and 80/100 of grade penetration bitumen. The purpose of this experiment is to study the physical properties of both bitumen grades and to understand the mechanisms of aging.

Above all, the relationship between the results of each physical test is the most critical aspect for this study in order to identify the productivity and quality of grade penetration bitumen. Thus, method and materials used for this system must be select intelligently in order to ensure the result of the experiment is accurate without any errors.

1.4 THE RELEVANCY OF THE PROJECT

This study is relevant in relation to the prospect of beneficial uses. While bitumen market in global is very promising nowadays; the require for innovating a more long-lasting, flexible and stronger bitumen that are more resistive towards aging problem such as fatigue and rutting failure; are crucial to cut the maintenance cost and short the operation. This project is also relevant towards improving the previous researches regarding modified bitumen on which lack of promising laboratory results, impracticality of usage on bigger scale as well as cost factors.

1.5 FEASIBILITY OF THE PROJECT WITHIN THE SCOPE

All of the required laboratory apparatus/equipments and machines are readily available in UTP Highway Laboratory. Plus, all experiments conducted are not so time-consuming (guaranteed to be within Final Year Project semester (FYP1 and FYP2).

CHAPTER 2

LITERATURE REVIEW

2.1 BITUMEN STRUCTURE

Bitumen, also known as asphalt, is a sticky, black and highly viscous liquid or semi solid present in most crude petroleum and in some natural deposits. Bitumen is primarily used in road construction, where it is used as the glue or binder mixed with aggregate particles to create asphalt concrete. It is also commonly used for bituminous waterproofing products, including production of roofing felt and for sealing flat roofs.

Bitumen properties are mostly related to numerous road pavement problems. Major distresses that lead to permanent failures are rutting and fatigue cracking in pavement construction. Bitumen is a visco-elastic material which its rheological properties are very sensitive to the temperature and rate of loading. The bitumen binder properties are always affecting the performance of road pavement properties. It is because the rheological properties and durability of bitumen that not sufficient to resist pavement distresses. In Malaysia the conventional bitumen that most commonly used is 80/100 penetration grade, due to the high traffic load and hot climate. Malaysia is the only ASEAN country that uses more bitumen penetration grade 80/100 compared to 60/70.

In warmer region, lower penetration grades are chosen to avoid softening while higher penetration grades are used in colder regions to avoid the incident of excessive brittleness. High penetration grade is used in spray application works. Factors that influenced the performance and characteristic of bitumen binder are known as aging. There are several factors that might cause bitumen hardening like oxidation, volatilization, polymerization, and thixotropy.

From the different layers of flexible pavement namely surface course, base course, sub base course and sub grade 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 60/70 and 80/100 Grade Penetration Bitumen. According to The Shell Bitumen Handbook (2003), the design of internal structure of bitumen is mostly determined by the chemical structure of the molecular species present. Bitumen becomes predominantly hydrocarbons with small amount of structurally analogous heterocyclic species and functional groups containing sulphur, nitrogen and oxygen atoms (Traxler et al, 1936).

2.2 RHEOLOGY OF BITUMEN

Science that deals with the liquid flow and deformation of matter is called rheology. The rheological characteristics of bitumen at certain temperature are found by the structure (chemical composition) and the physical arrangement of the molecules in the material. Change to the formation, structure or both will result in a change to the rheology. Thus, to understand changes in bitumen rheology, it is necessary to understand how the structure and constitution of bitumen interact to influence rheology. Bitumen also contains trace quantities of metals such as vanadium, nickel, iron, magnesium and calcium, which occur in the form of inorganic salts and oxides or in porphyrine structures. Elementary analysis of bitumen manufactured from a variety of crude oils shows that most bitumen contains:

- Carbon 82-88%
- Hydrogen 8-11%
- Sulphur 0-6%
- Oxygen 0-1.5%
- Nitrogen 0-1%

The precise composition varies according to the source of the crude oil from which the bitumen originates, modification induced by semi-blowing and blowing during manufacture and ageing in service

2.3 THE RELATIONSHIP BETWEEN CONSTITUTION AND RHEOLOGY

Systematic blending of saturates, aromatics, resins and asphaltene fractions separated from bitumen has demonstrated the effect that constitution has on rheology (Griffin R l, 1959). By holding the asphaltene content constant and varying the concentration of the other three fractions, it has been demonstrated that:

- Increasing the aromatics content at a constant saturates to resins ratio has little effect on rheology other than a marginal reduction in shear susceptibility;
- Maintaining a constant ratio of resins to aromatics and increasing the saturates contents softens the bitumen; and
- The addition of resins hardens the bitumen, reduces the penetration index and shear susceptibility but increases the viscosity.

Rheological properties of bitumen depend strongly on the asphaltene content. At continuous temperature, the viscosity of a bitumen increases as the concentration of the asphaltenes blended into the parent maltenes is increased. Though, the increase in viscosity is significantly greater than would be expected if the asphaltenes were spherical, non-solvated entities.

2.4 BITUMEN PROPERTIES

Lesueur (2008) stated that the density of bitumen lies typically between 1.01 and 1.04 g/cm3, depends on the paving grade and crude source. It is a viscous material and also possesses a thermoplastic manner 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 static 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. Other than that, Ductility test can be defined as the ability of the bitumen to extend 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. Bahia et al, (1991) has 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°C.

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

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.

It is become essential to test the different characteristic grades since the bitumen are manufactured wide diversity. It is feasible to approximate vital engineering properties from the results although they are arbitrary empirical tests, including high temperature viscosity and low temperature stiffness. The use of the penetration test for characterizing the consistency of bitumen dates from the late nineteenth century.

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 1.0: *Specification Requirement for Bitumen.*

2.5 PENETRATION GRADING

In the early 1900s, the penetration grading system was developed to characterize the consistency of semi-solid asphalts. Penetration grade bitumen is specified by the softening point tests and penetration test. The penetration grade bitumen produced is used in road construction. The tendency over the last decade was to adopt harder bitumen that produces asphalts which have superior properties to those that are manufactured using softer grades.

Table 4.1 Specifications for paving grade bitumens with penetrations from 20 to 330 dmm[53]

	Unit	Test method	Grade designation								
			20/30	30/45	35/50	40/60	50/70	70/100	100/150	160/220	250/330
Penetration at 25°C	×0·1 mm	EN 1426	20–30	30–45	35–50	40–60	50–70	70–100	100–150	160–220	250–330
Softening point	°C	EN 1427	55–63	52–60	50–58	48–56	46–54	43–51	39–47	35–43	30–38
Resistance to hardening, at 163°C		EN 12607-1 or EN 12607-3									
– change of mass, maximum, ±	%		0·5	0·5	0·5	0·5	0·5	0·8	0·8	1·0	1·0
– retained penetration, minimum	%		55	53	53	50	50	46	43	37	35
– softening point after hardening, minimum	°C	EN 1427	57	54	52	49	48	45	41	37	32
Flash point, minimum	°C	EN 22592	240	240	240	230	230	230	230	220	220
Solubility, minimum	% (m/m)	EN 12592	99·0	99·0	99·0	99·0	99·0	99·0	99·0	99·0	99·0

Figure 2.1: *Specification for paving grade bitumen with penetration from 20-330dmm*

The grades of the asphalt cement depending on the penetration in 1/10 mm are:

- AC 20 – 30 (hard & not effect with temperature) used for inclined planes due to its high viscosity.
- AC 40 – 50 used for filling isolation cracks & joints
- AC 60 – 70 hot weather,
- AC 80 – 100 & 120 – 150 cold weather, used for highway pavement
- AC 200 – 300 for emulsions because his flexibility

Penetration grading basic assumption is that the less viscous the asphalt, the deeper the needle will penetrate. This penetration depth is empirically (albeit only roughly) correlated with asphalt binder performance. Therefore, asphalt binders with high penetration numbers (called “soft”) are used for cold climates while asphalt binders with low penetration numbers (called “hard”) are used for warm climates. Penetration grading key advantages and disadvantages are listed in table 1.0.

Advantages	Disadvantages
The test is done at 25° C (77° F), which is reasonably close to a typical pavement average temperature.	The test is empirical and does not measure any fundamental engineering parameter such as viscosity.
May also provide a better correlation with low-temperature asphalt binder properties than the viscosity test, which is performed at 60° C (140° F).	Shear rate is variable and high during the test. Since asphalt binders typically behave as a non-Newtonian fluid at 25° C (77° F), this will affect test results.
Temperature susceptibility (the change in asphalt binder rheology with temperature) can be determined by conducting the test at temperatures other than 25° C (77° F).	Temperature susceptibility (the change in asphalt binder rheology with temperature) cannot be determined by a single test at 25° C (77° F).
The test is quick and inexpensive. Therefore, it can easily be used in the field.	The test does not provide information with which to establish mixing and compaction temperatures.

Table 2.0**:** *Advantages and Disadvantages of the Penetration Grading from Roberts et al., 1996)*

Penetration Grade	Comments
40 – 50	Hardest grade.
60 – 70	Typical grades used in the U.S.
85 – 100	
120 – 150	
200 – 300	Softest grade. Used for cold climates such as northern Canada (Roberts et al., 1996[1])

Table 3.0: *AASHTO M 20 and ASTM D 946 Penetration Grades*

CHAPTER 3

METHODOLOGY

3.1 METHODOLOGY

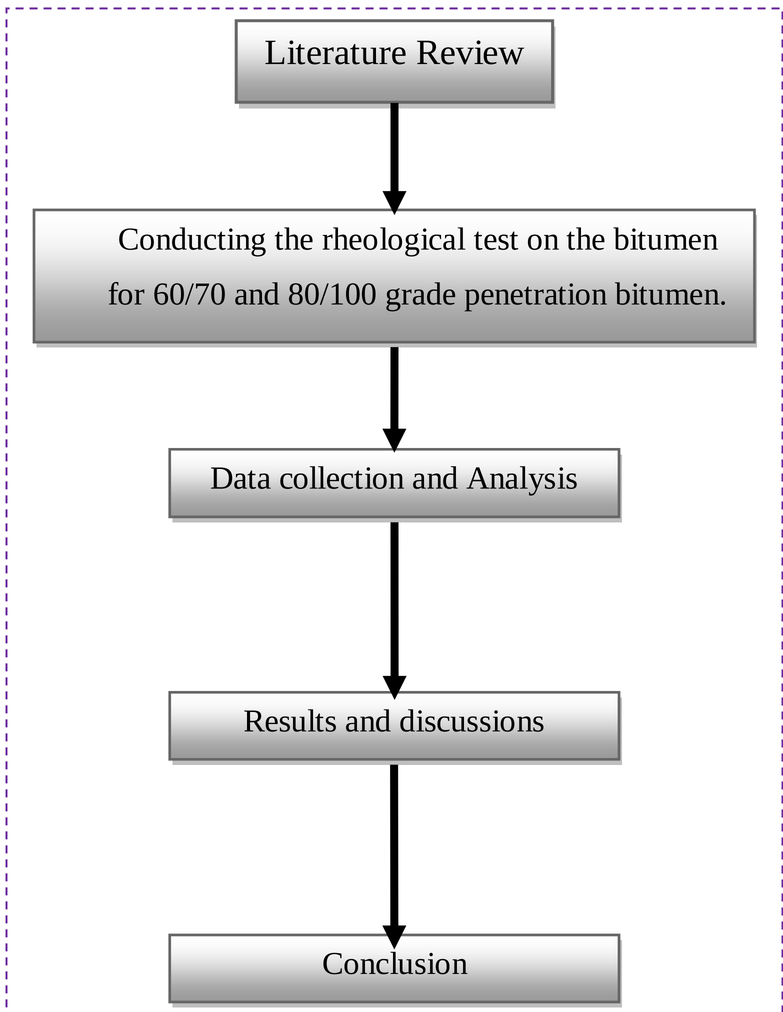


Figure 3.1: *Flow chart of the project*

3.2 PROJECT ACTIVITIES

3.2.1 BITUMEN PREPARATION

The bitumen has been completely prepared for the project according to the experiment with an appropriate amount. Shown below the production steps as well as the step had been taken during the bitumen process.

Penetration test:

1. The bitumen must be taken out from the storage by using hot scoop and it must be heated with care (use proper equipment full with safety). Stirring as soon as possible to prevent local over-heating, until it has become sufficiently fluid to pour.

2. Then, pour the sample into sample container to a depth and leave at least 10mm greater than the depth. The container must be covered loosely as protection against dust and it must be cooled down in the atmosphere at temperature between 15°C and 30°C for 1 to 1.5hours before proceed with the experiment.

Figure 3.2a & 3.2b: *the method how to taken out bitumen from it storage*

Softening point (Ring and Ball test):

1. The bitumen must be taken out from the storage by using hot scoop and it must be heated with temperature 75°C and 100°C above the expected softening point.

2. The sample must be stirred to avoid air bubbles and to make sure it completely melt into fluid.

3. Apply grease oil on a metal plate and pour the sample into the ring with sufficient molten sample so it can give an excess above the top of each ring when cooled. Let the sample in the ring cooled for 1 hour, then level the sample in the rings by cutting away the excess with warmed knife.

3.2.2 Physical Test (Before Aging)

The main objective of conducting Physical Test before laboratory aging test is to measure the initial physical properties of the bitumen samples. **Penetration Test** and **Softening Point Test** have been conducted to measure the penetration and softening point of all bitumen samples. Basically, these two properties are correlated to each other in terms of hardness and temperature susceptibility of the samples. Penetration Index graph can also be calculated and plotted by integrating both penetration and softening point data into a single graph. By comparing the data from Physical Test before and after aging, the degree of bitumen degradation can be obtained. The percentage difference in degradation values will be determined at the end of this project.

3.2.3 Penetration Test

BP Bitumen Australia website stated that Penetration Test can be applied on bitumen to determine the consistency of bitumen by measuring the distance that a standard needle will penetrate vertically into a sample (reported in tenths of a millimeter) under specified conditions of:-

- Loading = 100g,
- Temperature = 25°C, and
- Time = 5 seconds

Semi Automatic Penetrometer was adopted for this test (**Figure 3.2**). The standard procedure of this method is in AASHTO T 49 and ASTM D 5: Penetration of Bituminous Materials (Pavement Interative).

3.2.3.1 Basic Procedure of Penetration Test

1. The bitumen sample grade penetration 80/100 was heated until it becomes fluid. The heated bitumen sample was placed in a penetration cone such that when cooled, the depth of the sample is 10 mm greater than the expected penetration. For this experiment, 3 sets of cones containing bitumen sample were prepared.
3. The bitumen temperature is cooled in water bath so that its temperature maintained at 25°C.

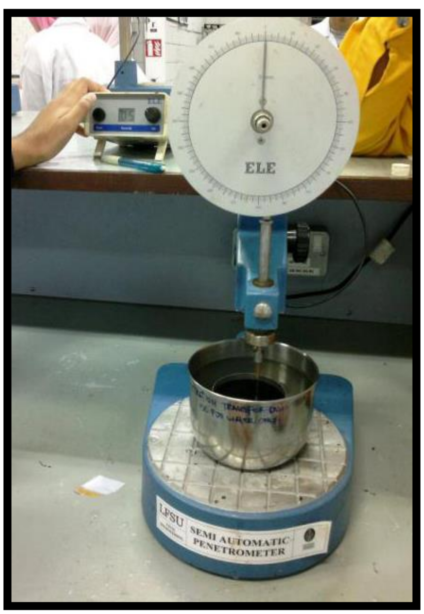


Figure 3.3a & Figure 3.3b: *Semi-Automatic Penetrometer & Checking the temperature*

4. The cooled bitumen was then placed below the needle, such that the needle just touches the bitumen surface.
5. Before starting the penetration, the load is set at 100g. The needle was then allowed to penetrate the bitumen and the test was stopped after 5 seconds.
6. The results were recorded in decimillimetre on which one penetration equals 1 dcm or equivalent to 0.1 mm. At least three (3) readings per cone were taken in order to confirm the accuracy of the result. The next needle point must not less than 10mm from the side of the container and not less than 10mm apart from previous points.
8. After three penetration values for every cup has been determined for all of the three cups; the test was repeated to different temperature of bitumen samples.

3.2.4 Softening Point Test

The softening point is defined as the temperature at which a bitumen sample can no longer support the weight of a 3.5g steel ball. Basically, two horizontal disks of bitumen, cast in shouldered brass rings (**Figure 3.4**), are heated at a controlled rate in a liquid bath (**Figure 3.5**) while each supports a steel ball (Pavement Interactive, 2007). The softening point is reported as the mean of the temperatures at which the two disks soften enough to allow each ball, enveloped in bitumen, to fall a distance of 25 mm (**Figure 3.6**). The standard procedure of this test can be viewed in AASHTO T 53 and ASTM D 36: Softening Point of Bitumen (Ring-and-Ball Apparatus).

Figure 3.4: *shoulder brass ring and ball*

3.2.4.1 Basic Procedure of Softening Point Test

1. The bitumen sample grade penetration 80/100 was heated between 75 oC and 100oC until it reached to pouring state. The sample was then stirred to remove air bubbles.
2. A set of brass rings were heated and glycerine was applied beneath the ring. The sample was filled into the ring and allowed to cool for 30 minutes.
3. Excess sample were removed with the help of a warmed, sharp knife.
4. The apparatus with the rings (containing sample), thermometer and ball guides were assembled in position and placed inside a beaker that is filled with distilled water cooled down to 5.0 oC ± 0.5oC using ice cubes. The apparatus was left for 15 minutes with the temperature maintained.

5. With the help of magnetic stirrer, the liquid was stirred and heat was applied to the beaker to increase the temperature of water at a uniform temperature rate of 5.0 ± 0.5oC per minute

6. The heat was applied until the sample softens and the ball was allowed to pass through the ring. The temperature at which the ball touches the bottom plate was recorded as the softening point temperature of the sample. The test was repeated again for bitumen penetration grade 60/70.

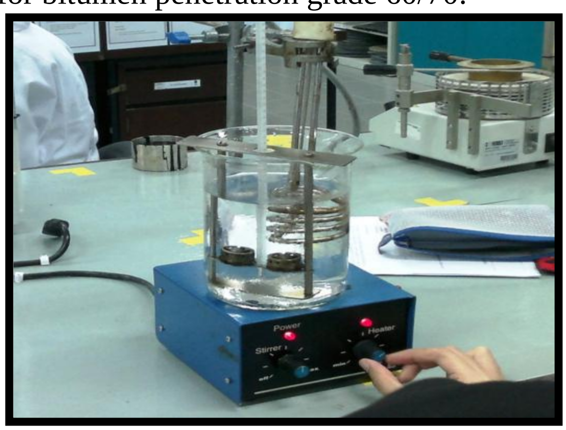


Figure 3.5: *the water bath temperature must be control at uniform rate (5.0 ± 0.5° per minute)*

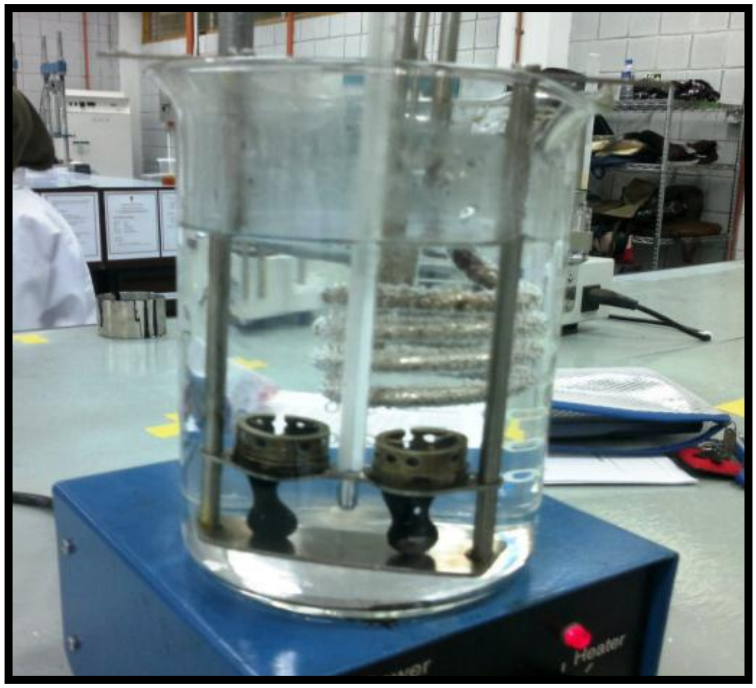


Figure 3.6: *when the bitumen is soften, the ball start fall down and touched the plate at the softening point temperature*

3.2.5 Laboratory Aging Tests

According to Kanabar (2010) to test for asphalt performance pertaining to aging resistivity, there are two major laboratory tests that previous researchers usually apply; Rolling Thin-Film Oven (RTFO) Test and Pressure Aging Vessel (PAV) Test. These two tests are preferred as RTFO can simulate the short-term aging while PAV can simulate the long-term aging.

3.2.6 Rolling Thin-Film Oven (RTFO) Test

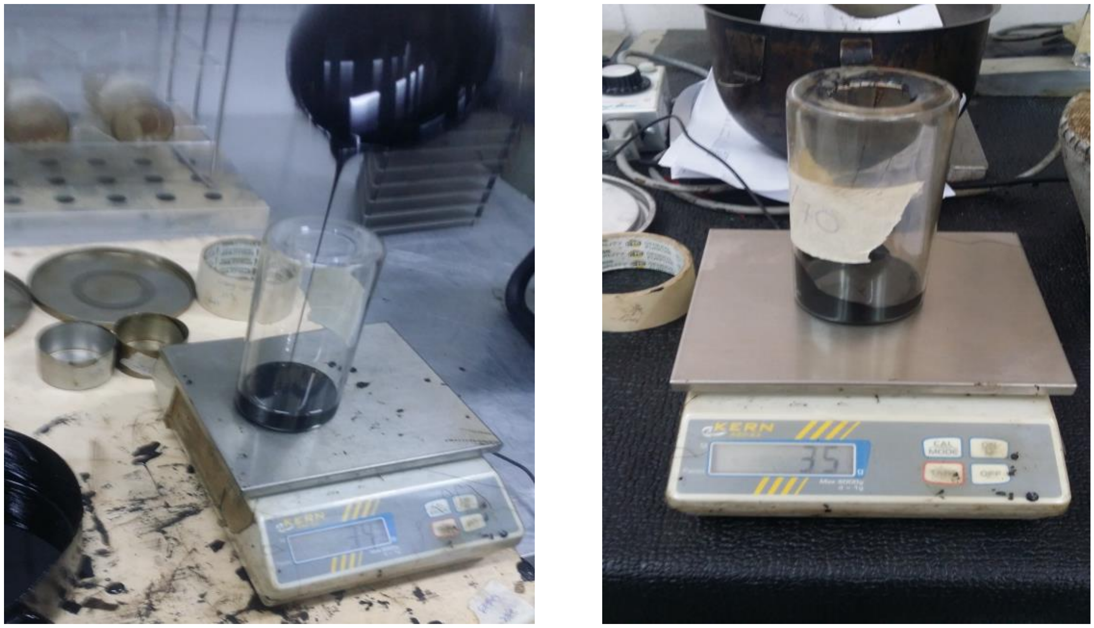
This laboratory test is very important in providing the best simulation of short-term aging as usually occurred during hot mixing and the placement process (Kanabar, A., 24 2010). Pavement Interactive (2011) website stated that the RTFO test also provides a quantitative measure of the volatiles lost during the aging process. The basic RTFO procedure takes unaged bitumen samples in cylindrical glass bottles and then places these bottles in a rotating carriage within an oven. At high temperature of 163°C, the carriage will rotate at 15 RPM within the oven and ages the samples for 85 minutes. The rotation effects are significant as it continuously exposes the bitumen with heat and air flow as well as slowly mixes each sample. Samples are then stored for use in physical properties tests or to be used for PAV test. The standard RTFO test procedure can be found in AASHTO T 240 and ASTM D 2872 "Effect of Heat and Air on a Moving Film of Asphalt (Rolling Thin-Film Oven Test)".

Figure 3.7: *RTFO Test Machine*

3.2.6.1 Basic Procedure of RTFO Test

1. A sample of bitumen was heated until it is fluid to pour. The sample was then stirred to ensure homogeneity and to remove air bubbles.
2. An empty RTFO bottle was weighed and recorded as W_o. This is designated as the "mass change" bottle.

3**.** 35g of bitumen sample are poured into the bottle (**Figure 3.8**) and (**Figure 3.9**) immediately the bottles are turned on their side without rotating or



twisting and placed on a cooling rack. Step 1 and Step 2 are repeated for other bitumen samples

Figure 3.8: *pour the bitumen sample into bottle*

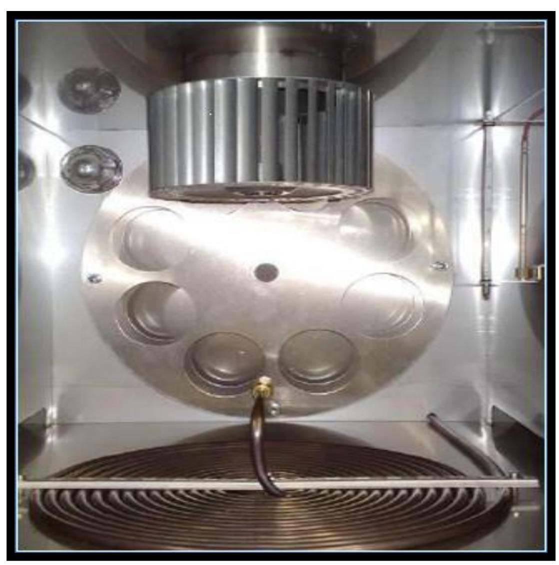


Figure 3.9: *the bottle will be placed into the hole and this machine will rotate the bottle*

4. All bottles were allowed to cool for 60 to 180 minutes.
5. After cooling, each bottle was weighed again and recorded as Wbi.
6. The bottles were then placed in the RTFO oven carousel, and after closing the door, the carousel was rotated at 15 RPM for 85 minutes. During this time, the oven temperature was maintained at 163°C and the airflow into the bottles was maintained at 4000 mL/min.
7. The bottles were removed one at a time from the carousel. The residues from each bottle were removed by first pouring as much material as possible, then the sides of the bottle was scraped to remove any remaining residue. There is no standard scraping utensil but at least 90% of the bitumen should be removed from the bottle. RTFO residue should be tested within 72 hours of aging.
8. Each bottle was then weighed and recorded as Wbf.
9. The procedures were repeated for the bitumen samples that

3.2.6.2 Basic Analysis of RTFO Test

After the aged bitumen sample has been collected, the calculation of the mass change of bitumen sample can be performed as below (*Pavement Interactive*, 2011):-

$$Mass\ Change = \frac{(A-B)}{A}(100)$$

Where A = Wbi - Wo B = Wbf - Wo

and Wbi = bottle + bitumen weight before aging

Wbf = bottle + bitumen weight after aging

Wo = empty bottle weight

A = initial sample weight

B = final sample weight

The loss in mass of the sample will indicate the mass quantity of volatiles lost from the bitumen during short-term aging.

3.2.7 Pressure Aging Vessel (PAV) Test

Pressure Aging Vessel (PAV) tests is most preferred by researchers in order to simulate the long-term aging of bitumen. As stated by Kanabar (2011) earlier, long-term aging occurred whilst in-service of asphalt pavement where the effects of thermal and load-induced loads gradually crack the pavement and causing fatigue failure. The PAV test can age the bitumen sample that simulates the in-service aging over 7 to 10 year period. The bitumen sample will be exposed to heat and pressure during PAV test and the simulated long-term aged bitumen sample can be used for physical property testing (Pavement Interactive, 2011).

Figure 3.9: Pressure aging vessel

The basic PAV procedure takes RTFO aged bitumen samples and exposes them to high air pressure up to 305 psi (2.10 MPa or 20.7 atm) and heated for 20 hours. The heating temperature, as according to Amit Kanabar (2011), can vary according to different climate simulation. Table shown below is the proposed heated temperature that simulates different climate:-

Temperature	simulation
90°C	Cold climate
100°C	Moderate Climate
110°C	Hot Climate

Table 4.0: *Temperature and simulation*

The preferred simulation for country like Malaysia is the moderate climate at which the PAV heating temperature test will be set at 100°C. The standard PAV procedure is embodied in AASHTO R 28: "Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)"**.**

3.2.7.1 Basic Procedure of PAV Test

1. The RTFO-aged bitumen samples were heated until fluid enough to pour. The samples were then stirred and poured (50 g) into a preheated thin film oven pan (**Figure 3.10**). This step is repeated for other bitumen sample.

2. All pans were placed in a pan holder (**Figure 3.11**) and placed inside preheated PAV (**Figure 3.12**).

3. PAV machine was sealed and the temperature was set at 100°C.

4. Once the PAV has reached the desired temperature, the PAV was then pressurized to 300 psi (2.07 MPa) for 20 hours.

5. At the end of the aging period, the pressure was gradually released and the pans were removed from the PAV.

6. The container (containing all samples) was then placed in a vacuum oven (**Figure 3.13**) at 170°C and the samples were degassed for 30 minutes to remove entrapped air. If not degassed, entrapped air bubbles may cause premature breaking in the DTT test.

7. After removing the sample from vacuum oven, the sample is now ready to be used for conducting Physical Test (after aging).

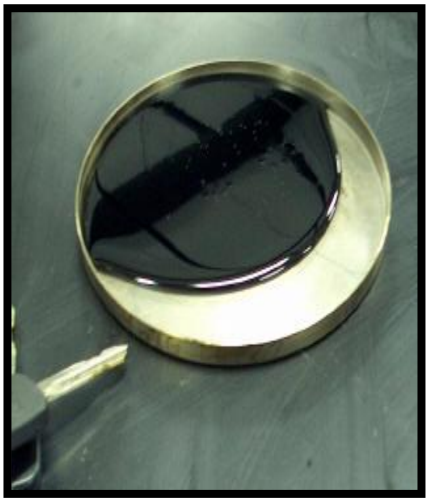


Figure 3.10 & Figure 3.11: *Preheated thin film oven pan & Pan Holder*

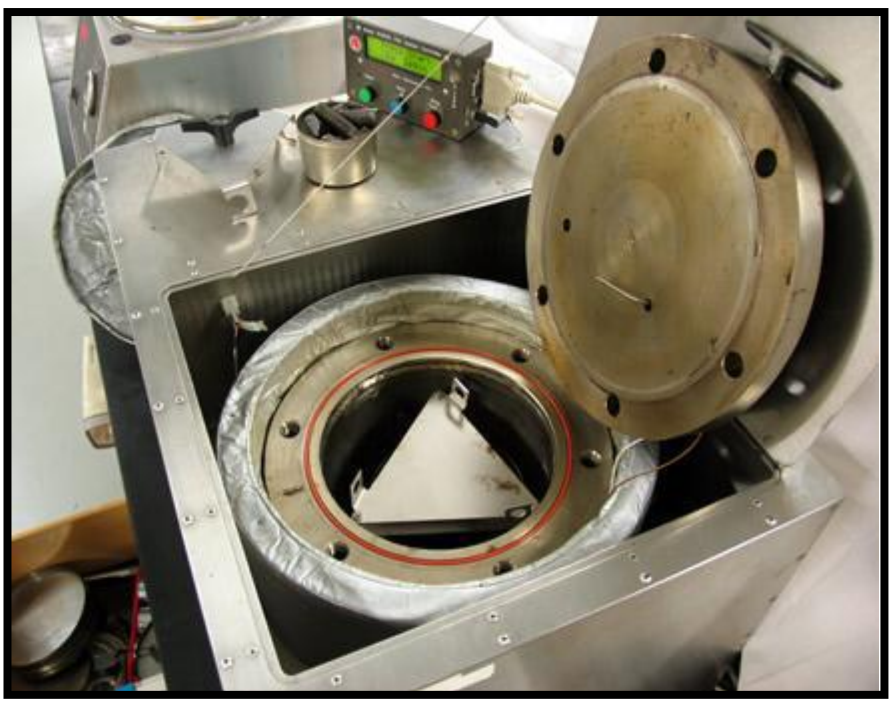


Figure 3.12: *Pan Holder inside preheated PAV*

3.2.8 Physical Test (After Aging)

After all bitumen samples have been aged the next step would be to test for their physical properties in order to access the effectiveness of aging-resistivity potential of bitumen. At the end of the Physical Test after aging, the results of physical properties of all tested bitumen samples before and after the aging process have been compared and analyzed.

3.2.9 Penetration Index

Penetration Index (PI) represents a quantitative measure of the susceptibility of bitumen towards variation in temperature. Penetration index is very important so as to predict the behavior of the bitumen for any application, in this case, the behavior of bitumen during HMA production as well as during in-service period. PI provides a more reliable information regarding the bitumen grade as it integrates both the Penetration value and Softening Point value into a single equation. It determines the degree of susceptibility of bitumen towards temperature changes, on which the lower the PI value, the more susceptible the bitumen towards temperature changes. Several equations exist that define the way that the viscosity (or consistency) changes with temperature. One of the best known is the one developed by Pfeiffer and Van Doormaal (Ehinola et al, 2012) which states that: If the logarithm of penetration, *P*, is plotted against temperature, *T*, a straight line is obtained such that:

$$\log P = AT + K$$

Where A = the temperature susceptibility P = Penetration at temperature T K = Constant

Pfeiffer and Van Doormaal developed an equation for the temperature response that assumes a value of about zero for road bitumen. For this reason they defined the penetration index (*PI*) as:

$$\frac{20 - PI}{10 + PI} = 50A$$

For Grade 80/100 bitumen, as according to ORJ Group Website, the typical range of PI value is from -0.8 to +0.7. The *PI* is an unequivocal function of *A* and hence it may be used for the same purpose. The values of *A* and *PI* can be derived from penetration measurements at two temperatures, *T1* and *T2* using the equation

$$A = \frac{\log Pen1 - \log Pen\ 2}{T1 - T2}$$

Where,

Pen1 = Penetration at temperature (T1) of 25°C.

Pen2 = Penetration at softening point temperature (T2)

Meanwhile, the consistency of bitumen samples at the softening point can be expressed in terms of linear extrapolation of logarithm of penetration (Pen1) versus softening point temperature (T2). Pfeiffer and Van Doormaal (Read, J., 2013) found that most bitumen had a penetration of about 800 dmm (deci-millimetre) at the ASTM softening point temperature. By replacing *T*2 in the above equation by the ASTM softening point temperature and the penetration at *T*2 by 800 the equation can now be simplified as:

$$A = \frac{\log Pen1 - \log\ 800}{25°C - T2}$$

In this project, equations (3) and (5) will be applied to calculate first for *A-value* (temperature susceptibility of bitumen) and *PI* (penetration index). These were calculated from the measured softening point temperatures and penetrations of every bitumen sample.

3.2.9.1 Significance of Laboratory Test Results

All of the laboratory tests are utterly important since measurement data can be analyzed and concluded to a concrete statement. The significance of all laboratory tests conducted is as listed:-

TEST	PURPOSES
Penetration Test	The consistency of aged bitumen can be determined. If the bitumen containing antioxidant is more resistive towards aging, the penetration grade of the bitumen should not degrade significantly. Each result from grade 60/70 and 80/100 can be compared and the best to lowest can be identified.
Softening Point test	This test indicates the hardness of bitumen. If the softening point of aged bitumen is higher than the unaged bitumen, the bitumen is considered to be increasing in hardness.
Rolling Thin-Film Oven (RTFO) Test	The bitumen sample can be short-term aged to simulate the hot mixing as well as during pavement laying. The lost of volatiles can also be determined by calculating the mass change after the aging test
Pressure Aging Vessel (PAV) Test	The test can long-term aged the RTFO aged sample to simulate the in-service life of over 7 to 10 years period. After the test, the bitumen sample can considered fully aged as it has covered short-term aging as well as long-term aging.

3.3 PROJECT WORKS

3.3.1 KEY MILESTONE

Table below shows the targeted timeline of project deliverables.

Event or Deliverable	Target Date	Responsibility
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 4.0: *Key Milestone*

3.3.2 GANTT CHART

In order to ensure that the direction of this project leads to success, a Gantt chart has been prepared to advance the key milestones as well as to monitor the project flow throughout the Final Year Project (FYP1 and FYP2) semester. The Gantt chart can be viewed **Table 5.0** (FYP2).

NO	DETAIL/WEEK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	**Laboratory Samples Preparation**															
	Highway Laboratory Safety Briefing															
2	**Laboratory Tests**															
	Physical test															
	Aging test															
3	**Data collection and compilation**															
4	**Progress Report Preparation**															
	Submission of Progress Report															
5	**Pre-SEDEX**															
6	**Project Dissertation Preparation**															
	Submission of Draft Report															
	Submission of Project Dissertation (Soft bound)															
	Submission of Project Dissertation (Hard Bound)															
7	**Submission of Technical Paper**															
8	**Oral Presentation**															

Table 5.0: *Timeline for FYP2*

CHAPTER 4

RESULT AND CALCULATION

The standard ranges for penetration and softening point value of 60/70 and 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 6.0: *standard ranges for penetration and softening point value of 60/70 and 80/100 bitumen based on Malaysian Standard MS124 1973*

All results of the **Physical Tests** which are Penetration Test and Softening Point Test before aging have been made available for further discussion. In this project, two samples were analyzed which is:

a) Bitumen grade penetration 80/100

b) Bitumen grade penetration 60/70

4.1 Penetration Test Results

For this test, three penetration cones have been prepared for 3 different temperatures of samples with four determinations per cone in order to improve the consistency of the results. The results of the penetration grade for the three temperatures before the aging process were as shown below.

STANDARD PENETRATION TEST BS2000 Part 49 1983/ ASTM D5

Grade 80/100 and 60/70

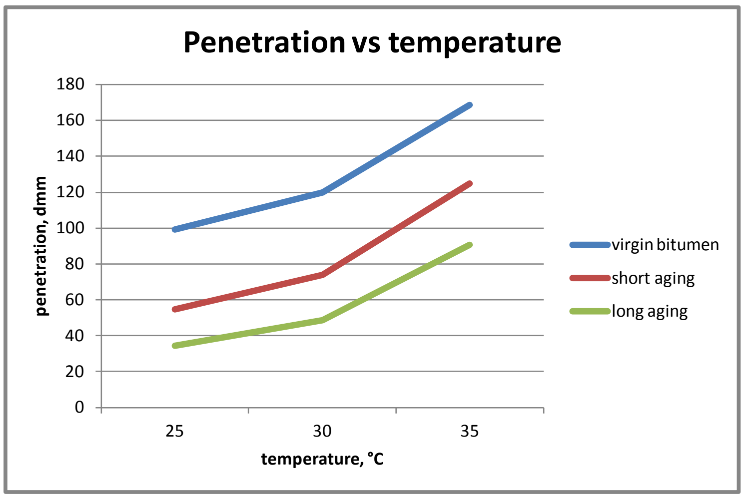


Figure 4.1: *Penetration vs Temperature at three different temperatures before and after aging bitumen grade 80/100.*

The results of the bitumen grade for three different temperatures after aging were shown in table 8.0 and 10.0. The graph shows the relationship between temperatures and penetration grade. Only one penetration cone instead of two for each temperature selected (due to time constraint) were prepared with four determinations per cone in order to minimize the percentage of errors happen. Figure 4.1 shows the value of penetration increasingly according to the temperature. When the temperature is higher, the value of penetration also will be higher. It is because of the characteristic of bitumen itself that will react on high temperature. in the graph, there are 3 type of line; virgin bitumen, short aging of bitumen and long aging f bitumen. The bitumen was tested on short and long aging experiment first before started with penetration test. Basically, the value of penetration for long aging sample was little bit lower compared to short aging and the virgin bitumen penetration.

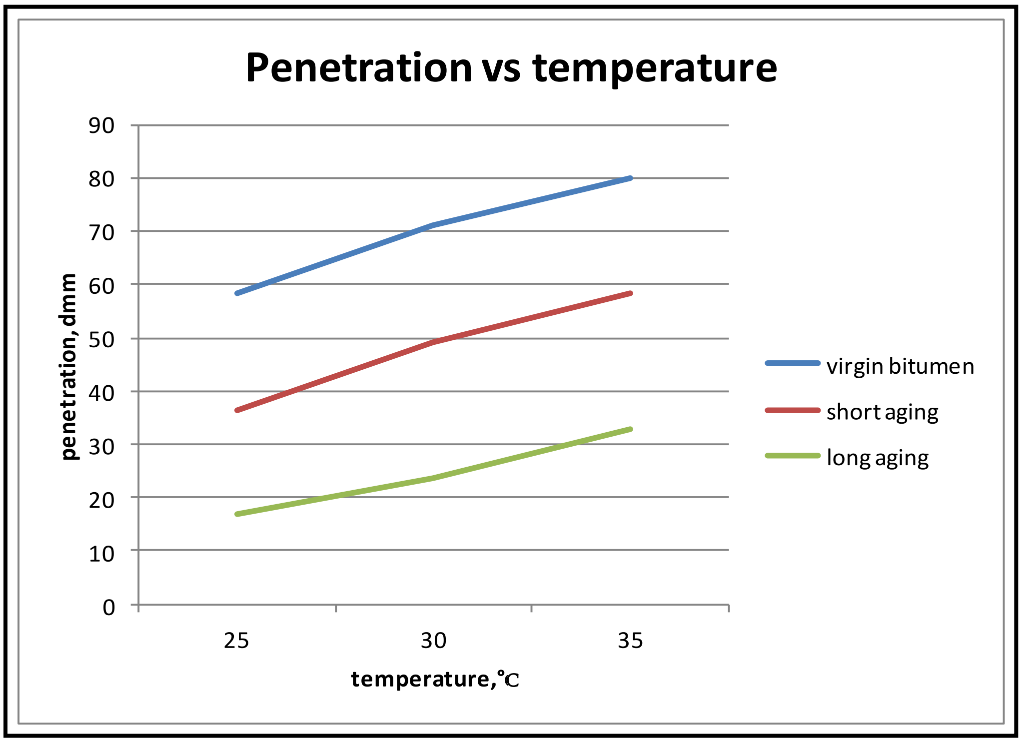


Figure 4.2: *Penetration vs Temperature at three different temperatures before and after aging bitumen grade 60/70*

Figure 4.2 shows penetration before and after aging on bitumen grade 60/70. The value of penetration between grade 60/70 and 80/100 is dramatically different. It is because bitumen grade 80/100 is more soften compared to this bitumen grade. After the bitumen was tested on aging test, the value of penetration after aging is lower compared to virgin bitumen. It shows that the hardness of this bitumen is getting higher after aging process. All the pen values of the highest and the lowest do not exceed maximum allowable differences as required according to BS2000-49:2007 standard.

STANDARD PENETRATION TEST (BEFORE AGING) BS2000: Part 49: 1983 / ASTM D5					
Type of bitumen: 80/100 grade penetration, Load: 100 gram, Time: 5 seconds					
Temperature 25°C					
Cone No.	Determination 1	Determination 2	Determination 3	Determination 4	Mean (mm)
1	86	84	85	85	85
2	94	97	96	94	95.25
3	96	97	98	96	96.75
				total	92.33
Temperature 30°C					
Cone No.	Determination 1	Determination 2	Determination 3	Determination 4	Mean (mm)
1	121	120	124	119	121
2	115	119	122	121	119.25
3	116	119	119	121	118.75
				total	119.67
Temperature 35°C					
Cone No.	Determination 1	Determination 2	Determination 3	Determination 4	Mean (mm)
1	164	163	167	165	164.75
2	168	163	172	172	168.75
3	170	172	177	170	172.25
				total	168.58

Table 7.0: *result penetration test bitumen grade 80/100 before aging.*

STANDARD PENETRATION TEST (AFTER SHORT AGING) BS2000: Part 49: 1983 / ASTM D5					
Type of bitumen: 80/100 grade penetration, Load: 100 gram, Time: 5 seconds					
Temperature 25°C					
Cone No.	Determination 1	Determination 2	Determination 3	Determination 4	Mean (mm)
1	54	56	53	55	54.5
Temperature 30°C					
Cone No.	Determination 1	Determination 2	Determination 3	Determination 4	Mean (mm)
1	72	70	78	76	74
Temperature 35°C					
Cone No.	Determination 1	Determination 2	Determination 3	Determination 4	Mean (mm)
1	122	128	127	122	124.75

STANDARD PENETRATION TEST (AFTER LONG AGING) BS2000: Part 49: 1983 / ASTM D5					
Type of bitumen: 80/100 grade penetration, Load: 100 gram, Time: 5 seconds					
Temperature 25°C					
Cone No.	Determination 1	Determination 2	Determination 3	Determination 4	Mean (mm)
1	38	34	30	36	34.5
Temperature 30°C					
Cone No.	Determination 1	Determination 2	Determination 3	Determination 4	Mean (mm)
1	50	48	49	47	48.5
Temperature 35°C					
Cone No.	Determination 1	Determination 2	Determination 3	Determination 4	Mean (mm)
1	90	91	92	89	90.5

Table 8.0: *result penetration test on bitumen grade 80/100 after aging*

STANDARD PENETRATION TEST (BEFORE AGING) BS2000: Part 49: 1983 / ASTM D5					
Type of bitumen: 60/70 grade penetration, Load: 100 gram, Time: 5 seconds					
Temperature 25°C					
Cone No.	Determination 1	Determination 2	Determination 3	Determination 4	Mean (mm)
1	62	61	58	59	60
2	58	62	58	60	59.5
3	55	51	55	59	55
				total	58.16
Temperature 30°C					
Cone No.	Determination 1	Determination 2	Determination 3	Determination 4	Mean (mm)
1	67	75	76	80	77
2	68	66	73	71	69.5
3	69	70	66	68	67.25
				total	71.25
Temperature 35°C					
Cone No.	Determination 1	Determination 2	Determination 3	Determination 4	Mean (mm)
1	80	77	75	78	77.5
2	83	82	81	83	82.25
3	79	81	77	83	80
				total	79.92

Table 9.0: *Result standard penetration test on virgin bitumen 60/70*

STANDARD PENETRATION TEST (AFTER SHORT AGING) BS2000: Part 49: 1983 / ASTM D5					
Type of bitumen: 60/70 grade penetration, Load: 100 gram, Time: 5 seconds					
Temperature 25°C					
Cone No.	Determination 1	Determination 2	Determination 3	Determination 4	Mean (mm)
1	35	40	35	36	36.5
Temperature 30°C					
Cone No.	Determination 1	Determination 2	Determination 3	Determination 4	Mean (mm)
1	46	49	51	51	49.25
Temperature 35°C					
Cone No.	Determination 1	Determination 2	Determination 3	Determination 4	Mean (mm)
1	56	58	60	60	58.5
STANDARD PENETRATION TEST (AFTER LONG AGING) BS2000: Part 49: 1983 / ASTM D5					
Type of bitumen: 60/70 grade penetration, Load: 100 gram, Time: 5 seconds					
Temperature 25°C					
Cone No.	Determination 1	Determination 2	Determination 3	Determination 4	Mean (mm)
1	16	15	16	20	16.75
Temperature 30°C					
Cone No.	Determination 1	Determination 2	Determination 3	Determination 4	Mean (mm)
1	23	25	25	22	23.75
Temperature 35°C					
Cone No.	Determination 1	Determination 2	Determination 3	Determination 4	Mean (mm)
1	30	33	35	31	32.25

Table 10.0: *result penetration test on bitumen grade 60/70after aging*

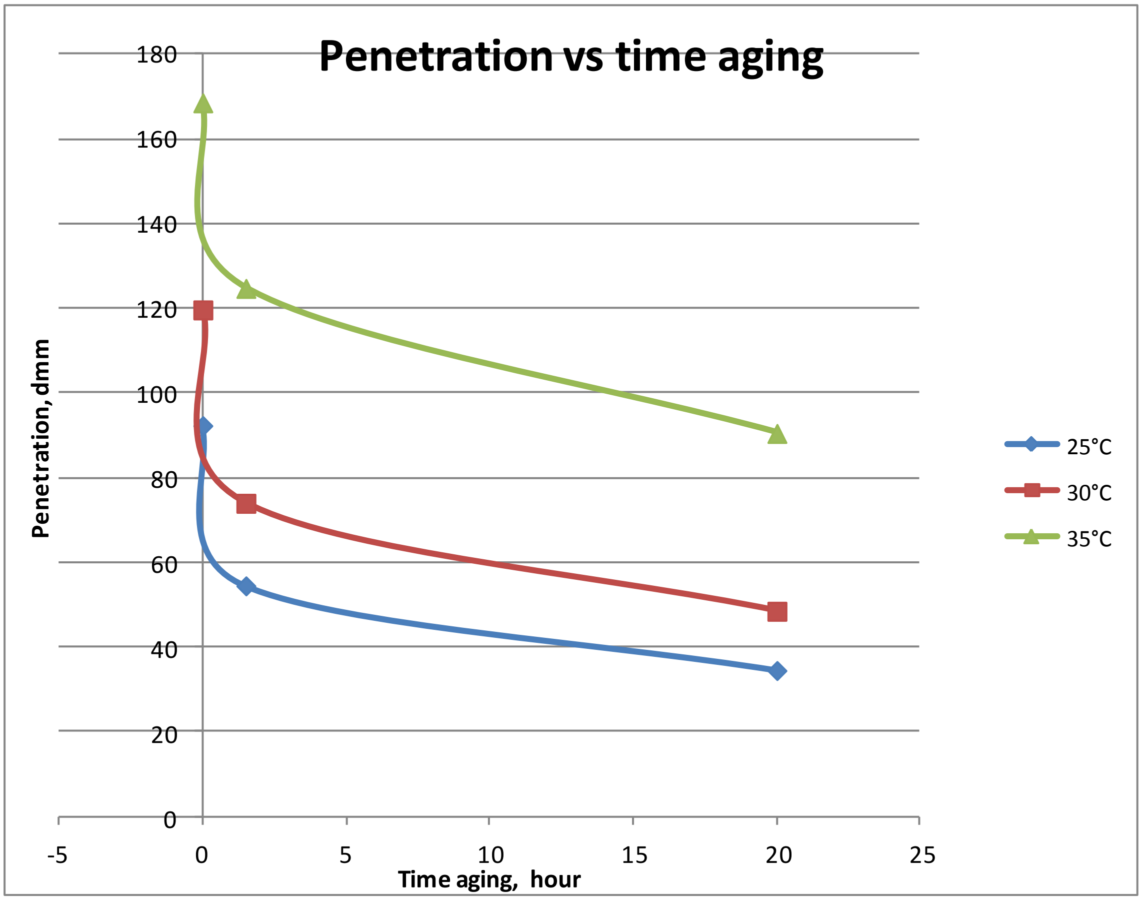


Figure 4.3: *Penetration vs time aging bitumen grade 80/100 at three different temperatures.*

Based on **figure 4.3**, it shows that the value of penetration before aging, aging at 1.25 hours and 20hours at three different temperatures. At first, the value of penetration before aging is slightly higher compared to the penetration values after 1.25hours. After 20hours aging, the penetration values has dramatically dropped due to oxidations occurs for long hours.

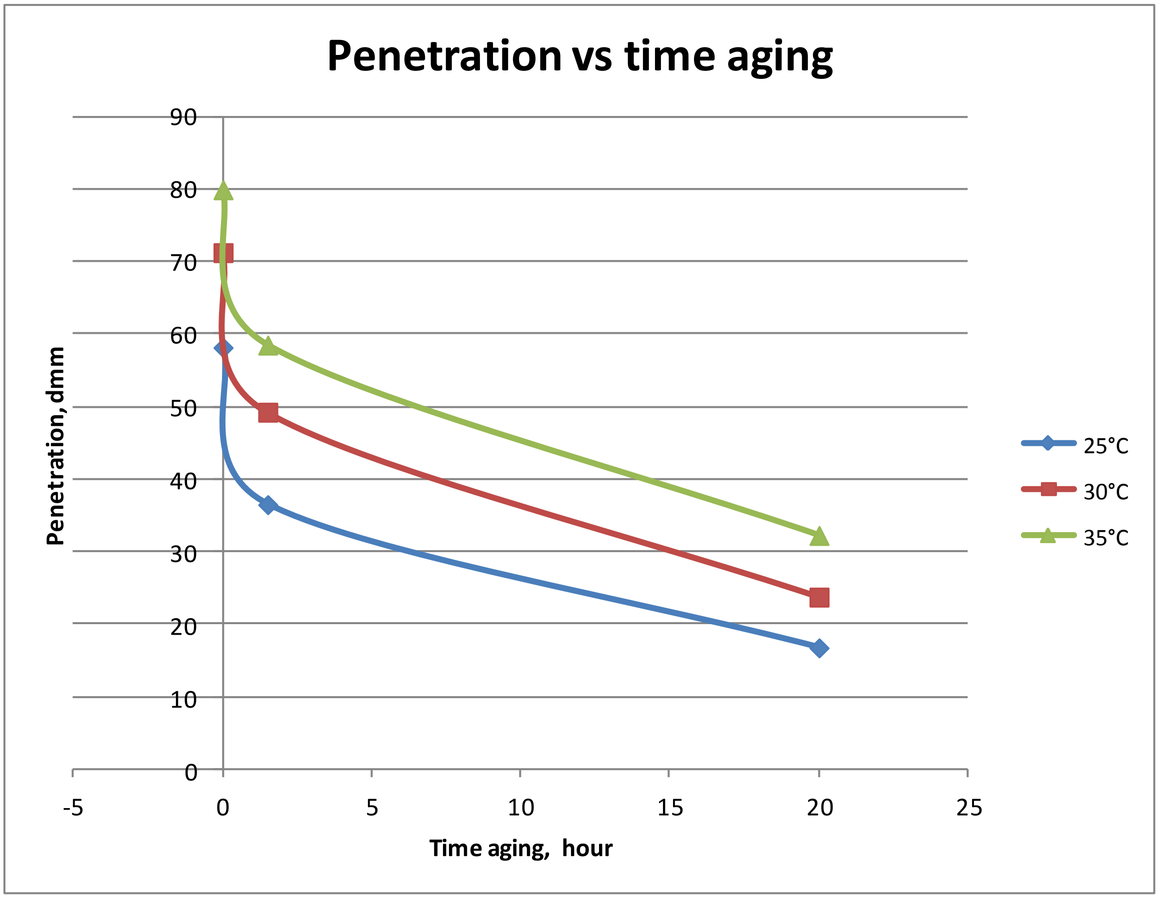


Figure 4.4: *Penetration vs time aging bitumen grade 60/70 at three different temperatures.*

According to the graph shown, bitumen grade 60/70 has higher value penetration compared to 80/100. At temperature 25°C before aging, the penetration is higher compared to penetration after 1.25hours aging and 20hours aging. After 1.25hours aging, the penetration has decreased into range 35-60 penetration at three temperatures. However, the penetration has dropped when longer aging has applied as per graph shown. The basic cause of the hardening during the Short Term Aging is mainly due to volatilization and oxidation, whereas, oxidation is the major factor for the second stage, Long Term Aging. An important factor that affects the durability of an asphalt concrete is the rate of hardening of the asphalt binder. The causes of hardening of asphalt have been attributed to oxidation, loss of volatile oils, and polymerization (changes in structure). Among all these possible factors, oxidation is generally considered to be the prime cause of asphalt hardening. The hardening of asphalt binders occurs in two major stages. These stages are:

1. Plant hot mix and laydown operation
2. Long term in-service hardening

4.2 Softening Point Result

The softening point of every sample has been successfully obtained. Note that 3 sets of experiments have been conducted; the results were recorded in the table 11.0, 12.0 and 13.0. The result shows softening point value before aging and after aging for bitumen grade 80/100 and 60/70.

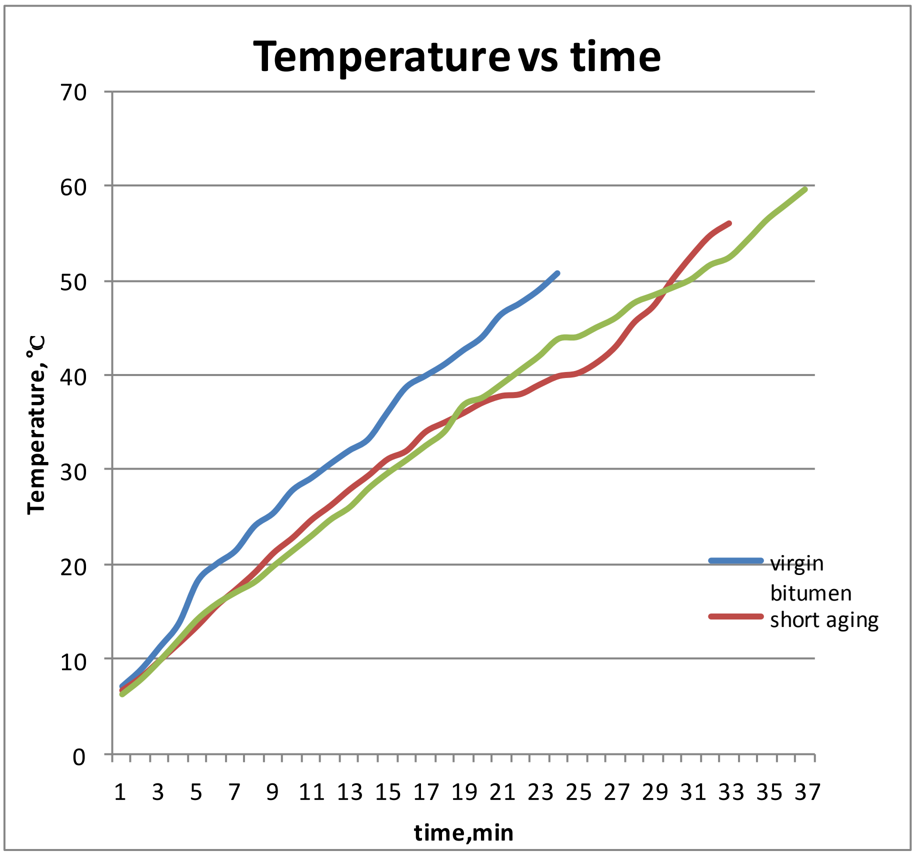


Figure 4.5: *Softening Point for grade 60/70 virgin bitumen and after short aging*

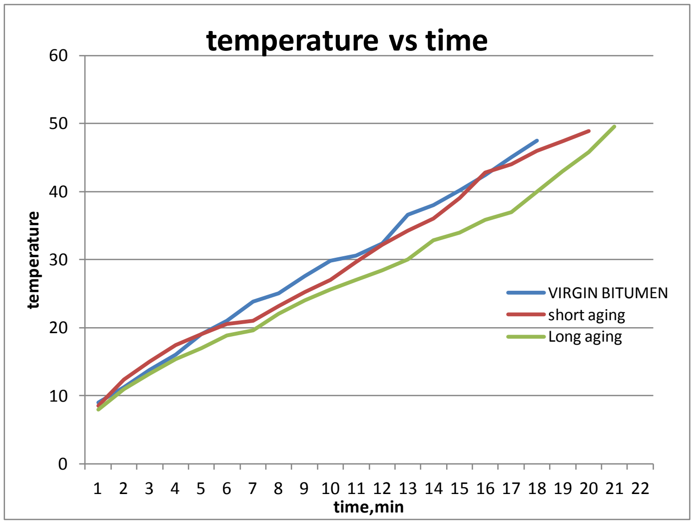


Figure 4.6: *Softening Point for grade 80/100 virgin bitumen and after short aging*

Based on figure 4.5 and 4.6, it shows that the virgin bitumen value got less time to reach it softening point rather than the aging bitumen. 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 after aging obtained are higher than the virgin bitumen softening point which is about 56.1°C and 59.5°C as tabulated in the table 13.0. However, compared to bitumen grade 80/100 the time taken for bitumen getting softens is quite shorter. Virgin bitumen reached it softens point at 47.5°C after 16minutes being heated. On the other hand, short term aging sample shows that the bitumen has reached softening point at temperature 48.9°C and the time taken is 20minutes. Not just short aging got high temperature to turn to soft, but long term aging also need high temperature to turn itself soften compared to virgin bitumen.

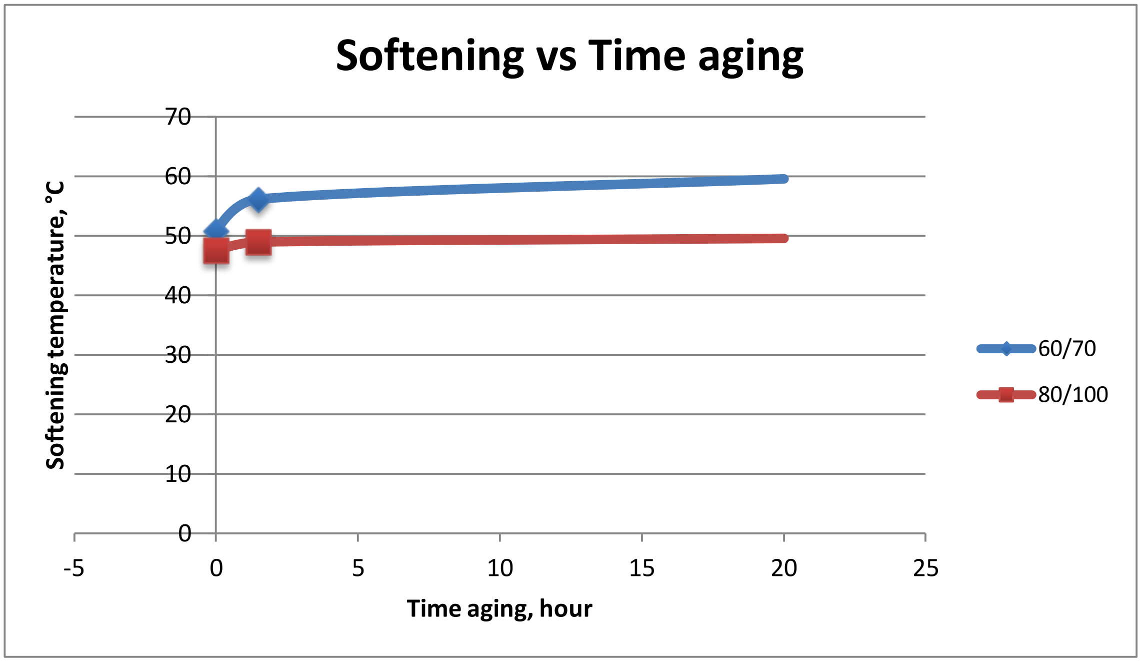


Figure 4.7: Softening point vs time aging.

Figure 4.7 shows the value of softening point for bitumen 60/70 and 80/100 before and after aging. Based on the graph above, it shows that the softening point after aging was increased (grade 60/70). The longer time for aging is taken, the higher temperature for the bitumen to reach softening point.

RING AND BALL TEST (SOFTENING POINT) VIRGIN BITUMEN BS2000 Part 58 1983/ ASTM D36

Grade 80/100

Sample No.	Ball 1	Ball 2	Mean	Time,s
1	47 °C	48°C	47.5°C	16:47

Table 11.0: *ring and ball result for virgin bitumen 80/100*

Grade 60/70

Sample No.	Ball 1	Ball 2	Mean	Time,s
1	50°C	51.6°C	50.8°C	24:02

Table 12.0: *ring and ball result for virgin bitumen 60/70*

RING AND BALL TEST (SOFTENING POINT) AFTER AGING BS2000 Part 58 1983/ ASTM D36

Grade 80/100

Type aging	Sample no.	Ball 1	Ball 2	Mean	Time,s
Short term	1	48.8°C	49°C	48.9°C	20:11
Long term	1	50°C	49°C	49.5°C	21:41

Grade 60/70

Type aging	Sample no.	Ball 1	Ball 2	Mean	Time,s
Short term	1	56°C	56.2°C	56.1°C	33:28
Long term	1	60	59	59.5°C	37:01

Table 13.0: *ring and ball test bitumen grade after aging*

4.3 Rolling Thin Film Oven Mass Change calculation.

In section 3.2.6.2 Basic Analysis of RTFO Test the mass change of bitumen samples before and after aging test has been calculated and as shown in **Table 15.0.**

Bitumen grade	Wbi (gram)	Wbf (gram)	A (gram)	B (gram)	A - B (gram)	[(A-B)/A] X 100 (%)	Average losses (%)
60/70	205	203	35	33	2	5.71	4.76
	205	204	35	34	1	2.86	
	205	204	35	34	1	2.86	
	205	203	35	33	2	5.71	
	205	202	35	32	3	8.57	
	205	204	35	34	1	2.86	
80/100	205	202	35	32	3	8.57	9.42
	206	201	36	31	5	13.89	
	206	203	36	33	3	8.33	
	205	203	35	33	2	5.71	
	205	202	35	32	3	8.57	
	205	201	35	31	4	11.43	

Table 14.0: *Average Mass Quantity of Volatiles Lost After Aging*

As the value shown above, we can calculate how much loss of volatiles during aging process. The table shown that bitumen grade 80/100 got more loss of volatile compared to bitumen grade 60/70.

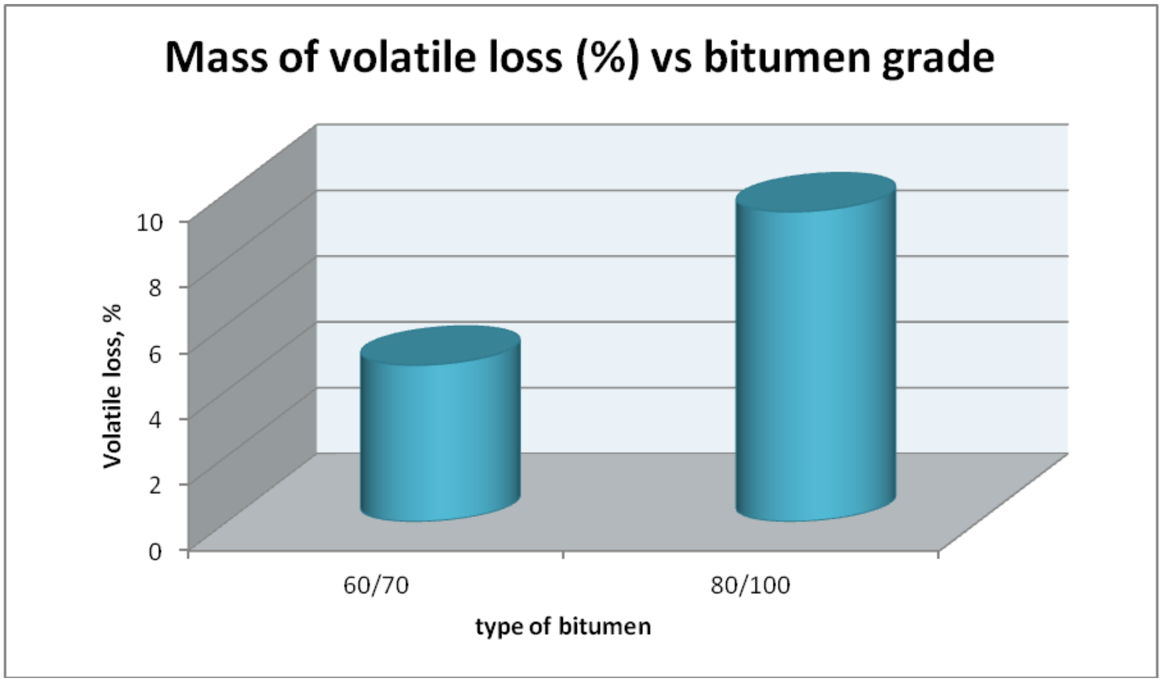


Figure 4.7: *Average mass quantity of Volatiles lost after aging*

Based on the experiment RTFO test, the result indicates that all bitumen samples that were going through RTFO-aged were losing their weights after the aging process. As shown in figure 4.4, bitumen grade 80/100 lost the highest percentage of its volatiles which is 9.42% followed by bitumen grade 60/70 with 4.76% weight reduction. In future, those volatiles lost can be prevented by using antioxidant material that was in the market to slow down the aging process and allow the bitumen to last longer.

CHAPTER 5

DISCUSSION

Based on the physical test result on bitumen samples and the aging test that were conducted followed by another physical test after aging using three different temperatures for each sample, there are significant trend that can be observed and analyzed.

5.1 Physical properties changes and observation

There are some significant differences between virgin bitumen before and after aging. Before aging, the conditions of bitumen are different. The physical condition of virgin bitumen at room temperature bitumen is soft with a density of 1 g/cm3, but at low temperature it becomes brittle and at high temperature it flows like a viscous liquid. However, it is different with condition bitumen after aging. The bitumen is stickier compared to the bitumen before aging and the ability to flow is decreasing. In addition, samples that were aged by PAV produced arrangements of air bubble on it surfaces.

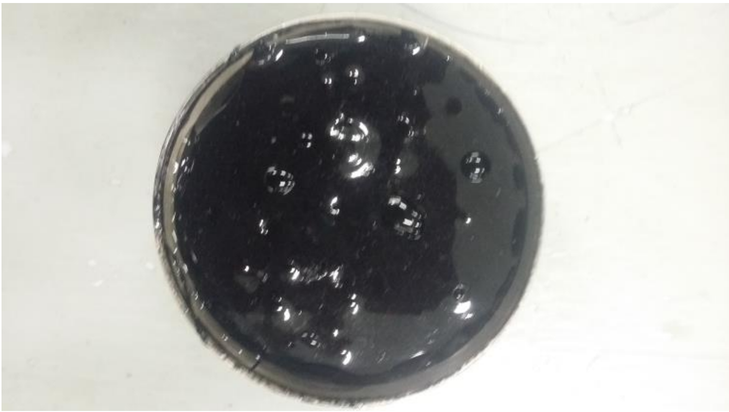


Figure 5.1: *the surface of bitumen aging*

5.2 Softening point test

Softening point data are very essential to verify the penetration data of bitumen. The softening point data must be logical with respect to the penetration data. The relation between softening and penetration is, when bitumen possess low grade penetration, the softening point must be higher. In contrast when bitumen possesses high grade penetration the softening point will be lower. Thus, softening point after aging was conducted, and it shows that the bitumen after aging is much harder compare to the virgin bitumen. The time for the bitumen to turn soften is getting longer compared to the virgin bitumen. In addition, the temperature for the bitumen to reach the soften point also at high temperature.

5.3 Penetration test

From the penetration test after aging, the results indicate that penetration after long aging score the least penetration grade 60/70 at 25°C, 30°C and 35°C with an average value of 16.75dmm, 23.75dmm and 32.25dm followed by virgin bitumen is 58.16dmm, 71.25dmm and 79.92dmm. All the penetration 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 after aging as tabulated in table 8.0 and 10.0 are lower than the penetration values obtained from the virgin bitumen. It is determined that, the bitumen after long aging has the highest degree of hardness as compared to the other sample, while virgin bitumen has the softest degree of hardness in terms of penetration value.

5.4 Constraint Faced and Mitigation.

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 penetrometer should be maintain regularly in order to make sure the load and needle is accurately fall to penetrate according to the stopwatch.

The main issue was the delay for conducting the Laboratory Aging Test as the aging machines namely Rolling Thin-Film Oven (RTFO) and Pressure Aging Vessel (PAV). Both machines are not 100% safe to be used to due to short circuit and electrical problems.
Due to this short circuit, it takes at least 3 weeks to be repaired before the machines are safe to be used. Thus, the equipment for PAV test and RTFOT should be checked for maintenance and record all expired date for the pressure gas on PAV machine to avoid using an expired gas and short circuit while testing the sample.

On the other hand, the lab technician also must be provided with some knowledge or skills on how to operate or conduct the machine and kindly do some demonstration on how to use, so it would be easier for students to use the machines.
In order to achieve the most reliable data for this project as stated in Results & Calculations, there has been numerous times of repetition/redo of laboratory test on penetration, softening point and RTFO test to determination as unreliable results that are usually out of range and illogical have been obtained due to lack of laboratory skills. The limited time-constraint has also affected the conduct of any required repetition/redo of the Physical Test.

CHAPTER 6

CONCLUSION & RECOMMENDATION

Results from the study indicated that aging resulted in oxidation of the bitumen with increase in the stiffness of the binder. It was observed that aging increased the viscosity, decreased the binder penetration and increased the softening point of the bitumen. Not just that, it can be concluded that aging increases hardness, thereby decreasing the penetration and increasing the binder softening point and viscosity. The effects of ageing are more notable for the softer bitumen (80/100) than hard bitumen (60/70) and the penetration index will decreased after aging and makes straight run bitumen harder and more elastic.

In conclusion, all the objectives are achieved. The physical tests for both bitumen grades was conducted and successfully obtained the result. The results obtained from the laboratory tests conducted shown that, bitumen grade penetration 60/70 is suitable to be apply in Malaysia based on the test conducted and comparison of the results, it shows that the penetration value after aging grade 60/70 got lower penetration compared to grade 80/100. It has been observed and analyzed that bitumen grade 80/100 has higher penetration value after long aging. It can be concluded that the lowest penetration aging ratio, will led to reduce the degree of aging. In addition, if the penetration after aging (60/70) is lower, the value of softening point will increase. In terms of PI value, the best paving binders are between +1 and-1. High temperature susceptibility occurs when the binder has PI below -2 for example in this study, bitumen pen 80/100 after long aging which the PI value is -2.941.

The higher penetration value after aging is not suitable to be used because of the penetration will be higher if the temperature increased. Higher temperature will turn the bitumen soften and this will reduce the stiffness and make the bituminous mixture more susceptible to rutting. Hence, when the temperature is lower, the stiffness will increase and it will reduce the flexibility and tend to fatigue failure.